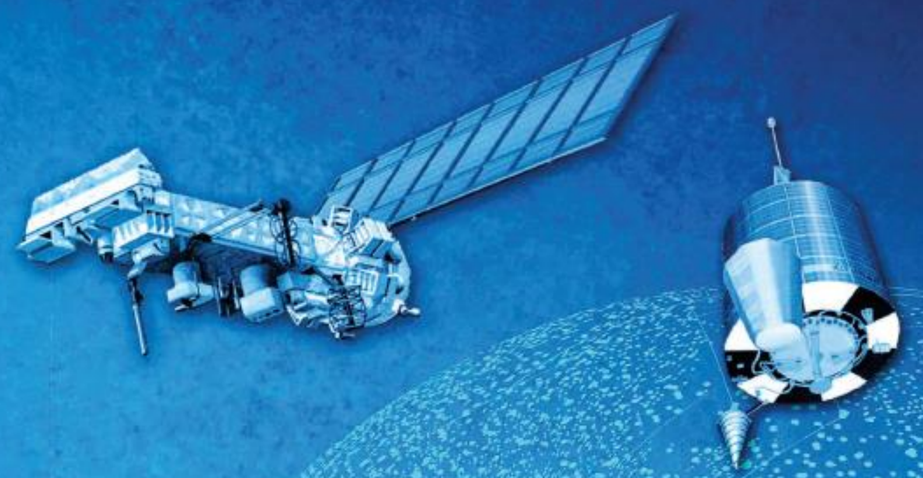

THE HISTORY AND EXPERIENCE OF THE INTERNATIONAL COSPAS-SARSAT PROGRAMME FOR SATELLITE-AIDED SEARCH AND RESCUE

IAF / IAA / IISL ADVISORY COMMITTEE ON HISTORY ACTIVITIES

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THE HISTORY AND EXPERIENCE OF THE INTERNATIONAL COSPAS-SARSAT PROGRAMME FOR SEARCH AND RESCUE

Editor: Daniel Levesque, Study Manager
International Astronautical Federation (IAF), Paris
30 July 2016

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Foreword

It is my great pleasure as President of the International Astronautical Federation to welcome the study report on the history and experience of the International COSPAS-SARSAT Programme for satellite-aided search and rescue. The COSPAS-SARSAT programme, initiated at the end of the 1970s, a difficult time of East-West confrontation, demonstrates the power of international cooperation when it is devoted to applying space technology to satisfy global public good requirements. By relaying distress signals anywhere around the globe in a timely and reliable manner, the COSPAS-SARSAT satellites detect distress situations even in very remote locations, and can alert the rescue authorities within a few minutes. Thus, tens of thousands of lives have been saved since the first deployment of COSPAS-SARSAT receivers/processors on board the Russian and American polar orbiting satellites in the early 1980s, providing a continuous service ever since.

The study report describes in a very lively style the origins of the distress alerting systems and why space-based relay could provide a major improvement to existing systems. It describes how the COSPAS-SARSAT system works and the excellent results obtained during its experimental phase, then goes on to tell the long story of acceptance by the international organisations such as IMO and ICAO, before the COSPAS-SARSAT organisation could find its final form and legal structure.

I am extremely grateful to Daniel Levesque, who was the Head of the COSPAS- SARSAT Secretariat for many years, for having accepted to lead the study and to all those who have contributed to the report. I wish also to express my thanks to the joint IAA-IAF-IISL Advisory Committee on the History of Astronautics (ACHA), to have supervised the production of this study.

Kiyoshi Higochi
President
International Astronautical Federation

Preface

It is an honour and a great pleasure, as Chairman of the Cospas-Sarsat Council, to introduce this remarkable study dedicated to the history and experience of the International Cospas-Sarsat Programme.

The Cospas-Sarsat Programme for search and rescue developed a unique satellite-based system that detects and locates emergency beacons activated by aircraft, ships, and adventurists (hikers, climbers, snowmobilers, etc.) in distress. The system provides accurate, timely and reliable alert and location data to search and rescue authorities who assist persons in distress, even in the world's most remote areas, at no charge to the end-user. Today, the system comprises several satellite constellations, numerous Mission Control Centres and ground stations, and around 1,800,000 distress beacons. It has helped rescue more than 40,000 people in more than 11,000 search and rescue events. In the last few years, Cospas-Sarsat has helped save an average of 7 lives every day.

Throughout this document Daniel Levesque, who led the Cospas-Sarsat Secretariat for many years, brings his vast experience along with the expertise of other contributors from several countries to thoroughly analyse the history of the programme, from its inception until 2009, and to draw a vivid picture of the inspiration and determination of those who set it up. The author provides a unique perspective on the multiple facets of this adventure, including challenging technical, operational, financial, legal, organizational, strategic, and diplomatic issues. The events leading to the current system come alive in this document, through the system's initiation in the singular context of the Cold War and its acceptance by search and rescue bodies around the world and by international organisations such as ICAO and IMO.

Whereas the story reported and analysed in the book stops in 2009, the International Programme has been undergoing great changes since then. More specifically, Cospas-Sarsat has begun work on the specification of a new generation of distress beacons, as well as on the preparation of the gradual transition from the use of low-altitude Earth orbit satellites to medium-altitude Earth orbit satellites that are expected to start providing operational data in 2016. As shown in this book, Cospas-Sarsat has continuously adapted to the evolution of its environment. Its participants are currently working on the development of aeronautical distress beacons that shall meet the new aviation distress-tracking requirements of the ICAO Global Aeronautical Distress and Safety System. All these current developments, which are probably the most significant in the history of the programme, reflect its rare vitality.

I want to express here my warmest thanks to Daniel Levesque, to the study team members and to all those who contributed inputs to this particularly instructive and valuable work. This preface gives me the opportunity to pay tribute to the whole Cospas-Sarsat community: the four founding countries – Canada, Russia, the United States and France – and the thirty-eight other participating countries and organisations, the Secretariat of the eponymous Montreal-based organisation, their private and public partners and, among them, search and rescue authorities. They all have dedicated remarkable efforts to one of the noblest causes: saving human lives. With this in mind, I regard Cospas-Sarsat as one of the greatest international programmes in the space sector, whose history and experience deserved to be passed on to its current and future stakeholders, and to all those interested in international cooperative programmes with technical and operational components. Daniel Levesque and the study team have completed this task most excellently.

Bruno Chazal
Chair of the Cospas-Sarsat Council

EXECUTIVE SUMMARY

The Cospas-Sarsat satellite system project for Search and Rescue (SAR) was launched in 1979 by four agencies in Canada, France, the United States and the USSR. The Cospas-Sarsat System provides timely alerts with reliable location data in many distress events on land and at sea, freeing SAR forces from long, costly and fruitless searches for missing aircraft, vessels, or persons. At the beginning of the twenty-first century, it continues to be a unique model of international co-operation among 42 States and Organisations, which provides an on-going open satellite service, free of charge to end-users in distress anywhere on the globe. The vision of the early System's pioneers must be acknowledged, together with the exceptional dedication of numerous industry and government professionals in Cospas-Sarsat's participating countries and organisations.

Space policies, International SAR Background and 121.5 MHz ELTs

Following the race to the moon in the 1960s, space policies were re-directed in the 1970s towards the development of space applications in Earth orbit, including mobile communication and navigation satellite systems. The 1970s also saw a boom in maritime trade and commercial aviation. Pleasure craft sailing and private aviation took off as well. Distress beacons became affordable thanks to the analogue VHF technology of 121.5 MHz Emergency Locator Transmitters (ELTs) and, following a few aviation distress incidents that were well publicised in the media, national regulations made ELTs mandatory safety equipment on aircraft in the United States and Canada. ELTs were then adopted by the International Civil Aviation Organization (ICAO) and included in international standards. Still, in addition to some serious initial technological bumps, 121.5 MHz ELTs lacked a global monitoring system, which made the detection and location of distress alerts rather problematic. A satellite system in low-altitude Earth orbit (LEO) using the Doppler positioning technique pioneered by Canada was the only viable approach to answer the urgent need for 121.5 MHz distress alert monitoring and locating.

By the end of the 1970s, an international maritime SAR Convention [1] was adopted and the International Maritime Organization (IMO) was striving to develop a new Global Maritime Distress and Safety System (the GMDSS) [2]. The Inmarsat mobile communication satellite system that began operation in 1982 was largely expected to become a cornerstone of the GMDSS, together with land-based radio communication systems. The GMDSS plan also featured automatic distress alerting using satellite Emergency Position Indicating Radio-Beacons (EPIRBs).

The Cospas-Sarsat Project: Two Inter-operable Satellite Systems

The 121.5 MHz analogue technology of existing aviation ELTs imposed severe limitations on the expected performance of the satellite system considered by Canada and the United States, in terms of coverage, capacity and location accuracy. A frequency band at 406 MHz had been reserved by the International Telecommunications Union (ITU) for satellite EPIRBs and the digital technology developed by France for the Argos data collection and positioning system was seen as the best way forward for an enhanced distress alerting and locating satellite system. Nevertheless, the 150,000 ELTs operating at 121.5 MHz already deployed in the United States and Canada could not be ignored and the

1/ The 1979 - Hamburg SAR Convention.

2/ See Annex 2 for detailed background on the international co-operation on aeronautical and maritime SAR.

"*SAR Satellite-Aided Tracking*" (SARSAT) co-operative project between the Department of Communications (DOC) of Canada, the Centre National d'Etudes Spatiales (CNES) of France, and the National Aeronautics and Space Administration (NASA) of the United States was designed to fulfil two objectives:

- providing the required monitoring and locating system for existing 121.5 MHz ELTs; and
- experimenting with the new 406 MHz technology for enhanced performance including global coverage, distress transmitter identification and accurate Doppler positioning.

In the USSR, Morflot, the Ministry of Merchant Marine of the USSR had initiated a similar project to assist vessels in distress, the COSPAS satellite system, focusing on the 406 MHz digital technology that was expected to be far more effective at sea than the old 121.5 MHz system. With a new emphasis on international co-operation in space despite the Cold War background, the considerable advantages of marrying the two projects to make the systems inter-operable were obvious. Distress beacon transmissions relayed through any satellite in the 'Cospas-Sarsat System' to any ground receiving station would cut in half the waiting time for a satellite to pass within visibility of a distress site. Therefore, the four partners embarked on the development, implementation, demonstration and evaluation of the joint Cospas-Sarsat satellite system for Search and Rescue. The official kick-off occurred in 1979 with the signing of a Memorandum of Understanding (MOU) between DOC, CNES, NASA and Morflot. The adventure was successful and continued with a second MOU signed in 1984 to allow the operational use of the satellite system.

The International Cospas-Sarsat Programme Agreement

Success in providing assistance to SAR authorities came swiftly to Cospas-Sarsat once the first satellite was launched (Cospas-1 in 1982)[3] and, after the successful conclusion of the Demonstration and Evaluation Phase, the partners could declare the satellite system available for operational use. However, international acceptance was not achieved easily. The international SAR community was concerned by the lack of a firm institutional basis to guarantee an open access to the satellite system and its continuity in the long term. Although the unique co-operative framework of the Cospas-Sarsat System development allowed other countries' participation and contribution to the system, it was seen as inadequate for the management of an international operational system. Because of diverging space policies and incompatible legal constraints among the four main partners, three years of tense negotiations were necessary to achieve a consensus on the appropriate institutional arrangements required to satisfy the international community. On 1 July 1988, the International Cospas-Sarsat Programme Agreement (ICSPA) was signed in Paris, France, securing the future of the Cospas-Sarsat System and clearing the path for its adoption by the IMO as part of the GMDSS.

The ICSPA encouraged other States, non-Parties to the quadripartite Agreement, to participate as 'Ground Segment Providers' or as 'User States', providing a new impetus to the transformation of the experimental system into a truly operational satellite service, open to all countries and free of charge for the end-user in a distress situation. A Cospas-Sarsat Secretariat was established as the permanent administrative body of the Programme to assist the Council. The ICSPA clearly helped weather the storm of political changes which resulted in the dissolution of the USSR in December 1991. The Russian Federation then took over all former responsibilities of the USSR in the Cospas-Sarsat Programme. By 2009, a total of 42 States and Organisations were actively participating in the operation of the System and the management of the Programme per the provisions of the ICSPA.

3/ See the Ziegleheim SAR case in Chapter 2, section 2.4.3.

Turning an Experimental Satellite System into an Operational System for SAR

The establishment of the Programme on a firm institutional basis had been long delayed and by 1988 considerable work had still to be done to meet the objectives of a truly operational satellite service. Ground receiving stations were being installed in a growing number of participating countries. The accuracy of alert data and the reliability of System performance had to be ensured and periodically assessed. A global communication network for the timely and reliable distribution of distress alerts to SAR authorities had to be designed and implemented, together with appropriate procedures for dealing efficiently with the continuous flow of alert data. These tasks were accomplished in the 1990s, in parallel with the development of a new, quasi real-time alerting capability for the 406 MHz system, using repeaters in geostationary Earth orbit (GEO) carried on operational satellites provided by the United States, India and the EUMETSAT[4] organisation.

The Cospas-Sarsat Secretariat moves to Montreal, QC, Canada

For political reasons, the Parties to the ICSPA had not granted an independent legal status to the new 'Programme'. The choice implied that Secretariat services would be provided by an existing international organisation under separate contractual arrangements. Inmarsat based in London, UK, was the preferred choice for the provision of the Secretariat services. However, in 1999, the ownership and operation of the Inmarsat satellite system were transferred to a new private entity, Inmarsat Ltd. The former 'Inmarsat international organisation' continued under a revised convention and a new identity, the 'International Mobile Satellite Organisation' (IMSO), which became the new home for the Cospas-Sarsat Secretariat. Nevertheless, this episode had revealed the fragility of the existing institutional arrangements, as the Cospas-Sarsat Council had no control over the host organisation of the Secretariat. A decision was made to seek an independent legal status for the Programme and its Secretariat. This was accomplished in 2005 through the signing of a new Agreement between Canada, France, the Russian Federation and the United States, which established the Programme as a Canadian corporate body with the privileges and immunities of an international organisation. The Secretariat moved to Montreal, Quebec, Canada in July 2005.

False Alerts and the Termination of 121.5 MHz Satellite Processing

The success of the Cospas-Sarsat System also generated a few frustrating problems, such as the large number of false alerts (i.e., alerts generated in non-distress situations) that were mainly the consequence of faulty automatic triggering devices and interference in the 121.5 MHz frequency band. False alerts were a serious concern to SAR authorities, particularly when caused by 121.5 MHz ELTs which provided no identification of the transmitter and required time consuming processing by Rescue Coordination Centre (RCC) personnel. Furthermore, the unexpected swift development of 'Personal Locator Beacons' (PLBs), portable terminals for personal use, added to those concerns. The proliferation of cheap 121.5 MHz PLBs, that would eventually also be carried on boats, and the potential impact of more false alerts on RCCs could lead to a rejection of the System, if viewed as unreliable and burdensome to SAR. These concerns resulted in calls by the IMO, and ultimately by the ICAO, for Cospas-Sarsat to plan and organise a termination of the satellite processing of 121.5 MHz beacon transmissions.

4/ EUMETSAT: European Organization for the Exploitation of Meteorological Satellites.

The matter was highly sensitive and created a dilemma for regulatory Administrations who had authorised or mandated the use of 121.5 MHz beacons. The estimated number of 121.5 MHz beacons had grown to over 600,000 by year 2000 and was continuing to grow. Furthermore, private aircraft owners' associations in North America strongly resisted any call for a switch to the new 406 MHz beacon type, mainly because of the high cost of retrofitting aircraft.

Despite the opposition and after long and difficult debates, in 2000 Cospas-Sarsat decided to terminate the satellite processing of 121.5 MHz signals on 1 February 2009 and approved a detailed 'Phase-Out Plan' to prepare for the transition. The decision led to a spectacular growth of the number of 406 MHz ELTs, EPIRBs and PLBs, which reached about 950,000 by 2009. However, the decision failed to convince all private aircraft owners and some Administrations allowed owners to keep the old 121.5 MHz fixed ELT installation after 2009, provided they also carried on board a 406 MHz PLB.

The Economy of Cospas-Sarsat Satellite Distress Alerting Services

In 2006, Inmarsat Ltd decided to terminate the L-band EPIRB system, an alternative to the Cospas-Sarsat 406 MHz system, which had not been adopted in large numbers by users. The Cospas-Sarsat 406 MHz distress alerting system thus became the sole international standard. Nevertheless, the economy of satellite alerting services provided free of charge to the owners of distress beacons and to SAR authorities remained a legitimate concern. A cost/benefit analysis was performed in the United States in 1996 clearly showing the potential savings that could be achieved by a transition from 121.5 MHz ELTs to the higher performance 406 MHz beacons. Analyses were run in 2000 in Canada on the savings actually provided in terms of search costs when a beacon signal and Cospas-Sarsat alert data were available for the rescue operation.

Building on input data from these studies and a review of investment costs in the LEO and GEO satellite systems, a conservative analysis shows that, over the first decade of Cospas-Sarsat System operation (1990 to 1999), estimates of annual savings in search costs for missing aircraft and ships were of the same magnitude as the typical annual investment cost for the satellite system (US$ 33 million). During the following decade (2000 to 2009), based on the increased System use, such savings were estimated at 1.6 times the average annual investment costs. These estimates of SAR savings only address search costs.

During the first decade (1990 to 1999), the average annual value of the 406 MHz beacon market was of the same magnitude as the average annual satellite system investment cost. During the second decade (2000 to 2009), the 406 MHz beacon market was on average 2.7 times the annual satellite system investment cost.

MEOSAR: The Cospas-Sarsat System Future

The 1990s saw a flurry of new mobile satellite system projects, which were potential competition for Cospas-Sarsat. With a few exceptions, most of them had disappeared by 2002. Among the Cospas-Sarsat partners, GNSS constellations in medium-altitude Earth orbit (MEO) were being considered as a replacement for the LEO 406 MHz system, potentially providing for enhanced performance. By 2009, the Cospas-Sarsat transition towards a combined GEO-MEO 406 MHz system was well underway. The implementation of the MEOSAR system should ensure that the Cospas-Sarsat Programme continues with success for the foreseeable future.

Cospas-Sarsat Operations

From September 1982 to the end of 2014, Cospas-Sarsat alert data were used in over 11,070 SAR events in which at least 39,565 persons were rescued.

Source:
Cospas-Sarsat System Data No. 41 (Dec. 2015)

The evolution in time of the Sarsat and Cospas-Sarsat shields reflects the international development of the cooperation, from a three, then four partners' project to the International Programme, open for the formal association of other countries. Personal beacons (PLBs) also appeared as a new dimension of the user base, together with planes and ships.

Ottawa, Canada - July 1979:

The first Cospas-Sarsat Memorandum of Understanding (MOU) was prepared at a July 1979 meeting in Ottawa, Canada and formally signed in Leningrad, USSR in November 1979. The photograph illustrates the successful outcome of the preliminary discussions in Ottawa (see section 2.4).

From left to right:

Mr. Yuri Zurabov, Morsviazsputnick, USSR
Mr. Jean-Louis Moalic, CNES, France
Dr. Bert Blevis, DOC, Canada
Dr. John McElroy, NASA, United States

A Canadian contribution quickly adopted by all. Getting the joke was part of the team building process, not always obvious for delegates from other countries.

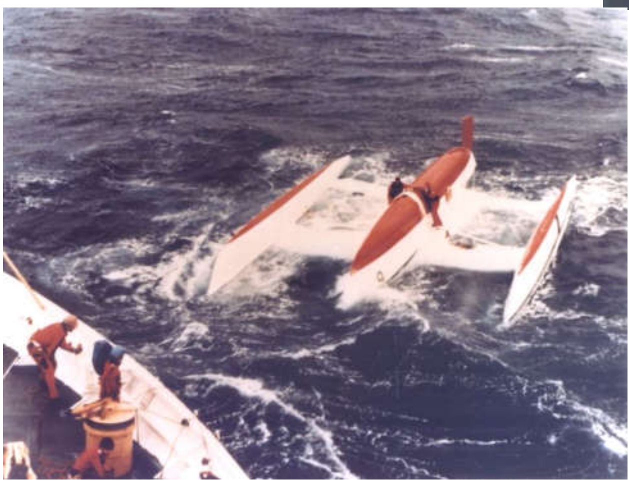
All photos and pictures in pages VII to X, are provided courtesy of
The International Cospas-Sarsat Programme

First Rescue using Cospas-Sarsat
121.5 MHz alert data - 10 September 1982

The SAR Ziegleheim case in the wilderness of British Columbia, Canada is described in Chapter 2, section 2.4. By 2009, when satellite processing of 121.5 MHz signals was stopped, over 3,500 distress events at 121.5 MHz had been recorded, in which almost 9,000 people were rescued

CSCG-4, Williamsburg, Va, USA, October 1982

Celebrating early successes of the international cooperation with toasts and vodka.
From left to right:
Mr. Bob Lowell, NASA
Mr. Tom McGunigal, U.S. Representative, NASA
Mr. Yuri Zurabov, USSR Representative, Morsviazsputnik
Mr. Gérard Brachet, French Representative, CNES
Mr. Don McKinnon, Canadian Representative, DOC
Mr. Bernie Trudell, Sarsat Technical Manager, NASA
At the back, right to left:
Mr. Claude Augoyard, CNES
Mr. Laurie Moore, DOT, UK
Mr. Fred Flatow, NASA



First Rescue at sea using Cospas-Sarsat
121.5 MHz alert data - 10 October 1982

The sailboat 'Gonzo' with 3 persons on board capsized in the Atlantic Ocean, 300 miles off the coast of New England. The only alert and location data was provided by the 121.5 MHz Cospas-Sarsat system. The crew was rescued by the U.S. Coastguard cutter 'Vigorous' assisted by the oil tanker 'California Gerry' and the merchant Vessel 'Atlantic Ace', in 25 ft swell.

Relaxing after a tense Council meeting
Inmarsat, London, UK (1989)

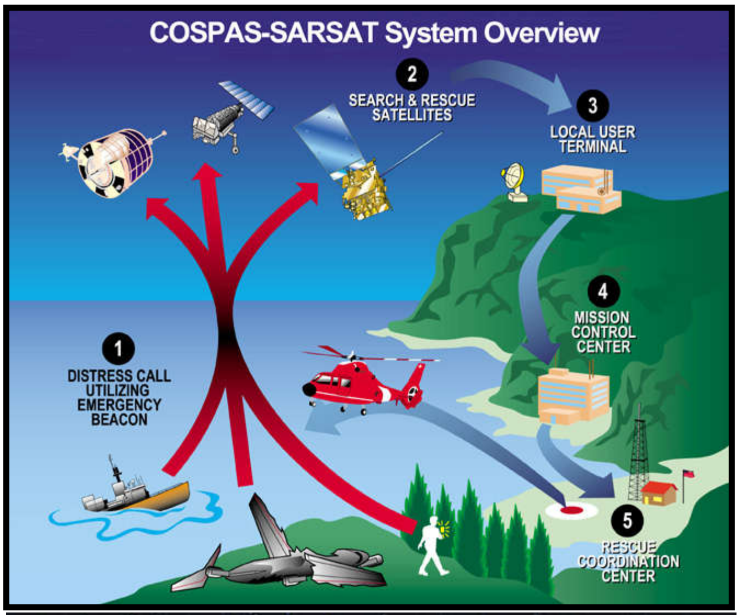
Left to right: Yuri Zurabov (USSR), Jim Bailey (USA)

Personal Locator Beacons (406 MHz PLBs)

Aviation Emergency Locator Transmitters (406 MHz ELTs)

Maritine Emergency Position Indicating Radio Beacons (406 MHz EPIRBs)

Cospas-Sarsat LEOLUT
Receiving station for the LEOSAR satellite system (1981 CAL model)



Cospas-Sarsat Space Segment
Artist views of the LEO polar orbiting system NOAA Advanced Tiros-N (Sarsat), Nadezhda (Cospas) LEO satellites and, at the back, the U.S. GOES geostationary satellite.

French Ministry of Foreign Affairs in Paris, France, 1 July 1988
ICSPA Signing Ceremony in the 'Salon de l'horloge' at the Quai d'Orsay

From left to right:

Mr. C. P. Srivastava, Secretary-General of the International Maritime Organization (IMO);
Mr. William Evans, Under-Secretary, Department of Commerce, United States of America;
Mr. O. A. Savine, Vice- Minister, Ministry of Merchant Marine (MORFLOT) of the USSR;
Mr. Gilbert Perol, Secrétaire Général, Ministère des Affaires Étrangères, France;
Mr. David S. Wright, Acting Ambassador of Canada in France;
Mr. Dieter Bartkowski, Regional Director, ICAO Paris Regional Office, representing the Secretary General of the International Civil Aviation Organization (ICAO)

Paris, 1 July 1988 - Last corrections to the CSSC Summary Record

From Left to right:
Mr. Dick Hodgson, Canadian Representative
Mr. Yuri Zurabov, USSR Representative
Mr. Jim Bailey, United States Representative

At the CSC-30 Council Meeting, in 2003, the Cospas-Sarsat Council decided to explore options for providing the Programme with an independent legal status. This was achieved in 2005 with the signing of a new Agreement and moving the Secretariat to Montreal, Quebec, Canada.

April 2003, Moscow, Russia

From Left to right:
Mr. Valery Bogdanov - Director General Morsviazsputnik, Russia's Representative in the Council
Mr. Ajay Mehta - United States Representative, NOAA

Chapter 1

Space Policies, Satellite Systems and Distress Beacons Prior to Cospas-Sarsat

1.1 Space Policies in the 1960s and 1970s

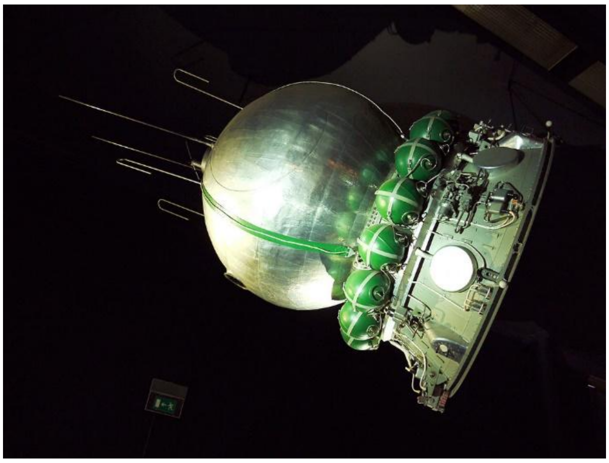
It is difficult to convey the amazement of the media and the public when news of the first Sputnik launch broke in 1957. In the 1960s the memory of the event was still fresh and the world was enthralled by the race to the moon. By the 1970s, the mood had changed and, with the first oil crisis in 1973, the world realised that successes in space exploration did not resolve more mundane problems down on Earth. Space policies had to take the new political environment into account to ensure continuing support for new developments.

1.1.1 Early Competition in Space

The first Earth orbiting satellite, Sputnik 1 was launched on 4 October 1957 by the USSR, generating enthusiasm around the world for breaking into a new frontier, together with political exaltation and anxiety about military and strategic implications. A race for achievements in space, and for the associated prestige and power, began between the two super-powers: the USA and the USSR. This space race merely continued and expanded the 'Cold-War' competition for political supremacy.

Space exploration seemed to progress at lightning-speed and the race continued to the Moon. The first unmanned spacecraft to reach the surface of the Moon, Luna 2, was launched by the USSR and landed on 13 September 1959. It was followed by Luna 3, which provided the first pictures of the far side of the Moon, never seen before, and then by three U.S. Ranger spacecraft.

The first human orbital flight was accomplished by the USSR on 12 April 1961 [1] with the Vostok spacecraft, followed by the first U.S. sub-orbital flight on 5 May 1961 [2] with the Mercury spacecraft. The USA successfully landed the first humans [3] on the Sea of Tranquility on 20 July 1969 during the Apollo 11 mission, less than 10 years after the first human space flight. The climax of the first landing was followed by a string of repetitive successes and public interest started to fade, although the incident during the flight of Apollo 13 temporarily renewed media



The Vostok spacecraft used for the first human orbital flight in 1962

1/ Yuri Gagarin

2/ Alan Shepard

3/ Neil Armstrong and Buzz Aldrin

interest for what remained a dangerous endeavour. The last manned flight to the Moon was accomplished in 1972, with no returns yet, more than 40 years later. The East-West competition in space and on Earth was not over, but governments had other priorities and funding gradually became more limited for a race that did not bring clear economic returns.

As dreamt by science fiction writer Arthur C. Clark in 1945, the less glamorous era of 'space applications' had actually begun in the 1960s, but was largely unnoticed after the successes of human space flight. In the 1970s, priorities gradually moved away from the manned exploration of space, towards automatic satellite observations of the sky and the Earth.

1.1.2 The Bumpy Road of East-West Space Cooperation in the 1960s and 1970s

The Space Age spawned two outstanding space programmes as a result of the hot competition between the United States and the Soviet Union. Both countries gave primary emphasis in their space efforts to a combination of national security and foreign policy objectives, turning space into an area of active competition for political and military advantage. The bumpy USA - USSR relationship in the years between 1957 and 1991 often was characterised by periods of mistrust and overt hostility.

The International Geophysical Year (IGY), a multinational scientific effort launched in 1957 to study the Earth on a comprehensive, coordinated basis, was the first opportunity for international cooperation in space. The IGY programme included a number of launches of sounding rockets. During the IGY preparation, the organisers had urged the USA and the USSR to consider launching scientific satellites. On 4 October 1957, a seemingly routine test launch of a Soviet ICBM (intercontinental ballistic missile known as the R-7 rocket) carried the first artificial satellite to orbit, Sputnik 1, followed by Sputnik 2 in November 1957. The United States' first satellite, Explorer 1, was launched in January 1958. One of the main discoveries of the IGY was the identification, location and confirmation of Earth's inner and outer Van Allen Radiation Belts [4].

In 1957 and 1958 the United States and the Soviet Union explored possible cooperative space initiatives, including the establishment of a process to secure peaceful uses of space. Meanwhile, the United States energetically pursued a multinational initiative under the umbrella of the United Nations to develop a legal framework for peaceful space activities. These initiatives eventually led to the creation of the United Nations Committee on the Peaceful Uses of Outer Space [5] and to the Outer Space Treaty [6].

In early 1962, an exchange of letters between President J.F. Kennedy and Premier N. Khrushchev initiated a new phase of the cooperation between the United States and the Soviet Union which would address three main areas:

4/ IAF/ACHA study of the International Geophysical Year, "Initiating International Scientific Space Co-operation" (published 2012).

5/ COPUOS, the United Nations Committee on the Peaceful Uses of Outer Space was established as a permanent Committee of the UN by the UN Assembly in 1959.

6/ The « Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies » , also known as Outer Space Treaty (OST) was signed on 10 January 1967 and entered into force on 10 October 1967

- the exchange of weather data from satellites and the eventual coordinated launching of meteorological satellites;
- a joint effort to map the geomagnetic field of Earth; and
- cooperation in the experimental relay of radio-communications.

The Cuban missile crisis in October 1962 put an end to all public cooperative activities in space between the United States and the Soviet Union. Efforts to revive space cooperation were renewed in the 1970s, after the end of the race to the Moon, when new objectives of space exploration were defined. The docking of the Soyuz and Apollo spacecraft in orbit in July 1975 [7] was a rare and dramatic display of United States - Soviet friendship during the cold war. The Apollo-Soyuz project was dictated by the will of the two countries' political leadership. The cooperation presented a serious management challenge for both sides, in particular because of the overall lack of compatibility between the two spacecraft designs. Each party would later separately follow its own objectives for manned flights in low Earth orbit. The concept of an international space station was several decades into the future and the Apollo-Soyuz project had no real follow-up developments.

Soon after the Apollo-Soyuz flight, both sides met to discuss potential joint space projects and agreed to establish a special bilateral working group. A number of U.S. life and bio-science experiments were flown on Cosmos spacecraft between 1977 and 1979 (see Chapter 2, section 2.1).

Following the USSR intervention in Afghanistan in December 1979, any hope of significant East-West cooperation in space vanished. The United States' White House authorised low-profile cooperation with the USSR only on a case-by-case basis. The humanitarian multilateral effort by Canada, France, the United States and the USSR to develop and implement a satellite-based system to locate airplanes and ships in distress was among the few activities that were allowed to continue.

The United States pursued its cooperation with Europe through projects such as a Spacelab module that could fly aboard the space shuttle, while the Soviet Union maintained its focus on flying the manned Salyut space stations. Only in the late 1980s, with warming political relations, would the momentum for major space cooperation between the USSR and the United States begin to build.

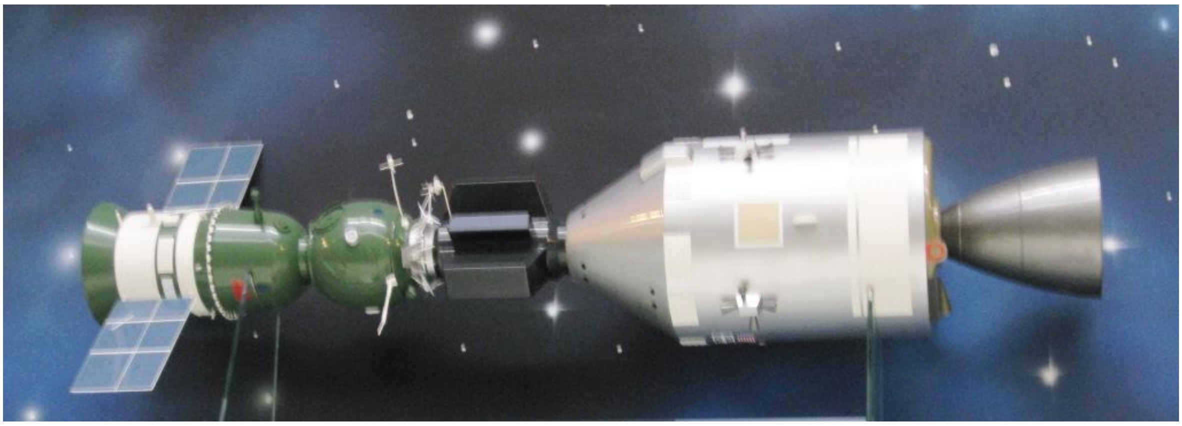
1.1.3 The Case for Cooperation on Space Applications

The space industry of the 1970s was not mature enough to attract large private investment. After the race to the Moon was over, space policy leaders needed to find new ways to generate public support and sustain the substantial funding effort required for further development. The space industry had to become 'useful' to the public and develop technologies which would offer new services to customers. Radio-communications, including satellite radio-navigation and positioning services, and Earth observation would be the next fields of rapid development in the 1970s. Both domains had the potential to offer practical applications for the public, as well as clear military returns, which would provide a noticeable advantage in the context of public funding competition. Major satellite telecommunication and navigation programmes were initiated by the United States

7/ The Apollo-Soyuz Test Project (ASTP) / Экспериментальный полёт «Союз» — «Аполлон» and the USSR in the 1970s (Intelsat, Intersputnik, Aerosat, Marisat/Inmarsat, Transit, Tsikada). A short outline of some of these programmes is provided in section 1.2 to illustrate the swift expansion of space applications and the context of the Cospas-Sarsat System development.

The race to the Moon had been dominated by objectives of strategic and military superiority. As these motives weakened and a new desire for "*détente*" was spreading in both Western and Eastern worlds, the theme of East-West cooperation in space became fashionable. The Apollo-Soyuz mission in July 1975 was the first response to the new environment. This first attempt at space cooperation was well received internationally and both parties could measure the political benefits that could be derived from ‘the peaceful use of outer-space’. Therefore, both parties were prepared to find new themes for cooperation in space, provided that strategic national interests would remain unaffected.

Satellite based navigation systems and fixed or mobile communication systems were being developed by both space powers. These fields of space applications also raised significant interest among emerging space powers, particularly in France and Canada. However, the space technology associated with these developments had obvious strategic implications and could provide immediate military applications. This was also the case for Earth observation. The competition was tense, which made direct, large scale East-West cooperation in these domains of space applications impractical. Nevertheless, some cooperative work had already started bilaterally between Canada and the United States on satellite telecommunication projects and scientific experiments, as well as between the USA and France, and between the USSR and France.



A Mock-up of the Apollo-Soyuz Docking Arrangement
(Moscow Museum of Space Flight - Photo D.Levesque 2011)

1.2 The New Frontier of Mobile Satellite Communications and Satellite Positioning

After its early successes in low-altitude Earth orbit and the excitement of the moon race in the 1970s, space technology opened up a whole field of new applications. Mobile satellite communications and satellite navigation services offering permanent worldwide coverage for all users with unparalleled reliability and quality became the new dream of many developers, although efforts to turn science fiction into reality were not always met with complete success.

1.2.1 AEROSAT

Air traffic managers who knew the limitations of ground based mobile communication technologies, particularly over oceans and remote continental areas, began dreaming of the ubiquity of mobile satellite communications to resolve safety and traffic management issues. The new technology could certainly be used over the Atlantic Ocean, where traffic volumes were growing, and in regions like the Sahara desert in central Africa, largely deprived of reliable communication means. At the end of the 1960s the aviation community was experiencing a boom linked to jet air travel. Pan Am completed the first transatlantic flight of the new Boeing 747 jumbo jet aircraft on 12 January 1970. In Europe, France and the UK had launched a cooperative programme in 1962 to develop a supersonic air transport vehicle, the Concorde, which would make its maiden flight in 1969. Similar supersonic aircraft programmes were considered in the USA (L 2000, B 2707) and were under development in the USSR (TU 144). Manufacturers and governments expected that by the mid-1970s, on top of the jumbo-jet traffic, hundreds of supersonic Concorde aircraft would be crossing the Atlantic Ocean every day.

The civil aviation community began careful studies of the practicability of satellites for providing long distance communications, primarily as a replacement for high frequency (HF) communications available over oceanic and remote areas, which were of poor quality and unreliable, unsuitable for the management of heavy air traffic. Early experiments with satellites focused on the use of the very high frequency (VHF) spectrum (118 to 136 MHz). The feasibility was demonstrated using the NASA ATS 3 experimental satellite and, in 1968, the International Civil Aviation Organisation (ICAO) established a panel of experts to explore the Application of Space Techniques Relating to Aviation (ASTRA). However, mobile satellite communications to/from aircraft in VHF were a technical challenge, in particular because of the need for bulky moving antennas on the aircraft.

Between 1971 and 1975, several experiments were accomplished with NASA's ATS 5 and ATS 6 satellites, demonstrating the feasibility of satellite communications to aircraft in the 1.5 GHz and 1.6 GHz frequency bands with the technology that was available at the time.

An international aeronautical satellite programme (AEROSAT) was set up in the early 1970s to jointly plan, construct and manage a dedicated aeronautical experimental satellite system. The programme, established under a memorandum of understanding signed in August 1974, was sponsored by Canada, the European Space Agency (ESA) and the United States of America.

The objectives of the AEROSAT programme were to develop and launch several satellites and to perform a variety of experiments to determine the preferred characteristics of an operational aeronautical system. However, the projected costs of the satellites grew much larger than anticipated. Furthermore, a downturn in economic conditions linked to the first oil crisis in 1973, which considerably increased the cost of jet fuel, resulted in the lack of the expected traffic growth and caused the airlines to withdraw their support, ending the dream of a dedicated aeronautical satellite system for mobile satellite communications.

1.2.2 INMARSAT

Recognising the potential for mobile satellite communications to assist the safety of merchant shipping, the Maritime Safety Committee (MSC) of the International Maritime Organisation (IMO) decided in February 1966 to study the operational requirements for a possible maritime communication system using satellite technology.

In 1973, IMO convened a diplomatic conference for the purpose of establishing a new maritime satellite communication system with the goal *"to improve maritime communications, thereby assisting in improving distress and safety of life at sea communications, the efficiency and management of ships, maritime public correspondence services, and radio-determination*[8] *capabilities".*

The 'Convention on the International Maritime Satellite Organization (Inmarsat)', signed at London, UK, on 3 September 1976, entered into force on 16 July 1979. The Inmarsat organisation was headquartered in London. The Inmarsat satellite system began to operate on 1 February 1982 using a variety of systems, including leased capacity on three Marisat satellites built by Hughes Aircraft Corporation (HAC) for COMSAT Corp, four Intelsat V satellites built by Ford Aerospace and Communications Corp., and two Marecs satellites built in Europe for the European Space Agency (ESA). The three Marisat geostationary satellites had been launched in 1976 to provide services to the US Navy in the Atlantic Ocean, the Pacific Ocean, and the Indian Ocean. They were designed with three communications payloads: a UHF payload (240 to 400 MHz) for the U.S. Navy; an L-band payload (1.5 to 1.6 GHz) for maritime mobile communications via voice, telex, facsimile and high speed data; and a C-band payload (6 to 4 GHz) for communications to fixed shore-based stations. The four Intelsat V satellites were launched from 1982 to 1984, providing 30 communication channels each for the Inmarsat-A system in L-band. Three Marecs satellites were launched in 1981 (Marecs-A), 1982 (Marecs-B) and 1984 (Marecs-B2), respectively, with Marecs-B failing to reach orbit. Each Marecs satellite provided 40 Inmarsat-A communication channels.

The establishment of the Inmarsat organisation provided the assurance of service continuity, therefore, there were no objections to incorporating Inmarsat's mobile satellite communications at L-band into IMO's Future Global Maritime Distress and Safety System (FGMDSS). This in turn would provide a clear impetus for the development of maritime mobile satellite communications. For the following decades, except for the Cospas-Sarsat distress alerting service, Inmarsat would be the sole provider of maritime mobile satellite communications for distress and safety services as well as commercial applications.

Inmarsat was the only international organisation providing satellite communication services that was open to Eastern bloc countries as well as Western countries, at a time when the Cold War was still on-going. The USSR did not participate in the Intelsat organisation, established in 1964,

8/ Radio-determination: The determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves. (RR 2012-Vol.I, Chapter 1, Article 1, paragraph 1.9) which provided fixed satellite communication services to the 'Western' world. Instead, an Eastern-bloc satellite organisation, the International Organisation of Space Communications, for short Intersputnik, was established in November 1971 to compete with Intelsat. This unique posture of Inmarsat in East-West relations would be instrumental in the organisation being chosen as provider of secretariat services to the Cospas-Sarsat partnership in 1987.

In 1994, the Assembly of Inmarsat renamed the organisation to the 'International Mobile Satellite Organization (Inmarsat)', replacing 'Maritime' with 'Mobile' and thus proclaiming the ambition of the inter-governmental organisation to provide mobile satellite communication services not only to ships, but also to aircraft and land mobiles as well, world wide.

In the USA and a few other countries the monopoly position of Inmarsat as sole service provider of mobile satellite communications and its status as an international organisation with associated privileges and immunities were seen as unfair advantages over other possible service providers. In 1998, after a long and tense debate, the Inmarsat Assembly agreed to the call for privatisation and on 15 April 1999 Inmarsat was established as a public limited company (Inmarsat Ltd) under UK corporate law. The new Inmarsat Ltd Company was to receive all the assets and take over the commercial activities of the preceding international organisation. The main legal difficulty was with regard to the public service responsibilities of Inmarsat as provider of maritime safety services. Specifically, the 1988 amendments to the SOLAS [9] convention required that ships sailing in specified sea areas carry Inmarsat communication equipment for distress and safety. No alternate mobile satellite communication equipment was available and the Global Maritime Distress and Safety System (GMDSS) was planned to become fully operational in 1999. SOLAS would therefore mandate ships to carry equipment provided by a single private commercial entity, with no control on the provision of the required services. Such a situation would be contrary to international practice and was clearly unacceptable to many States.

The issue was addressed with the establishment of the International Mobile Satellite Organisation (IMSO) on 15 April 1999, as the legal continuation of the former international organisation, but with a revised mandate [10] to ensure that:

- *"Inmarsat Ltd continues to meet its public service obligations, including those relating to the GMDSS;*
- *services are provided by Inmarsat Ltd. free from any discrimination and in a peaceful way to all persons living or working in locations that are inaccessible to conventional, terrestrial means of communication; and*
- *principles of fair competition are observed."*

1.2.3 Doppler Satellite Navigation and Positioning Systems

Soon after the launch of Sputnik 1 by the USSR on 4 October 1957, physicists at the Johns Hopkins Applied Physics Laboratory in the United States measured the Doppler shift that affected the signal broadcast by Sputnik 1 when received by a fixed station on the ground. Using these measurements, they managed to determine the orbit of the satellite.

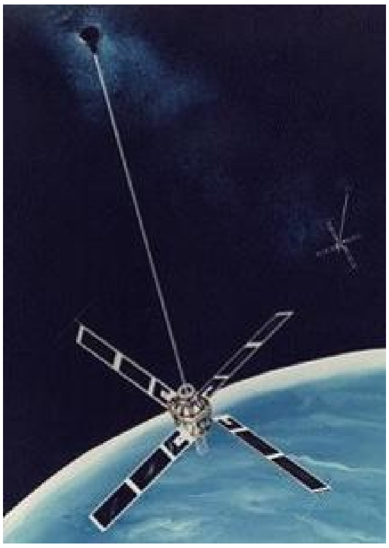
9/ SOLAS: Safety Of Life At Sea convention - See Annex 2 on Maritime SAR

10/ Convention on the International Mobile Satellite Organization signed at London on 24 April 1998. See also Chapter 4, section 4.4.5 on Inmarsat's privatisation.

If one can determine the orbit of a satellite from Doppler shift measurements on a single satellite pass over a known, fixed point of the Earth, it is quite straightforward to imagine that a position on the Earth can be determined from Doppler measurements on radio transmissions from a satellite, assuming the orbit of the satellite (i.e., its position in space at the time of measurement) is known to the user.

This is the basic principle of physics that would be used in all satellite navigation and positioning systems developed in the 1960s, until the launch and demonstration of the Navstar-Global Positioning System (GPS) system in the 1980s.

Transit



Operational Transit Satellite

The U.S. Transit system was the first Doppler navigation satellite system to enter operational service in 1964, despite a number of failures affecting early launch vehicles or the satellite platform. The system comprised up to 10 satellites in low-altitude polar orbit, including spares, five of them being required in normal operational conditions.

Transit was designed to provide position fixes to U.S. Navy submarines with an accuracy of around 200 m on a single pass. It was later made available for civilian applications and widely used at sea. Transit also opened new perspectives for accurate geo-positioning on the ground and was the first satellite positioning system to provide world wide, in the same geodesic reference system, sub-meter accuracy when measurements on successive passes could be merged. As with all low-altitude polar-orbiting systems (about 1,100 km or 600 NM in the case of Transit satellites with an orbital period of about 106 minutes), the coverage was global but not continuous, and waiting times of several hours between visible satellite passes could be experienced at the equator.

Tsikada

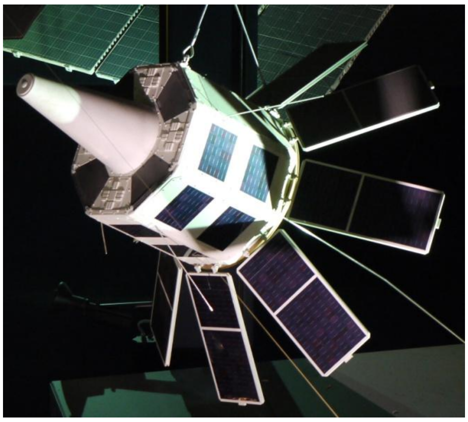
In the 1960s, the USSR also developed a military Doppler navigation satellite system, similar to the U.S. Transit system. Both systems transmitted two reference signals with encoded data providing orbit information on 150 and 400 MHz. The first satellite for the Soviet system was launched in 1974.

The initial constellation of the USSR system consisted of six satellites distributed in orbital planes 30 degrees apart. This network was primarily dedicated to the support of military forces. A similar civilian satellite navigation network referred to as Tsikada (Russian: Цикада, meaning cicada), began deployment in 1976 on four orbital planes separated by 45 degrees. The civilian Tsikada orbital planes were carefully offset from the military satellite orbital planes to minimise the mean time between satellite sightings when both systems were used. From 1982, some of the Tsikada civilian satellites would carry the Cospas SAR payloads and would then be renamed Nadezhda (Hope) satellites.

Argos

In these early years of Space exploration, no other nation active in space could afford the cost of developing, maintaining and operating a navigation satellite system equivalent to Transit or Tsikada. Both systems had been established to meet military requirements and their civilian applications were mere side benefits of strategic military developments.

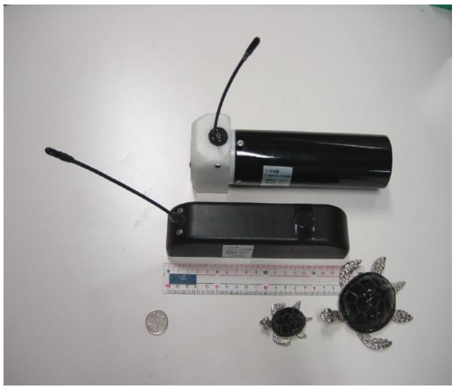
However, these navigation satellite systems had clearly demonstrated the potential of the Doppler location technique using Low-altitude Earth Orbiting (LEO) satellites and the demand for accurate locating techniques for a wide range of applications on land was growing. If a mobile could determine its own position using satellite transmissions, the same Doppler technique could also be used to locate a mobile, with a reverse methodology, using radio transmissions from the mobile relayed through a satellite in LEO orbit and received on the ground.



The Eole Satellite;
Photo: Museum of Air and Space, Paris, France

The first large scale application of the Doppler locating technique was part of a cooperative research programme between France and the USA in 1971 and 1972. The French Eole satellite, launched by NASA, tracked 500 balloons flying at an altitude of around 10,000 m to study the high atmosphere in the Southern Hemisphere. The Eole satellite would later be used to test the technologies developed for its successor: Argos.

The first Argos instrument was launched in 1979 on the NOAA 6 satellite and in 2016, more than 35 years later, the system is still operational with over 8,000 data collection platforms. The Argos system consists of communication equipment provided by France and flown on US polar-orbiting meteorological satellites of the Advanced Tiros-N series operated by NOAA. Its objective is to collect environmental data from drifting buoys or moving platforms and download this information to a network of ground receiving stations. Frequency measurements of the radio signal received by the satellite allow a computation of the Doppler shift that affects the signal, which ultimately provides the transmitter position.



Argos Beacons
Designed for Animal Tracking (2002)
Copyright CLS/Argos

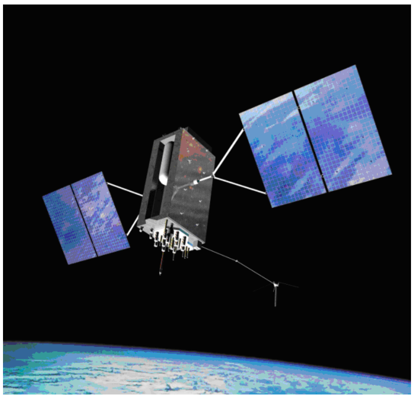
In 1979 the buoys equipped with Argos transmitters could be rather bulky. Today, miniature Argos transmitters can be carried by sea mammals, turtles or birds to track their migrations. Argos buoys transmit at 401 MHz. The same proven technology would give birth to the Cospas-Sarsat 406 MHz system, a few years after Argos' beginnings, and both systems evolved with the benefit of parallel technological advances.

1.2.4 The GNSS revolution: GPS, GLONASS, Galileo

While Transit, Tsikada and Argos provided new reliable navigation and positioning services using the same proven Doppler technique, a true revolution in global satellite navigation systems was in the making with a different technique. Based on signal propagation time measurements rather than frequency shift measurements, the United States' Global Positioning System (GPS) would provide the first truly global, continuous and accurate navigation system, firstly to military users and ultimately to every possible application that needed accurate positioning and timing.

The technique requires extremely accurate time measurements with the same time reference in a system comprising up to 24 satellites in medium-altitude Earth orbit (MEO), at roughly 20,000 km. The time keeping requirements on-board the satellites cannot be achieved with the usual ultra-stable oscillator (USO) technology. Hydrogen maser atomic clocks have to be installed on the satellites, and properly synchronised at all times. By the end of the 1970`s this was a formidable and expensive challenge. Only the USA and the USSR had the appropriate resources to develop, build and operate this type of satellite system. A constellation of 24 operational satellites must be maintained and controlled with sophisticated computation systems on the ground. The complexities of the navigation receiver, which must acquire signals from several satellites from a cold start, download satellite ephemeris data and compute its own position while estimating the system time reference, were by themselves a challenge. This was a time when personal computers were just arriving on the desks of scientists and engineers, with very limited computation power when compared with today's standards.

GPS



GPS Block III Satellite
Photo: GPS.gov

The first satellite of the U.S. Global Positioning System was launched in 1978 and the nominal constellation of 24 operational satellites plus four spares was achieved in 1995. Designed to meet military requirements, GPS is now available for civil use, albeit with a lesser positioning accuracy and with no guarantee of quality. The U.S. Air Force, which operates the system, reserves the right to alter the signal in case of military confrontation and degrade the positioning accuracy available to non-military users, or the enemy.

Despite these limitations, the success of the system was almost immediate as it provided unparalleled accuracy and a service that none could match. By the year 1998, after receiver manufacturers had achieved weight and cost reductions through high density integration of components on dedicated chips, GPS technology began to invade almost all mobile applications, including smart-phones and Cospas-Sarsat distress beacons. Future GPS satellites are expected to carry a 406 MHz repeater for use in the Cospas-Sarsat MEOSAR system[11].

Glonass

Glonass was designed to support the same strategic objectives as GPS. The development of the system began in 1976 and the first three satellites were launched in 1982 on a single Proton rocket. The full constellation of 24 operational satellites was achieved in 1995, but the Glonass navigation service degraded in the following years as a result of political changes in Russia and a lack of funds to maintain the system. No launches occurred between 1995 and 1999 and by 2001, only 6 satellites were still fully operational.

11/ MEOSAR : Medium-altitude Earth Orbiting satellite system for Search and Rescue (SAR). See Chapter 7 for a short introduction to the Cospas-Sarsat MEOSAR system.

From 2003, a second generation satellite design, Glonass-M, was introduced with a design life-time of seven years instead of three. With restored financing driven by President Putin, the system constellation was replenished and in 2008, 16 satellites were available in orbit. The full 24-satellite constellation was not achieved as planned in 2010 due to a launch failure with the Proton-M rocket.

GLONASS-K Satellite
Photo: Russian SpaceWeb

Both GPS and Glonass systems use a similar binary phase-shift keying (BPSK) modulation of the signal. GPS satellite signals are identified by different codes using code division multiple access (CDMA), while Glonass satellites all utilise the same standard code but with a frequency separation technique using a 15-channel frequency division multiple access (FDMA).

In February 2011, the first improved satellite of the Glonass K series was launched carrying an experimental 406 MHz repeater for use in the future Cospas-Sarsat MEOSAR system.

Galileo

GPS and Glonass were both developed initially to meet essential military requirements. Both systems were later made available for civilian uses, although with some performance limitations due to strategic considerations. GNSS receivers are now standard equipment on most mobile communication systems and have significantly modified consumers' expectations regarding navigation capabilities: global navigation accuracy in the range of ten to a hundred metres is now considered a standard requirement, even for general public applications.

In the 1980s, Europe began to develop its own version of a GNSS system called Galileo. However, there was no possibility to base such development on military requirements as the European Union has no military mandate. As of 2016, after much hesitation and changes to the European approach regarding the funding of a 'civilian' GNSS, the implementation of a 24-satellite Galileo constellation is in progress. The first satellites have been launched and the complete deployment is expected by 2020. The European Union and the European Space Agency have responsibility for the development and implementation of the Galileo system.

Galileo Satellite
Photo: ESA

The civilian emphasis on system requirements will result in the provision of a variety of services defined as Open Service, Commercial Service, Safety of Life (SOL) service, Public Regulated Service (PRS), and Search and Rescue (SAR) service. The Galileo SAR service will provide 406 MHz repeaters for relaying the transmissions of existing and new generation Cospas-Sarsat beacons to Cospas-Sarsat ground receiving stations (MEOLUTs).

1.3 Emergency Communications and Distress Beacons Prior to Cospas-Sarsat

1.3.1 Emergency Communications

Emergency radio communications have been used since the advent of radio over 100 years ago. Early in the 20th century, the radio frequency of 500 kilohertz became an international calling and distress frequency for Morse code maritime communication. The Morse letters SOS, simple yet distinctive letters in the code which could also be memorised as an abbreviation for 'Save Our Souls', indicated a distress situation. International standards for the use of 500 kHz first appeared in the Second International Radiotelegraphic Convention, held in Berlin in 1906 and were expanded by the Third Convention, held in London in 1912, soon after the sinking of the RMS Titanic.

As commercial aviation was evolving in the 1920s, aeronautical communications were also developing and at the Fourth International Radiotelegraphic Convention held in Washington in 1927, the voice call 'Mayday' (from the French words "*m'aider*" meaning "*help me*") was adopted to signal a distress, in place of the SOS Morse code call. The very first automatic SOS radio transmitters were developed in the 1930s. These devices transmitted in the HF [12] band (at about 4 MHz) and needed a long wire antenna. As they used vacuum tubes, they also required huge battery packs, which made the device unsuitable for use on small aircraft.

In 1947, the ITU World Radio Conference held in Atlantic City allocated a range of frequencies in the VHF [13] band for the aeronautical mobile radio service, including the 121.5 MHz international emergency frequency for air distress calls. The channel would be monitored by air traffic controllers, as well as aircraft in flight, to listen for emergency voice calls. However, in-flight monitoring was not mandatory for civilian air transport and the limited range of the transmissions reduced effective detection capabilities of distress calls to the vicinity of airfields.

Specific maritime mobile service emergency frequency channels for voice communications (radiotelephony) were also allocated by the ITU in the HF and VHF bands, including 2,182 kHz and 156.8 MHz. However, the ITU also allowed the 121.5 MHz channel to be used by the maritime mobile service to communicate with aircraft for safety purposes.

1.3.2 The Case for Distress Beacons

With the advent of the tiny 'transistor' replacing bulky vacuum tubes in the 1950s, small battery-operated distress transmitters could be developed. Operating at higher frequencies in the VHF and UHF [14] bands allowed for shorter antennas and self-contained portable devices. Rather than the former "*Mayday-Mayday-Mayday*" voice call, such beacons were designed to emit an audible 'sweep tone' alarm signal, simple to generate automatically, that would be heard on monitoring receivers and immediately recognised as a distress signal.

Several military forces were using 243 MHz as their exclusive emergency frequency, which they monitored continuously in flight. In many countries the Air Force would also carry out civil

12/ HF : High Frequency - 3 to 30 MHz

13/ VHF : Very High Frequency - 30 to 300 MHz

14/ UHF : Ultra High Frequency - 300 to 3,000 MHz aviation search and rescue missions. As 243 MHz is exactly double of 121.5 MHz (i.e. the second harmonic), it was easy to make distress beacons transmit on both frequencies simultaneously, using only one oscillator and common electronics and antenna, thereby allowing both civil aviation and military aircraft to monitor the distress transmissions. Some manually-activated beacons, known as Emergency Locator Beacon Air (ELBA), were developed and deployed in the 1950s, operating on one or both of these emergency frequencies.

Just before World War II began, Harry Stevinson, a Canadian Engineer, had developed the concept of an automatic Crash Position Indicator (CPI), a radio beacon designed to be ejected from an aircraft when it crashed. This feature helped ensure the CPI would survive the crash and any post-crash fires or sinking, allowing it to broadcast a homing signal to search and rescue aircraft. In the CPI, a radio transmitter operating on 121.5 and/or 243 MHz and its omni-directional antenna were housed in a Frisbee-shaped package resulting in a tumbling-airfoil beacon. The CPI became a standard item on many Canadian and U.S. aircraft, including military aircraft and smaller planes working in the Arctic.

Harry Stevinson displays the Crash Position Indicator.

CPIs were still being manufactured in 2015 and flown mainly on military aircraft and commercial helicopters. Most of the new CPIs incorporated a distress beacon operating at 406 MHz and 121.5 MHz, a flight data recorder and a cockpit voice recorder, all within the same unit. The deployable device must survive temperature extremes, high-speed ejection and landing, fire, be able to float in water and still transmit a distress signal for over 24 hours. Automatically-deployable CPIs able to survive most aircraft crashes were rather complex devices, far more expensive than small fixed or portable distress transmitters. Therefore, CPIs could not be made mandatory equipment on small, privately owned aircraft.

By 1959, the first automatic 121.5 / 243 MHz distress beacons for life rafts had been produced in the UK, as well as a range of 121.5 / 243 MHz beacons for aircraft, some including a radio for voice communications between the survivors and rescuing personnel. In the 1960s, the term Emergency Locator Transmitter (ELT) became the common name for the small aviation distress beacons operating at 121.5 and / or 243 MHz, while the term Emergency Position-Indicating Radio Beacon (EPIRB) generally referred to maritime distress beacons. In the ITU regulations, the term EPIRB designates all distress beacon applications, whether aviation, maritime or personal portable devices.

Various types of early 121.5/243 MHz ELTs
Photo The International Cospas-Sarsat Programme

The number of beacons deployed gradually increased during the 1960s, but the big impetus came from United States legislation. On 16 October 1972, U.S. Congressmen Hale Boggs and Nick Begich were lost when their small plane went down in the Alaskan wilderness. A massive 39-day search effort failed to locate them. The result was a United States law mandating ELTs in all civil aircraft.

As a result of the U.S. Federal Aviation Administration regulation approximately 150,000 U.S. civil aircraft had ELTs installed by July 1974. Similar unsuccessful searches for downed aircraft also occurred in northern Canada, resulting in Canada mandating carriage of ELTs on all its civil aircraft. The regulatory move to mandate ELTs on small aircraft gradually spread to Europe.

In the maritime domain, distress beacons were designated 'Emergency Positioning-Indicating Radio Beacons' (EPIRBs). The 1960 Safety Of Life At Sea (SOLAS) Conference adopted Recommendation 48 which stated: "*The Conference, recognizing that an automatic non-directional emergency position-indicating radio beacon will improve safety of life at sea by greatly facilitating search and rescue, recommends that governments should encourage the equipping of all ships, where appropriate, with a device of this nature which shall be small, lightweight, floatable, watertight, shock resistant, self-energizing and capable of 48 hours operation*".

Early maritime EPIRBs were designed to transmit at 2182 kHz and / or 156.8 MHz in the maritime distress channel 16, but eventually the frequencies 121.5 / 243 MHz, which allowed 'homing' on the distress transmission by search aircraft, were adopted for most maritime EPIRBs. SOLAS Recommendation 48 prompted the U.S. National Transportation Safety Board (NTSB) to recommend in 1972 that the U.S. Coast Guard require all U.S. vessels subject to SOLAS provisions to carry a 121.5 MHz, 243 MHz and 2182 kHz distress beacon. The final U.S. regulation which mandated 121.5 / 243 MHz EPIRBs without the 2182 kHz frequency resulted in approximately 1,700 U.S. vessels equipped with the device.

By the end of the 1970s, the total number of 121.5 / 243 MHz beacons deployed worldwide likely reached 250,000, including ELTs, EPIRBs and PLBs (Personal Locator Beacons).

1.3.3 Distress Beacons' Virtues and Shortcomings: A Brief Summary of the Alerting System Deficiencies

Undoubtedly, distress beacons on ships and aircraft, whether at sea or on land, helped rescue numerous crash survivors and mariners on sinking boats or disabled vessels. However, the device was far from perfect and experienced three major limitations:

a) a high number of false alerts;

b) frequent equipment failure; and

c) patchy monitoring radio coverage.

False Alerts

U.S. Air Force sources indicate that 98% of all reported incidents initiated by ELT transmissions during 1976 proved to be false alarms. Misuse of distress beacons, whether intentional or resulting from careless handling or ignorance of proper operation, was a source of non-distress, inadvertent activations which raised questions on the efficiency of the alerting system, at least in the early years of its deployment. However, other issues were more difficult to address. In aircraft, the automatic triggering system, the G-switch, designed to detect violent decelerations in a crash situation, sometimes did not react at all and sometimes reacted to vibrations experienced in a hard landing or simply to shock or banging doors. The device, usually mounted in the tail section of the aircraft to enhance survivability, could not easily be monitored and numerous false alerts in hangars resulted from pilots failing to power-off their beacon after the flight.

An automatic ELT is often installed in the aircraft tail section, which is assumed to better survive a crash.
Photo courtesy The International Cospas-Sarsat Programme

Better G-switches, more careful installations and pilot education did improve the situation with time, but false alert rates were still excessive, creating a heavy burden on SAR forces. On ships, EPIRBs designed to be automatically released if the ship was sinking had other failure modes which also resulted in a high false alarm rate. For instance, in early designs spraying water on the device could release it and only a combination of triggering conditions, such as a water activated power switch requiring full immersion after the EPIRB was automatically released, would reduce unwanted activations.

ELT and EPIRB Malfunctions

Better design and better user education prevented a fair number of false alerts, but could not always preclude equipment malfunction. In aircraft, beacon crash survival was and still is clearly a major challenge, particularly for high speed, large commercial transports. Possible solutions currently being investigated include the automatic detection of abnormal flight conditions, in-flight activation of distress transmissions and/or a pre-crash release mechanism of the device coupled with flight data and cockpit voice recorders, as in the early CPI design described above.

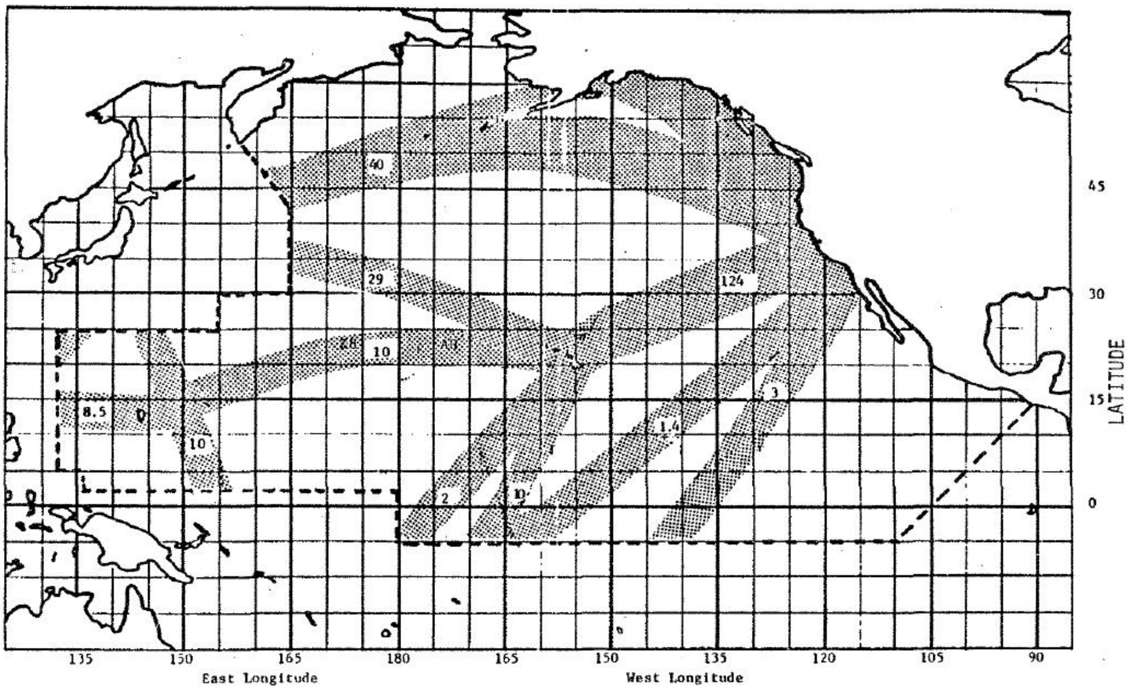
Another failure mode that affected both ELTs and EPIRBs involved the power source. Lithium batteries were chosen to provide the expected operating life for beacons stored over many years in difficult environmental conditions. The initial battery technology, using lithium-sulphur dioxide, proved somewhat defective with leaking cells and risks of sulphur dioxide out-gassing, or fire, possibly explosion. At sea, corrosion of the power source and electrical circuits in defective containers was a concern.

The Issue of Monitoring Coverage

The above considerations did not preclude the rapid deployment of distress beacons, but the third limitation of the system, that is the absence of a continuous, global monitoring network for 121.5 / 243 MHz transmissions, soon became the bigger concern. When beacons did work and transmit the required signals, there was no guarantee of detection, particularly at sea or in remote areas, far from the usual air traffic routes.

Low-power ELTs and EPIRBs operating in the VHF frequency bands had a fairly limited range, particularly if the beacon was lying on the ground after a crash, with line-of-sight blocked by obstacles, or floating in heavy seas. Although there was no regulatory obligation for aircraft pilots to monitor the distress frequency, high flying aircraft were still the best opportunity for long range detection. This brought up another aspect of the issue; if detected by high-flying aircraft, the location of the transmitter was not known with any precision. A long, costly and uncertain search by specially tasked SAR aircraft was still required.

The need for a truly global monitoring system is illustrated with the 1975 map of radio coverage by aircraft on Pacific routes in the United States' area of SAR responsibility. Even on these routes, beacon detection was a matter of chance and the waiting time could be very long.



Radio Coverage of Aircraft on Oceanic Routes within the U.S. Pacific SAR Region (1975)

Fortunately, the ‘space age’ had arrived. It was definitely the best chance of establishing the badly required monitoring system and, with the help of clever scientists and engineers, of providing a position determination capability for distress beacons. 121.5 / 243 MHz beacons had not been designed to operate via satellites in space, so the technical challenges were daunting. Nevertheless, if such a satellite system could be built, it would immediately have many potential users anxious to see an improved search and rescue capability.

ELT operation in Northern Canada prior to Cospas-Sarsat

My first successful search and rescue mission resulted in the location of a pilot who survived **30 days** in the Arctic wilderness. The pilot was aware of the limits of ELT batteries, and carefully protected his ELT until an aircraft was spotted flying nearby. He was very fortunate because many ELTs were automatically activated and the batteries would have expired within hours.

Subsequent flying missions made me quite aware of the limitations of homing on ELTs in mountainous regions where signal reflections would mislead pilots in the wrong direction and searching could be time consuming.

Major (retired) Herbert Edward (Ted) King,
Officer in Charge of the first Canadian MCC
in Trenton, Ontario Canada

Chapter 2

Experimenting with Satellite Detection and Location of Distress Alerts

2.1 Overview of Space Policies and International Cooperation among the Cospas-Sarsat Partners in the 1960s and 1970s

The following sections briefly introduce the national space policies of the four Cospas-Sarsat partners (the USSR, the United States, Canada and France) and their participation in international cooperative space projects in the 1960s and 1970s.

2.1.1 The USSR Space Effort before the Cospas Project

The source of Soviet and Russian expertise in space can be seen in some unique theoretical developments in 19th century Imperial Russia, many of those derived by Konstantin Tsiolkovsky, known as the father of theoretical astronautics.

Early Soviet Achievements

The Soviet achievements in space flight during the so-called 'Cold War' are impressive. The list includes the first intercontinental ballistic missile (R-7), the first Earth-orbiting satellite (Sputnik-1), the first animal in Earth orbit (the dog Laika on Sputnik-2), the first human in space and Earth orbit (cosmonaut Yuri Gagarin on Vostok-1), the first woman in space and Earth orbit (cosmonaut Valentina Tereshkova on Vostok-6), the first spacewalk (cosmonaut Alexey Leonov on Voskhod-2), the first Moon impact (Luna-2), the first image of the far side of the Moon (Luna-3) and unmanned Moon soft landing (Luna-9), the first space rover (Lunokhod-1), the first sample of Moon soil automatically extracted and brought back to Earth (Luna-16), and the first space station (Salyut-1).

In addition, the list should also mention Soviet interplanetary probes: Venera-1 and Mars-1, first fly-by of Venus and Mars, respectively; Venera-3 and Mars-2, first impacts on the surface of those planets; and Venera-7 and Mars-3, first soft landings on Venus and Mars, respectively. Finally, the probes Venera-15 and Venera-16 provided the first images of the surface of Venus.

Objectives of the USSR Space Programme

The former USSR space programme comprised two major objectives: rocket development and space exploration. The rocket development programme started in 1946, in accordance with a resolution of the Central Committee of the Communist Party of the Soviet Union and the USSR Council of Ministers. However, its implementation really started in 1957, after new research institutes, design bureaus and manufacturers for the space industry were established. In the USSR, the space programme was split among several competing design groups led by Sergey Korolev, Mikhail Ryazansky, Valentin Glushko, Nikolay Pilyugin, Aleksey Bogomolov, Vladimir Barmin and Victor Kuznetsov. Sergey Korolev was the head of the major rocket design group, with the official title of "Chief Designer".

In the mid-1960s, the Soviet Union intended to enhance its image as a technical, scientific and military power and expanded the objectives of its space programme by launching new types of satellites for military and civilian applications. While applications directed toward meteorology and civil radiocommunications received considerable publicity, others such as those designed for photographic and electronic intelligence (ELINT) reconnaissance, radar calibration, covert communications, navigation, geodesy and satellite interception were accomplished as part of a continuing programme of scientific research.

In the late 1960s, the Soviet Union started testing larger and more complex space boosters and spacecraft. However, after the race to the Moon, the effort on manned lunar missions was redirected towards Earth-orbiting space stations. Interest in constructing manned orbital space stations went all the way back to 1896, when Konstantin Tsiolkovsky described such an undertaking in his book “Beyond the Planet Earth”.

In the early 1970s, the USSR strove to improve the capabilities of their ELINT and photo reconnaissance satellites and constructed geosynchronous communication satellite networks. The USSR also sought to maintain the image of Soviet expertise in space by heavily publicizing the missions of the Salyut space station, choosing to promote the purely scientific objectives of these missions, such as biomedical research, Earth resource studies and materials processing.

International Cooperation

Despite the difficult relationship with the West and particularly the United States during the Cold War, international cooperation on scientific matters was also part of the Soviet space programme. In the 1960s, the United States and Soviet Union cooperation in space was pursued in three main areas: the exchange of weather data from satellites, a joint effort to map the geomagnetic field of the Earth, and the experimental relay of radio communications. The USSR also cooperated with France on scientific experiments and the development of the color TV system ‘Secam’ using the Molnya-1 relay satellite.

The cooperation with the United States was expanded in the 1970s to life sciences and biomedical research. Following the emblematic Apollo-Soyuz mission in 1975, seven U.S. biological experiments and medical devices were flown aboard the Cosmos 936 mission in 1977, which also flew experiments from France and a number of Eastern block countries. Cosmos 1129 in 1979 carried 17 additional U.S. experiments and devices.

After the collapse of the Soviet Union in 1991, Russia inherited the on-going space programme of the former USSR and established the Russian Federal Space Agency (Roscosmos) to run the new Russian space programme.

2.1.2 The United States Space Effort in the 1960s and 1970s

In the years immediately following World War II the United States concentrated its space flight efforts on military applications and research in recognition of the looming Cold War. From 1946, the National Advisory Committee for Aeronautics (NACA) started experimenting with rocket planes such as the supersonic Bell X-1. In the early 1950s, the U.S. objective was to launch an artificial satellite for the International Geophysical Year (IGY) (1957–58), which became known as Project Vanguard.

NASA and the United States International Cooperation Objectives

After the Soviet launch of the world's first satellite (Sputnik-1) in October 1957, the United States quickly re-evaluated its fledgling space efforts. In July 1958, President Eisenhower signed the National Aeronautics and Space Act, establishing the National Aeronautics and Space Administration (NASA). When it began operations in October 1958, NASA absorbed the 46-year-old National Advisory Committee for Aeronautics, including its employees, physical properties and research facilities, and its annual budget. Separately, the Advanced Research Projects Agency (ARPA) was created to continue development of space technology for military applications.

As the leader of the U.S. civilian space effort, within a few months of its establishment, NASA engaged in preliminary technical discussions with Canadian scientists on cooperation in space activities using sounding rockets and satellites. In March 1959, NASA authorised the National Academy of Sciences delegate to COSPAR[1] to offer, on behalf of the United States, to place in orbit individual experiments or complete satellite payloads prepared by scientists of other nations. NASA also started exploring possible avenues for international cooperation with European governments and major scientific institutions. The pattern of cooperation would involve substantive contributions of instrumentation and services without exchange of funds. Although cooperative programs might ultimately be formulated at the diplomatic level when required by reason of magnitude or content, such formal governmental agreement would always be preceded by technical discussions and informal arrangement.[2]

By 1960, the United States had reached agreement with Canada, represented by the Canadian Defence Research Board, on a joint project to sound the ionosphere: the Alouette mission. In the 1960s and 1970s, other projects of international space cooperation included[3]: Project Helios with the Federal Republic of Germany to study solar processes and solar terrestrial relationships, Direct Community Instructional TV Broadcasting with India, and Earth Resources Surveying, along with the U.S. participation in INTELSAT. The United States also entered into an arrangement with the European Space Research Organization (ESRO), at that time composed of ten European nations, for the launch of several satellites.

On-Off Cooperation with the Soviet Union during the Cold War

In early 1962 negotiations on cooperation in space were undertaken between the United States and the Soviet Union following an exchange of letters between President Kennedy and Premier Khrushchev in which both made detailed suggestions regarding the form such cooperative projects

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1/ COSPAR: Committee on Space Research of the International Council for Science (ICSU), a non-governmental organisation. In 2015, ICSU membership comprised 121 national scientific bodies and 32 international scientific unions.

2/ Hugh L. Dryden, Deputy Administrator NASA; Luncheon Talk, Institute of the Aeronautical Sciences, Hotel Astor, New York - January 27, 1960).

3/ Arnold W. Frutkin; Assistant Administrator for International Affairs NASA; Subcommittee on International Cooperation in Science and Space, Committee on Science and Astronautics, United States House of Representatives - May 18, 1971.

might take.[4] The proposals included communications satellites, weather satellites, satellite tracking and data services, space medicine, and mapping of the Earth's magnetic field.

The Cuban missile crisis in October 1962 put a temporary end to the public cooperation between the United States and the Soviet Union on space-related activities. From that time, the United States concentrated on unilateral manned space flight in a heated race with the Soviet Union to put a man on the moon and return him safely to Earth. The first Moon landing occurred during the Apollo 11 mission in July 1969. The United States had won the race, but Apollo 17 was the last mission to the Moon in December 1972.

In the early 1970s, after six successful Moon landings, other priorities became more pressing. The United States scaled down its space program. Some Apollo missions were scrapped and only one of two proposed Skylab space stations was built. Attention turned again to cooperation with the Soviet Union. This new phase in the relationship started in 1969 when discussions began on compatible rendezvous and docking arrangements as well as broader opportunities for cooperation. The resulting agreement, through a combination of independent and coordinated actions, led to compatible docking systems that culminated in the Apollo-Soyuz mission in 1975.

2.1.3 Canada - United States Bilateral Cooperation in Space in the 1960s and 1970s

John H. Chapman and the Alouette1 satellite
Photo courtesy of the DOC of Canada

Because of its large territory and pressing need for an alternative to terrestrial fixed and mobile communication systems, early Canadian interest in space technology focussed primarily on satellite radio-communications capabilities.

When the United States created NASA in July 1958, one if its objectives was to foster international scientific cooperation, and Canada welcomed this opportunity to partner with the USA on new space projects. Canadian and American scientists held discussions that year about a new satellite equipped to bounce radio signals off the top of the ionosphere to complement the knowledge gained from ground-based equipment bouncing radio signals off the bottom of the ionosphere, in an effort to improve long-range radio communications, vital in Canada's far North.

Alouette and Communication Satellites

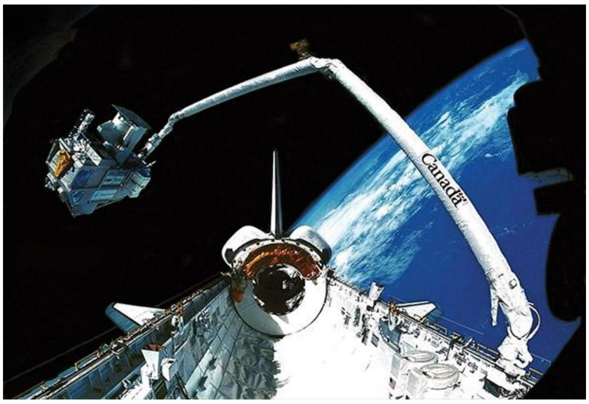
The Canadian Defence Research Board (DRB) proposed a top-side sounder, and in 1959 Canada and the USA agreed that NASA would supply a launch vehicle and Canada would design and build the satellite at the DRB. The satellite, named Alouette, was built under the direction of physicist John H. Chapman, who later became known as the father of the Canadian space program. The equipment to be flown on Alouette, including a new, long, extendable 'roll-up' antenna, was tested on sounding rockets, and in 1960, the U.S. Navy launched the Transit 2A navigation satellite that included the first Canadian equipment sent into orbit, preparing the way for Alouette by testing for background radio noise in space.

4/ Robert C. Seamans, Jr. Associate Administrator NASA; Address to the American Ordnance Association, San Francisco, California - May 24, 1962.

The Alouette 1 satellite was launched in 1962. Although it was designed to operate for only one year, Alouette 1 was still working after ten years. When Alouette 1 was finally switched off, it had sent back two million soundings of the ionosphere to scientists in Canada, the United States and the United Kingdom. With this success, Canada built and NASA launched Alouette 2 in 1965, followed by ISIS 1 [5] in 1969 and ISIS 2 in 1971. All were successfully built with steadily increasing participation by Canadian industry, advancing scientific knowledge about the ionosphere and its impact on radio communications.

However, other satellites had shown that repeater satellites operating in geosynchronous orbits 35,800 km above the equator would be the dominant space-based communication tools for the coming decades. Television signals relayed by satellites were to become far more important than radio signals bounced off the ionosphere. The Canadian government decided to review its space policies, with a special emphasis on communications.

In 1967, a study group led by Dr. Chapman produced a report on Canada's space programs that called for Canada to set up a domestic geostationary communications satellite system. The Canadian government was anxious to improve communications systems around the country and, in 1969, set up the federal Department of Communications (DOC) and its Communications Research Centre (CRC), as well as Telesat Canada, a corporation owned both by government and private interests, to carry out this policy. Telesat's Anik A-1 satellite was launched in 1972, becoming the world's first domestic communications satellite in geostationary orbit operated by a commercial company.



The Shuttle Remote Manipulator System also called 'Canadarm'

Canada's Participation in the U.S. Shuttle Programme

Canada was invited by NASA to participate in the Space Shuttle programme and in 1975, Canada agreed to develop and build a series of robotic arms called the Shuttle Remote Manipulator System, later coined the 'Canadarm'. These were installed on all five Space Shuttles and were used for a multitude of applications on over 90 missions, from 1981 until the Shuttles were retired in 2011.

The Canada-United States cooperation continued in the 1970s. The new and powerful Communications Technology Satellite, named Hermes, was designed and built by Canada and launched by NASA in 1976. Hermes pioneered new satellite technologies in the Ku-frequency band (12-18 GHz), including direct-to-home broadcasts to small satellite dishes and helped ensure that Canada played a key role as a builder of systems for communications satellites up to the present day. Also in the mid-1970s, Canada-United States discussions and experiments were underway on a possible new satellite system for Search and Rescue - SARSAT, which eventually evolved into the very successful international Cospas-Sarsat system.

5/ ISIS: International Satellites for Ionospheric Studies.

2.1.4 France Bilateral/Multilateral Cooperation in Space in the 1960s and 1970s

After a period devoted to rebuilding its industrial capabilities in the 1960s and in a more stable political environment following the long episode of decolonisation, France was keen to acquire and develop its own competences in space technologies. CNES [6], the French national space agency established in 1961, was open to all opportunities for cooperation with States that had confirmed space capabilities.

CNES First Steps and the Cooperation with NASA

The first opportunity was offered by NASA. In May 1962, CNES participants in the COSPAR conference were invited to the White House by Jerome Wiesner, scientific adviser to President Kennedy, to discuss France-USA relations on space matters [7]. Rules for bilateral cooperation were quickly established: the U.S. provided support in the field of satellite technology but no help for launch vehicle development. Through an arrangement with NASA on the FR-1 external geophysics satellite project, to be developed by France and launched by NASA, twelve French engineers were accepted by NASA at GSFC [8] for a one-year training period. FR-1, launched in 1965, was a success and in 1966, CNES and NASA extended their cooperation with an experimental meteorological satellite, Eole.

With the Eole satellite launched by NASA in 1971, France demonstrated its competences for in-situ collection of meteorological data. This would be followed in 1979 by a more permanent system for environmental data collection, Argos, developed by CNES and flown on U.S. operational meteorological satellites operated by NOAA [9]. A short description of the Eole and Argos systems is provided in Chapter 1, section 1.2. The Argos system is still in operation to date and its success opened the way for France's participation in the Sarsat project together with Canada and the United States. In particular, Argos pioneered the Doppler location technique implemented in the Sarsat 406 MHz system.

Other Horizons for International Cooperation in Space

However, the possible domains for cooperation with the USA remained limited and France had ambitions beyond scientific applications. France had successfully launched a satellite in 1965 with the French Diamant rocket. The effort to develop national launchers independently from the USA or the USSR would be pursued until 1975. The independent launcher objective would then be redirected to create the basis of the European Ariane rocket under the auspices of the newly established European Space Agency (ESA). Similarly, efforts to develop fixed-service telecommunication satellite capabilities were pursued through the Franco-German 'Symphonie' satellite programme and later with national or European projects such as OTS [10].

6/ CNES: Centre National d'Etudes Spatiales.

7/ 'The First Thirty Years of CNES, the French Space Agency' - La Documentation Française - (Claude Carlier, Marcel Gilli).

8/ GSFC: the Goddard Space Flight Center near Washington D.C.

9/ NOAA: the National Oceanic and Atmospheric Administration of the United States of America.

10/ OTS: Orbital Test Satellites - European experimental telecommunications satellites in geostationary orbit launched in 1977 and 1978 by the European Space Agency.

Meteorology would also remain a French space policy priority with the 'Meteosat' geostationary satellite project proposed by France, but developed under the responsibility of ESA and operated by the European Meteorological Satellite Organisation (EUMETSAT). Although most of the French space development effort was later accomplished through ESA, CNES retained a strong capacity for independent national development, particularly regarding satellite telecommunications and Earth observation programmes.

Cooperation with the Soviet Union provided more opportunities which were actively pursued by CNES. In 1966 an agreement was signed in Moscow during the visit of the French President, Charles de Gaulle, to the USSR. Franco-Soviet cooperation in space was placed under the responsibility of CNES for France and the Intercosmos Council for the USSR, who would report annually to a joint Franco-Soviet 'Grand Commission'. The agreement for the 'study and peaceful exploration of space' included space science, meteorology, aeronomy and telecommunications. The scientific part of the cooperation was the more productive and was later expanded to include geophysics, astronomy, biology and space medicine. The cooperation had to overcome a number of hurdles stemming from difficult communications during the time of the Cold War and significantly different working methods. When French scientists asked to integrate their experiments themselves at the launch site, as they did when cooperating with their American colleagues, their soviet partners from the Academy of Sciences discreetly advised the Director General of CNES that even the USSR Academy of Sciences was not authorised to do so, as this had always been the responsibility of military personnel. As CNES refused to go ahead with the cooperation on this restricted basis, the Soviet Government adopted a more flexible attitude, which ultimately benefited the Academy of Sciences [11].

11/ Quoted from "The First Thirty Years of CNES, the French Space Agency" - La Documentation Française.

2.2 Sarsat Genesis

2.2.1 The Definition of a Satellite System for Distress Alerting and Locating in the United States

Bernard D Trudell
Sarsat Technical Manager, NASA
First quadripartite Cospas-Sarsat meeting at GSFC, Greenbelt, MD (June 1978)
Photo courtesy of The International Cospas-Sarsat Programme

The installation of Emergency Locator Transmitters (ELTs) on private fixed-wing aircraft was made mandatory in the United States in 1974, via a 1970 amendment to the U.S. Occupational Safety and Health Act. Soon, however, the severe deficiencies of the 121.5 MHz ELT system were revealed, in particular the poor reliability of early equipment installed on light aircraft and the lack of a continuous monitoring system with adequate coverage. While the beacon deficiencies could be addressed by hardware improvements and proper user education, there was no easy solution to the issue of monitoring coverage.

NASA started investigating the feasibility of satellite monitoring of distress alerts. Mr. Bernard (Bernie) Trudell, Study Manager in the Applications Group at NASA's Goddard Space Flight Center in Greenbelt, MD, was tasked with reviewing past efforts and user needs, and developing a 'Search and Rescue Orbiting Satellite' (SOS) concept. Preliminary studies had highlighted the potential of orbiting satellites at an altitude of about 1,000 km for monitoring and data collection. A demonstration with the OSCAR-6 amateur-radio satellite in 1975 had confirmed the feasibility of the concept with a simulation of the relay of 121.5 MHz beacon transmissions.

In November 1975, encouraged by recommendations of the U.S. Aircraft Owners and Pilots Association (AOPA) and the National Association of Search and Rescue (NASAR), the U.S. Interagency Committee on Search and Rescue (ICSAR) consisting of representatives from the FCC[12], NASA and the Departments of Commerce, Defense, and Transportation, established an ad-hoc working group on satellite distress alerting and locating. After reviewing possible options for the distress alerting and locating function, including the use of existing (Omega, Loran, Decca) and future (GPS) navigation systems, the ICSAR working group report, published in October 1976, recommended that:

- *Demonstration of a satellite-aided search and rescue system capable of monitoring and locating existing ELT and EPIRB equipped vehicles should be implemented immediately to provide operational experience and cost-benefit data to user organizations.*

> When I completed my initial review of studies and programs on satellite-aided search and rescue, I became convinced that only a program that served the existing 121.5/243 MHz ELTs and EPIRBs had a chance for gaining a project approval with the required budget. I was also convinced that the program had to be linked with a system that was designed for satellite tracking, patterned after the satellite Data Collection Systems such as the NIMBUS RAMS and the TIROS-N ARGOS system being flown on the NOAA-A through G satellites. My promotion expression was "provide a limited capability at 121.5 MHz while allowing for the gradual transition to the 406 MHz - a system designed for satellite tracking".
>
> Bernard D Trudell
> Sarsat Technical Manager, NASA

12/ FCC: Federal Communications Commission.

- *Development of an advanced distress ELT/EPIRB at the internationally accepted 406 MHz frequency for use on aircraft and ships and designed for operations with a satellite system should be implemented.*
- *The advanced EPIRB should contain identification and situation coding which would be an optional feature for ELTs.*
- *Since the international aspects of a SARSAT*[13] *have been recognized with the possibility of reducing SAR costs, foreign participation is encouraged in any demonstration satellite system in order to promote international acceptance.*
- *Any satellite system proposed should be outlined to ICAO and IMCO*[14] *to ensure international participation and a uniform worldwide system.*
- *The aviation and maritime communities and government agencies should support and actively participate in any satellite demonstrations.*
- *Government and civilian organizations should study the management, cost, and operations aspects of implementing an operational SARSAT system, including international participation.*
- *Continued development of techniques for the use of future satellite systems such as INMARSAT, AEROSAT*[15]*, and others, for SAR [...] should be encouraged.*

The ICSAR report had clearly identified the technical options and the basic goals of the proposed satellite system, including a dual approach to:

- address current needs for monitoring and locating distress alerts from existing ELTs and EPIRBs transmitting an analogue signal at 121.5 MHz and 243 MHz; and
- investigate the expected enhanced performance of a new system using advanced digital technology and operating at 406 MHz, a frequency already assigned by the ITU for distress alerting with low-power satellite EPIRBs.

The Advanced Tiros-N Spacecraft with Sarsat Payload and Antennas
Photo courtesy of NOAA

Furthermore, the ICSAR report also stated the objective of a global satellite system open to international cooperation and aiming at global international acceptance. Bernie Trudell had been instrumental in the development of the concept and its adoption by the ICSAR working group. He would continue with unabated enthusiasm to push for his ideas, firstly in the context of the United States-Canada cooperation already under discussion regarding the 121.5/243 MHz portion of the future system, and later in discussions with CNES for the development of the 406 MHz system.

13/ This is the first recorded use of the acronym SARSAT, defined as 'Search and Rescue Satellite', to be later adopted for the joint cooperative project between Canada, France and the USA, with the definition 'SAR Satellite-Aided Tracking'.

14/ The 'Inter-governmental Maritime Consultative Organisation' (IMCO) was renamed the International Maritime Organisation (IMO) in 1982.

15/ INMARSAT, AEROSAT: see short description of both projects in Chapter 1, section 1.2.

NASA was under contract to design and build the NOAA operational meteorological satellite series in low-altitude polar-orbit. The satellite was designed to carry a collection of meteorological instruments, including the Argos 401 MHz data collection system provided by CNES in France. It seemed logical to try to modify the satellite platform to accommodate the SAR payloads, provided the integrity of the system could be maintained. For NASA, the challenge would be to accommodate new antennas on the satellite bus, in particular the rather bulky 121.5 MHz helix, and provide the required electrical power for the SAR payloads, including an additional L-band transmitter for continuously broadcasting the repeated SAR frequencies bands (121.5 MHz, 243 MHz and 406 MHz, plus the processed data stream of the 406 MHz system).

2.2.2 Canada's Effort towards Satellite Detection of 121.5 MHz Beacons

In 1971, a theoretical study [16] by Harry Stevinson, who had developed the CPI [17] in the 1950s, and his colleague from the National Research Council of Canada, D.A. Baker, determined that satellites could probably relay and locate distress signals from CPIs and ELTs, and that various satellite orbits could be considered.

The concept for a Search and Rescue Satellite system was originally discussed during a coffee break at the Communications Research Centre (CRC), in the Space System Group led by Larry Maynard. CRC, which was originally attached to the Defence Research Telecommunications Establishment of the Department of National Defence (DND), had recently been created as a civilian agency linked to the newly formed Department of Communications (DOC). One morning after Larry Maynard had described a false alarm ELT incident that he had with his own aircraft, the discussion turned to how space technology might be useful to 'pin-point' the location of these incidents and thereby save significantly on the costs of searching for downed aircraft. In a situation of real emergency, such a system would shorten the time to initiate and execute the rescue operation, which was known to be a critical factor in the Arctic and remote regions of Canada.

With the United States' Transit navigation satellite system already in orbit, using the Doppler shift of the satellite's downlink signal to determine a user's location, the idea of an "inverse Transit" was one option considered. The Doppler shift of the ELT uplink signal to an orbiting satellite would be measured and used to compute the ELT location. The transmitted power from the ELTs of the day was very limited, which favoured the use of a lower altitude satellite and hence generally a 'polar orbiting' satellite.

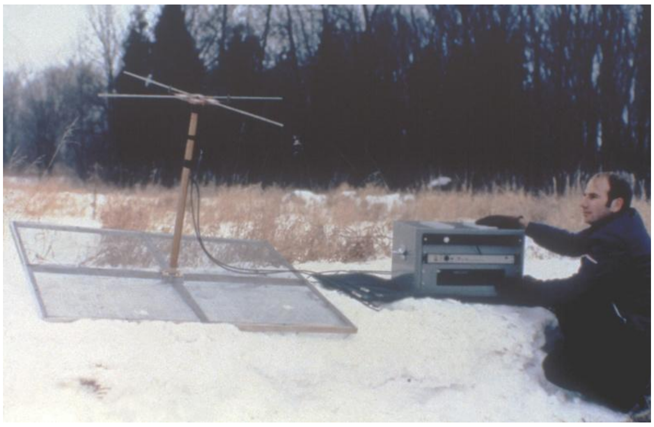
A key concern was whether the signal would have enough of a shift in frequency and a high enough signal-to-noise level to permit a reliable and accurate prediction of location. Nevertheless, if you had an appropriate satellite to relay the signals, if you knew where the satellite was at any particular point in time, and if you could do the signal processing, the only unknown to the problem would be the location of the ELT. The idea was hatched but it was a long way from being a 'real project' with 'real money' to spend. It was also not considered to be a 'mandated activity' or a core research area.

At the time, amateur radio operators in the AMSAT organization had an orbiting satellite, named OSCAR, that used an uplink frequency of 145 MHz, very close to the 121.5 MHz ELT frequency.

16/ Stevinson, H.T., and Baker, D.A. (1971). Locating People in High Latitudes. Laboratory Technical Report LTR-FR-32 and –32A, National Aeronautical Establishment, National Research Council, Ottawa, Canada.

17/ CPI: Crash Position Indicator - See section 1.3.2.

Any experimentation at the operational ELT frequency would have been difficult due to the possibility of interference with real-life incidents. The closeness of the OSCAR uplink frequency would yield propagation effects and Doppler frequency shifts very close to what could be expected from an operational system at 121.5 MHz. The idea of attempting a demonstration using the Oscar satellite was developed under Larry Maynard's leadership and the work was progressed largely by LeRoy Pearce, Doug Lambert and Menno Stoffels, who were later joined by Alan Winter.



Dr. Alan Winter conducting a Sarsat proof-of-concept demonstration at CRC in Ottawa, Canada via the Oscar-6 satellite in 1975
Photo Courtesy of the DOC of Canada

In order to conduct a demonstration, a signal processing technique was developed that could best be described as the use of a prediction software package based on orbital elements to locate the satellite in its orbit at any particular time, plus an optimisation package to match the observed uplink signal Doppler shift curve to curve templates that would have occurred, had the ELT been transmitting at various assumed locations. The assumed location was varied so as to achieve the best possible match with the observed curve. This process yielded two locations on either side of the orbital track on the Earth, the true location and a mirror location that could usually be eliminated by knowledge of the likely region of the crash or after a second satellite pass. An 'experimental ELT' was made by shifting the operational ELT centre frequency of the transmitter to match the OSCAR satellite uplink frequency of 145 MHz.

The work so far had been carried out by CRC on a cost-recoverable basis, within the military satellite communications research and development programme performed for DND. Canadian Forces tasks include Search and Rescue in Canada, nevertheless, the support level for the initial research activities was minimal as there was a stronger interest in space communications for military operational missions than in domestic search and rescue matters. Notwithstanding the low initial level of sponsorship, the potential value of the concept was recognised and hence the research and development work continued. Larry Kaiser of the AMSAT organization was contacted and the group was successful in gaining permission to conduct experiments in 1975, making use of the OSCAR-6 satellite. Without the cooperation of AMSAT, the demonstration would not have happened and it is unlikely that full support would have been forthcoming for the subsequent operational project.

> We never would have been taken seriously by DND or NASA if we had not been successful demonstrating the SARSAT concept using the OSCAR satellite. The key demonstration was finding General Mackenzie's helicopter via OSCAR, where only he and his pilot knew the location, and from then on we had the support of DND to negotiate a joint SARSAT system with NASA and other countries!
>
> Alan E. Winter, Project Leader, SARSAT Systems, CRC.

The experiments were very successful. One key moment was a demonstration to senior DND personnel. The OSCAR 'experimental ELT' was flown in a helicopter to a remote lake in northern Quebec and hidden under a cover of foliage. The ELT location for the trial was selected by, and known only to, the senior DND personnel and the pilot of the helicopter. Shortly after the next orbital pass of the OSCAR satellite the 'secret' location of the ELT was computed and presented to the senior DND personnel who were immediately convinced of the value and feasibility of the idea. The successful demonstration secured the support of both DND and

DOC. A second key breakthrough came when Larry Maynard received a telephone call from Bernie Trudell of NASA in the United States. Bernie had heard of the successful demonstration and indicated that they had been looking into a similar concept. A presentation of the trial results convinced NASA of the feasibility of the venture. It was agreed that a joint USA/Canada cooperative project could result in a more effective solution and a more cost-effective approach for both countries. With the assistance of DND, approval was obtained for the joint project with NASA. France's national space centre, CNES, also joined shortly thereafter. DND funded CRC to set up and run a technical project office. Mr. Harvey Werstiuk was appointed to lead this technical project office in 1977, with responsibility for the subsequent Sarsat experimental phase.

Canadian industry also played a significant role in this phase of the project, particularly in developing the operational Sarsat 121.5 MHz system by the early 1980s. The proof-of-concept experiment in 1975 was done using laboratory test equipment and mathematical computations done by hand to determine the beacon location, since no computer algorithm was yet available to do such automatic processing. Doing hand calculations would not be feasible for a satellite alerting system that had to operate 24 hours a day. This hurdle still had to be overcome.

Canadian Astronautics Ltd. developed a new signal processing algorithm, called the Constant Bin Correlator (CBC), that was able to automatically track and extract very weak signals received from 121.5 MHz distress beacons. Michael Stott and Richard Renner of Canadian Astronautics demonstrated the performance of their algorithm at an international meeting of the Sarsat partners in Ottawa in May 1978. The company was later contracted to build an "Advanced Development Doppler Processor - ADDP", as a precursor of a complete satellite ground receiving station.

Now that automated signal processing was shown to be possible, development of other elements of an experimental satellite system could be undertaken by Canadian industry, including designing and building satellite payloads (the SAR Repeaters) by SPAR Aerospace, a Canadian Mission Control Centre by SED systems, 406 MHz prototype test beacons by Bristol Aerospace Ltd. and MPR Teltech, and later portable beacon testers by WS Technologies.

2.2.3 France's Expertise in Satellite Data Collection and Doppler Positioning Systems

France's DGAC[18], the French civil aviation administration, had mandated the use of 121.5 MHz ELTs for commercial flights in accordance with 1967 ICAO requirements. Mandatory carriage was extended to all general aviation aircraft in 1979. However, although the same limitations affected the efficiency of the 121.5 MHz system as in the USA and Canada, there was no pressing demand in France for a satellite monitoring system, probably because of a lesser development of general aviation in Europe. France's involvement in the Sarsat project was entirely the consequence of CNES[19] experience in satellite data collection and Doppler positioning systems acquired while cooperating with NASA on the Eole experiment and later on the operational Argos system (see Chapter 1, section 1.2.3).

The French Argos instrument operating at 401 MHz was carried on board NOAA's Advanced Tiros-N meteorological satellites. Argos was designed to collect environmental data from light

18/ DGAC: Direction Générale de l'Aviation Civile.

19/ CNES: Centre National d'Etudes Spatiales.

buoys and locate the transmitter anywhere on the globe, after each pass of the LEO[20] satellite in visibility of the drifting buoys. This was very similar to detecting and locating 406 MHz distress beacons. However, the 406 MHz SAR mission requirements were not identical to the Argos system requirements. On-board signal detection and Doppler shift measurement, storage and retransmission to the ground were similar in principle, but implementation was different.

Because of the assumed distress situation, a higher detection probability was desirable on the first available 406 MHz bursts received by the satellite and a good Doppler location computation accuracy was desirable after the first satellite pass in visibility of the beacon. This had to be achieved in unfavourable environmental conditions and potentially immediately after the beacon had been turned on, during warm-up time. Using oscillators commercially available at the time, the beacon bursts emitted before a stable operating temperature was reached would exhibit an unstable carrier frequency, which could severely impact the Doppler location accuracy. In all other aspects, the technical challenge was identical. The real difficulty of the project would be to achieve the performance targets in terms of minimum detection time, Doppler location accuracy and reliability, using beacons affordable to users, but far more advanced than existing 121.5 MHz units.

To CNES, the project was essentially a technical challenge and a new opportunity to develop its own expertise. It was presented as a limited extension of the Argos project, which was to become operational with the launch of the first Advanced Tiros-N satellite in 1978[21]. The 406 MHz SAR instrument was almost identical to the Argos 401 MHz receiver-processor equipment and procured from the same manufacturer, the Dassault company, hence it did not require additional costly development.

The CNES team at the Toulouse Space Centre, led by Dr. Daniel Ludwig and Mr. Maurice Winterholer, was focussed on the 406 MHz system and initially paid little attention to the 121.5 MHz system developed by Canada and the United States. Many doubted that proper Doppler processing could be performed using the weak 121.5 MHz repeated signal. Initial plans in 1979 for a receiving station in Toulouse did not include any 121.5 MHz processing capability. Such capability would be procured in 1981 from Canada, after initial testing of available equipment showed promising results. Following contacts with the French civil aviation administration, CNES had realised that, to ensure appropriate visibility of its own Sarsat experiment at 406 MHz, 121.5 MHz beacons already deployed in France and other European countries could not be ignored.

From 1979 to 1983, Daniel Ludwig led the development work at CNES as Head of the Argos and Sarsat Department in the Satellite Directorate of the Toulouse Space Centre, with Claude Gal in charge of the satellite payloads, Philippe Goudy as system engineer and Michel Alonso in charge of the ground segment procurement. From 1983, Claude Gal continued as Head of Department and Claude Augoyard assumed the challenging task of setting up the French MCC and organising the transition to full operational capability, under the leadership of Pierre Bescond as Director of Satellite Operations. Daniel Ludwig continued with new responsibilities as the overall project coordinator in Toulouse, until he joined the Galileo Supervisory Authority in Brussels where he initiated the co-operation with Cospas-Sarsat on the SAR-Galileo MEOSAR project.

20/ LEO: low-altitude Earth orbiting satellites.

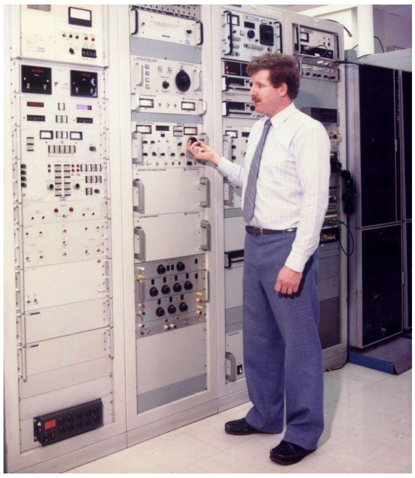
21/ Tiros-N was launched on 13 October 1978. The Argos system became operational in 1979.

2.2.4 The 1979 Sarsat MOU

The Sarsat experimental project was born officially on 27 August 1979, the day of the last signature of the "*Memorandum of Understanding between the National Aeronautics and Space Administration of the United States of America, the Department of Communications of Canada and the Centre National d'Etudes Spatiales of France Concerning Cooperation in an Experimental Satellite-Aided Search and Rescue System*".

The MOU highlighted the results of coordinated studies in the USA and Canada which had confirmed the technical feasibility of a joint experimental system (i.e., the 121.5/243 MHz repeater system) and the objective to "*meet current search and rescue requirements defined by user agencies in the USA and Canada*". The goals were to "*improve monitoring coverage, reduce detection time and provide more accurate initial location of distress incidents*". In addition, the MOU recalled that "*the CNES SARGOS*[22] *system, an on-board receiver-processor operating in the 406 MHz frequency band, [was] consistent with the requirements and constraints of the [SARSAT] project which [had] been previously discussed between NASA and DOC*". Finally, the MOU noted that the Parties were undertaking the joint project "*with a view to the possibility that it may lead to an operational satellite-aided search and rescue system under the direction or on behalf of the search and rescue user agencies in each country*".

The MOU then proceeded with a description of each party's responsibility in building and procuring the required equipment: 121.5/243/406 MHz repeaters for DOC, to include the 1,544.5 MHz downlink transmitter, and 406 MHz receiver-processor instruments for CNES; while NASA would provide antennas and ensure the proper integration of the SAR equipment on the NOAA satellite bus. NASA specifically retained full responsibility for the overall integrity of the satellite system. The MOU also highlighted that, in line with the experimental nature of the project, the SAR system would not impose constraints on the management of the NOAA satellite system, particularly in case of failure of the satellite or of the SAR instruments. Furthermore, all Parties to the MOU recognised that NOAA had made no commitments towards of a possible future operational system.



Antenna Control Unit of Prototype LUT 1981
Jim King at the Communication Research Centre, DOC, Canada

The project management was assigned to a tri-partite 'Steering Group' and a 'Joint Working Group' was tasked with the preparation of a 'Joint Project Implementation Plan'. Because of the nature of the cooperation, which involved the transfer of hardware and the exchange of proprietary data, the MOU carefully addressed, inter alia, customs matters, the restricted use of information and proprietary data, and liability issues as well as the settlement of disputes.

22/ The 'SARGOS' name of the CNES system was a contraction of SAR and Argos, the data collection system carried on NOAA polar orbiting satellites and first launched in 1979. This terminology was dropped when discussing the Cospas-Sarsat MOU which included a similar 406 MHz system provided by the USSR.

2.3 Cospas Genesis

SAR Background in the Soviet Union

In the 1970s, ICAO and IMO had developed requirements for 121.5 MHz distress transmitters. The characteristics of the radio signal for these 'Emergency Position Indicating Radio Beacons' (EPIRBs) had been summarised in the ITU Regulations [23], which assumed that the 121.5 MHz distress signal would be received by standard radio receivers and audio-detected by radio operators or pilots. Some types of aviation 121.5 MHz distress transmitters were already in use in the USSR (R855UM Komar), but the ITU requirements did not include a demand for high frequency stability, which made this type of transmitter difficult to locate via satellite with a Doppler positioning technique. Another frequency band at 406 MHz had been identified by the ITU and reserved exclusively for future devices to be relayed by satellites.

The huge, sparsely populated territories of the Soviet Union, bordered by large oceanic areas, made the creation of an efficient alerting and search and rescue system of paramount importance, socially as well as economically. The USSR was also investing heavily in the development of space systems, which led naturally to the decision to investigate the potential of low-altitude Earth orbiting satellites for distress alerting and locating.

The need to assist mariners in distress situations at sea was seen as a priority and the Ministry of Merchant Marine (MORFLOT) was appointed as the responsible organisation for the implementation of the "*Коспас*" project. "*Коспас*" (Cospas) is an acronym for "*Космическая система поиска аварийных судов*" meaning 'Space system for the search of vessels in distress'. Because of the poor characteristics of the 121.5 MHz signal of existing distress transmitters, the USSR choose primarily to develop a new type of EPIRB operating at 406 MHz and designed specifically for satellite processing, which would allow for significantly better performance in terms of alert detection and location accuracy.

However, the USSR also acknowledged the attention paid by Canadian experts to the processing of 121.5 MHz distress transmissions relayed by satellites and their efforts to develop appropriate Doppler processing techniques to locate the source of such emissions. Therefore, considering the large number of 121.5 MHz ELTs/EPIRBs already in use, probably over 250,000 worldwide at the end of the 1970s, the Soviet Union supported the proposal for global monitoring of 121.5 MHz beacon signals using satellites in low-altitude Earth orbit, which provided an opportunity to increase the probability of detecting these distress signals.

The Cospas Project

The initial contact between a delegation led by Mr. Yuri Atzerov, Director General of Morsviazsputnik, a subsidiary company of MORFLOT established to operate maritime mobile satellite communications, and NASA on a satellite system for SAR occurred in March 1977 in Washington, D.C., USA. The meeting resulted in an agreement in principle to cooperate, which was later acknowledged in a formal USSR-USA high level agreement on cooperation in the fields of science and technology signed on 24 May 1977.

23/ Appendix 37A of the Radio Regulations - Technical characteristics of EPIRBs operating on the Carrier Frequencies 121.5 MHz and 243 MHz

In June 1978, the second meeting of a Soviet delegation with NASA in Washington, D.C. marked the actual beginning of the East-West cooperation on the Cospas-Sarsat project. The Soviet delegation was led by Mr. Yuri Zurabov, the Deputy Director General of Morsviazsputnik, who would become the head of the Cospas delegations to numerous international meetings until April 1999. The Cospas project was formally established by the USSR Council of Ministers resolution No.33-15 of 12 January 1978, with MORFLOT in charge of its implementation.

The 'Radio Support of Space Systems' Division of the USSR Research Institute of Space Devices Engineering (RISDE) was appointed in June 1978 to conduct the development of the new satellite system. Yuri Makarov, the Chief of RISDE Radio Division, who had 20 years of experience in the development of radio communication systems for Soviet satellites and deep space spacecraft flown to the Moon, Venus and Mars, had full responsibility for this development. Mr. Makarov was replaced as project leader in 1982 by Arnold Selivanov, himself replaced in 2002 by Igor Nikushkin. A detailed Cospas Implementation Plan was approved in 1979 to support the development work.

Yuri F. Makarov,
Cospas Project Technical Manager (1978-1982),

Designed to be inter-operable, the Cospas and Sarsat projects were actually developed separately. While Sarsat would use a large U.S. meteorological satellite bus to accommodate the SAR payloads provided by Canada and France, functionally similar 406 MHz and 121.5 MHz payloads developed independently in Russia were flown on the satellite bus of the Tsikada Doppler navigation system. The Tsikada satellites, illustrated below, were launched on a near-polar orbit at an altitude of 1,000 km, with a 83° inclination. The accommodation of the Cospas system payloads required additional transmit and receive antennas, including a fairly large 121.5 MHz receive antenna, as well as additional electrical power for the continuous broadcast of alert data on the 1544.5 MHz downlink. Electro-magnetic compatibility of the Cospas payload with the Tsikada satellite Doppler navigation payload transmitting in the frequency bands around 150 MHz and 400 MHz, close to the SAR payload receive frequencies, was also a difficult technical issue. This matter was successfully addressed by a RISDE division led by Yuri Bekhterev. The Soviet receiving station (called a Local User Terminal or LUT) for Cospas and Sarsat satellites was developed at RISDE by Evgeny Molotov's division, while the software was produced by Vyacheslav Arkhangelsky for the Cospas system and Vilen Krupen for the Soviet LUT.

Arnold Selivanov,
Cospas Project Technical Manager (1982-2002)

Another important aspect of the project was to ensure the full interoperability of the Cospas and Sarsat communication systems, which imposed similar radio signal characteristics, antenna patterns, communication protocols, message structure and message processing, etc. Under the leadership of Vladislav Rogalsky from RISDE, interoperability was successfully accomplished through the exchange of detailed technical interface specifications collected in a joint Cospas-Sarsat Implementation Plan (CSIP). In addition, 'compatibility trials' were run before launch by Cospas and Sarsat technical experts jointly, in 1982. These trials took

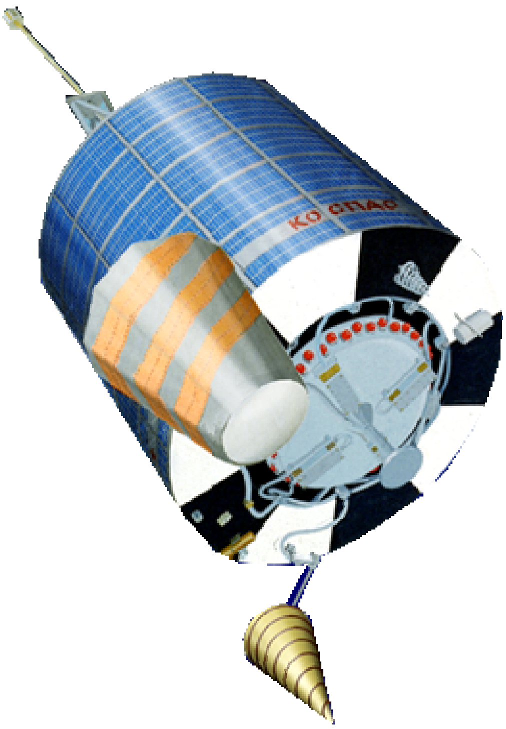
Vladislav Rogalsky
Cospas System Interoperability Manager (1978-2009)

place both at RISDE in Russia and at CNES Toulouse Space Centre in France.

The project was completed according to the planned schedule of the Cospas-Sarsat Implementation Plan and the first launch of the Cospas-1 (Cosmos 1383) satellite occurred on 30 June 1982 from the Plesetsk launch site in the USSR. The second Cospas satellite (Cosmos 1447) was launched on 24 March 1983 and Cospas-3 (Cosmos 1574) was launched on 21 June 1984. The first Sarsat satellite launch on 28 March 1983 completed the desired four-satellite constellation, allowing a swift conclusion of the Demonstration and Evaluation phase started in October 1982.

By 1984, with three Cospas satellites in orbit, three LUTs in operation (Moscow, Arkhangelsk and Vladivostok) and a Mission Control Centre (MCC) established in Moscow under the direction of Vyacheslav Semikolenov, the Cospas system was declared pre-operational. This paved the way for a continuation of the international cooperation, with a new Cospas-Sarsat MOU signed in 1984.

On 8 December 1987, Resolution No.1414-350 of the Central Committee of the Communist Party of the Soviet Union and the USSR Council of Ministers declared the Cospas system in full operation and recommended its use by merchant marine and fishing fleets, civil aviation and other interested parties. This decision preceded the signing of the International Cospas-Sarsat Programme Agreement (ICSPA) in July 1988, which made the Cospas-Sarsat system available to the international community on a non-discriminatory basis.



The Tsikada / Nadejda Spacecraft with Cospas Payload and Antennas

Yuri Zurabov, former Deputy Director General of Morsviazsputnik, led the Soviet and Russian delegations at Cospas-Sarsat meetings between 1978 and 1999 and chaired numerous Cospas-Sarsat Coordinating Group, Steering Committee and Council meetings, as well as many Experts meetings during the negotiation of the International Cospas-Sarsat Programme Agreement, which would establish the institutional structure of the international programme. His personal leadership and diplomatic skills were instrumental to the success of the Cospas project and the International Cospas-Sarsat Programme. Konstantin Ivanov, former Cospas Department Manager at Morsviazsputnik, chaired numerous Cospas-Sarsat meetings and served as head of the Cospas delegation between 1999 and 2001. The contribution of Valery Bogdanov, Director-General of Morsviazsputnik from 1999 to 2010, who also participated in early Cospas-Sarsat meetings between 1978 and 1985, is acknowledged, together with his successor Andrey Kurupiatnikov and his Deputy, Andrey Kushev.

> The main scientific and technical challenge to be resolved within the framework of the Cospas-Sarsat project was the requirement for compatibility and interoperability of the different satellites, beacon signals and the alert messages transmitted among System components.
>
> Vladislav Rogalsky

2.4 The Joint Cospas-Sarsat Project: A Successful Marriage of Convenience

When the spectacular Apollo-Soyuz mission ended in July 1975, the race to the moon was definitely over[24]. Although both the USSR and the USA would actively pursue manned space exploration programmes, there was no desire for direct cooperation in this area. The development of 'useful' space applications was booming, but the Cold War was still dominating East-West relations and strategic concerns restricted actual opportunities for cooperation.

However, the merits and feasibility of satellite mobile communications were actively debated at IMO and ICAO and it became clear to space policy makers that satellite systems in the mobile communication service would have to be open to users on a global basis. The use of satellites for distress alerting and locating was a typical example of an application where Cold War boundaries did not make sense. Furthermore, the prospect of cooperating on a humanitarian multilateral project, with no real economic or strategic significance, was attractive to politicians as well as space policy makers.

2.4.1 Learning to Cooperate across Cold War Boundaries

The first lesson of the meeting was that success in developing international cooperative endeavours required time and persistence.

In October 1976, a high-level meeting was held at NASA Headquarters in Washington, D.C. between NASA and a Soviet delegation to explore possible future cooperative space projects. Although the 'Search and Rescue Orbiting Satellite' (SOS) project had not yet been approved in the USA, the theme of 'satellite-aided search and rescue' was on NASA's wish list presented to the Soviet delegation. There was no immediate outcome to this meeting. However, a telegram was later received by NASA asking for a 10-day meeting in Washington D.C., for a Soviet team of 10 people, to discuss the satellite-aided SAR proposal. Clearly, the prospect of an international cooperation on the matter was attractive to the USSR, who had their own plans for a system similar to NASA's SOS project.

At the request of Bernie Trudell, the leader of NASA's SOS initiative who thought a 10-day meeting was unnecessary, the duration was cut to 2 days. The meeting was held at NASA Goddard Space Flight Center (GSFC) in Greenbelt, MD from 16 to 17 March 1977. The Soviet delegation was headed by Yuri Atserov, Director General of Morsviazsputnik, the maritime mobile satellite telecommunications agency of the Soviet Ministry of Merchant Marine (MORFLOT).

Bernie Trudell is making a point
Photo courtesy of The International Cospas-Sarsat Programme

The first lesson of the meeting was that success in developing international cooperative endeavours required time and persistence. There was no alternative to allowing time for consecutive translation of any speech, document presentation or discussion, and no shortcuts for building mutual understanding and confidence. Later, Bernie Trudell recognised that if a 10-day meeting did seem an excessive duration to technical managers who valued efficient work practises, two days were definitely not enough. In addition to translation constraints, any meeting was to be concluded with a summary of discussions, carefully reviewed by both delegations and signed by the Heads of delegations.

24/ For the Apollo-Soyuz Test Project, the Apollo spacecraft was launched using the last available Saturn-1B rocket, developed for the U.S. Lunar Program.

Discussions on the participation of Canada in the SOS project had already started between Canada and the United States, but no formal document had been finalised at the time. A Canadian delegation attended the bi-lateral USA-USSR meeting as observers and the final 'protocol' of the meeting did mention the possibility of a Canadian instrument on the U.S. satellite, but Canada did not sign the protocol which expressed the desires of NASA and MORFLOT to establish a joint project. The French participation in the Sarsat project was still at the stage of preliminary contacts; therefore CNES did not attend the bilateral NASA-MORFLOT meeting. After signing the meeting protocol, attendees were invited for a proper celebration at the USSR Embassy, with a fair number of toasts with vodka.

At the following meeting between the Cospas and Sarsat teams, in June 1978, again in Washington D.C., preliminary agreement had been reached among the Sarsat partners; DOC of Canada, CNES of France and NASA in the USA; to proceed with a trilateral cooperative project as described above in section 2.2. Although the Sarsat MOU had not been finalised yet, the June 1978 quadripartite meeting between MORFLOT, NASA, DOC and CNES was actually a bilateral negotiation between the Sarsat partners and the Soviet delegation represented by Morsviazsputnik's Deputy Director General, Yuri Zurabov. The meeting was chaired by the NASA Associate Administrator. The climax of the discussion was reached when the three Sarsat partners insisted that the Soviet side provide a 121.5 MHz repeater on the proposed Cospas satellite, in addition to the 406 MHz receiver-processor-transmitter unit. The Cospas team only proposed to provide the 406 MHz instrument, arguing that there were no 121.5 MHz beacons on Soviet ships. It is also probable that they considered the prospect of success at 121.5 MHz extremely slim, due to the very weak signal transmitted by the beacon and the expected complexity of ground processing. To the Sarsat partners, the main goal of the East-West cooperation was to increase from two to four the number of polar orbiting satellites simultaneously in operation, thus cutting in half the waiting time for a satellite to fly in visibility of a beacon. If the Cospas satellites did not include the 121.5 MHz repeater system, there would be no benefit for the large number of existing users of 121.5 MHz ELTs/EPIRBs [25].

The meeting closed with the repeated statement by the Sarsat side that the dual frequency approach was a prerequisite for engaging into a joint East-West cooperative project, but no commitment was provided by the Soviet side. However, the Soviet delegation took an action to reconsider the matter at home and explore the feasibility of providing a 121.5 MHz repeater with the basic specifications provided by the Sarsat team. After signing the 'Summary of Discussions', the Soviet delegation opened a number of vodka bottles for a proper celebration and started to distribute small gifts to the Sarsat team members. The surprise was welcome but embarrassing for the unprepared Sarsat delegates who could not reciprocate. The Soviet initiative started a tradition of drinks and small gifts at the end of Cospas-Sarsat meetings.

The next meeting was held from 13 to 16 February 1979 at the historic Observatory of Paris, France. The Soviet side had agreed to fly a 121.5 MHz repeater on their Cospas satellite and the main thrust of the meeting was to explore technical details of the two 'inter-operable' systems: Sarsat and Cospas. The partners wanted to avoid the complexities of the Apollo-Soyuz experience

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25/ The Canadian contribution to the Sarsat project would also include a repeater for the frequency 243 MHz, the first harmonic of the 121.5 MHz frequency. Many ELTs were actually transmitting on both frequencies 121.5 MHz and 243 MHz. However, this capability was not advertised to the Soviet team as the 243 MHz frequency was used by NATO on military aircraft for distress alerts and communications. Cold War attitudes were still alive and the 243 MHz capability was not included in the Cospas-Sarsat project.

where hardware had to be made compatible with two different and in many ways incompatible designs. Only interface requirements for communications with the satellites' onboard radio-equipment would be specified. The Sarsat and Cospas specific implementations of the communication system would not be considered as long as 'transparent' operations were assured, i.e., both satellite systems would receive the specified distress beacon emissions and broadcast a downlink signal with appropriate characteristics that all parties could receive and process.

The major negotiating point was to try to obtain a Soviet commitment for launching two satellites instead of only one. The Sarsat project would include three satellites and it seemed that a meaningful demonstration of the Sarsat and Cospas systems interoperability would require at least two Cospas satellites. The Sarsat team had a longer-term view of a future transition to an operational system and the objective was to convince SAR authorities worldwide of the value of satellite detection and location of distress alerts. Some continuity of service with a sufficient number of satellites was essential to achieving this goal. Again, repeating the cautious scenario of the preceding Washington meeting, which would become the trademark of the future cooperation, the Soviet delegation agreed to explore further at home the possibility of committing to a second satellite.

As in Washington, the meeting was concluded with an exchange of small gifts and toasts, the Soviet delegation graciously providing the vodka. The tradition was set and would be followed at every Cospas-Sarsat meeting for the next few years. The exchange of small gifts of no commercial value would continue until the growing attendance at meetings would make it rather cumbersome. It was later replaced by the more usual distribution of pins, pens or logo stickers. The tradition for drinks strangely continued, with vodka as well as wine or beer, but moved from a celebration of the work accomplished at the conclusion of the meeting, after report signing, to a "*reception party*" at the end of the first meeting day, which helped in breaking the ice between delegations after the warm-up run of first day discussions. Considering that, by 1985, CSSC meetings would regularly close at early hours on the morning following the 'last' meeting day and delegates would rush to catch their flight home, the move was definitely wise.

Another meeting of the four partners was held in July 1979 in Ottawa, Canada to prepare a draft Memorandum of Understanding (MOU), which would describe the scope and content of the planned cooperation on the joint satellite project for search and rescue. The following meeting was set for Leningrad, USSR in November 1979, with two clear objectives; firstly, agreeing the draft formal MOU and secondly, drafting a 'Cospas-Sarsat Implementation Plan' (CSIP), which would precisely define the technical contributions of each partner and the specific communication systems interface requirements.

2.4.2 The First Cospas-Sarsat MOU

The "*Understanding among the National Aeronautics and Space Administration of the United States of America, the Ministry of Merchant Marine of the Union of Soviet Socialist Republics, the Department of Communications of Canada and the Centre National d'Études Spatiales of France concerning Cooperation in a Joint Experimental Satellite-Aided Search and Rescue Project*" was signed at

Leningrad[26], USSR on 23 November 1979. The agreed text, in three languages, was signed by NASA's Assistant Administrator, Dr. John McElroy, for NASA, Mr. Yuri Zurabov, Deputy Director General of Morsviazsputnick for MORFLOT, Dr. Bert Blevis, Director General, Space Technology and Applications for DOC and Mr. Gérard Brachet, Director for Programmes, for CNES.

Leningrad, USSR - November 1979 - The Cospas and Sarsat Delegations

Top - Cospas Delegates, front row from left to right,: Y. Zurabov, Y. Makarov, V. Rogalsky, Y. Beckterev.

Bottom - Sarsat Delegates: Canada: first from the left: H. Werstiuk,
USA: fourth from the left: J. McElroy, T. McGunigal, B. Trudell,
France: ninth from the left: J.-L. Moalic, D. Ludwig, M. Winterholer.

Photo courtesy The International Cospas-Sarsat Programme

The successful conclusion of the Leningrad meeting was delayed by translation difficulties, the text being finalised at about 04:00 the next morning, but the date of signature remained unchanged. The document outlined the separate Sarsat and Cospas projects and stated the common objective of making the two systems inter-operable to "*demonstrate that equipment carried on low-altitude, near polar-orbiting satellites can facilitate the detection and location of distress signals*". The MOU also stated that "*the joint Project [would] permit the Parties to make recommendations on follow-on global operational applications*". To achieve these objectives the Parties would "*each launch and maintain in orbit one spacecraft equipped with repeaters and processors […]*" and "*use their best efforts to each launch and maintain in orbit a second spacecraft […]*"

After the first Sarsat and first Cospas spacecraft had been launched, a 'demonstration and evaluation phase' of a least twelve months duration would be conducted with the active participation of 'user services' (SAR authorities). While most testing activities would remain the responsibility of each party, the D&E phase would include a "*joint test program*" to be defined in the CSIP document and would be concluded by publication of a joint report.

26/ Leningrad: today Saint Petersburg, Russia

Zenith Rocket Launch (USSR)

Atlas Launch (United States)
Photos courtesy of the International Cospas-Sarsat Programme

The Understanding would become effective after confirmation by exchange of letters among the parties, which was accomplished in 1980, not without some concern. In January 1980, the Soviet Union had started its intervention in Afghanistan and East-West relations cooled to freezing point. All scientific ties between the U.S. and Canada on one hand and the Soviet Union on the other hand were discontinued. As a result, Canada's Ministry of External Affairs put the signing of the confirmation of the MOU on hold, until the United States decided that the agreement was a humanitarian issue and indicated their intent to proceed with the confirmation of the MOU [27].

Although a profound desire for success guided the open and frank cooperation between the technical teams, diplomatic and leadership considerations were never forgotten. The D&E phase was supposed to start after "*the first Sarsat spacecraft and the first Cospas spacecraft equipped with search and rescue spaceborne capability have been launched and are successfully operating in space*", as spelled out in paragraph 6.2.2 of the MOU. The terminology had been long debated and pre-eminence had been given to the Cospas project in the title of the cooperative endeavour (Cospas-Sarsat). However, during the discussion, the U.S. side insisted that the Sarsat team should launch first and the Cospas team should launch their first satellite within six months following the Sarsat launch, which the Soviet side accepted.

Unfortunately for the Sarsat side, the operational constraints of NOAA prevailed and the NOAA-E satellite call-up for launch, which was dependent upon the actual performance of other NOAA satellites in orbit, was delayed repeatedly due to the good health of the existing constellation [28]. When it became clear that NOAA-E would not be launched in 1982, the planned target date for the D&E, the Soviet team argued that the project should not be further delayed and they should be allowed to launch the Cospas-1 satellite that was ready. Aware of the potential embarrassment that a refusal could create, NASA finally agreed. At the third Cospas-Sarsat Coordinating Group meeting held in April 1982 in Moscow, the parties adopted an amendment to paragraph 6.2.2 of the MOU, to read "*[The D&E] phase will begin when the first Cospas or Sarsat spacecraft equipped with search and rescue spaceborne capability has been launched and is successfully operating in space*". The change allowed going ahead with the D&E using a single spacecraft.

An additional change also extended the D&E to 15 months instead of 12, to accommodate the expected late launch of the Sarsat spacecraft, and stated: "*It is expected that [...] both the Cospas and Sarsat satellites will be operating simultaneously for at least six months during that time*".

27/ Cospas-Sarsat Background Information - contributed by Dr. Bert Blevis, CRC Canada.

28/ The delayed launch of NOAA-E was also due to an EMI (electro-magnetic interference) problem discovered during satellite testing, after integration of the SAR instruments. The EMI affected the 121.5 MHz receiver and required a significant EMI reduction program, in itself a good reason for delaying the launch (see Chapter 3, section 3.1).

The amendment was confirmed by Canada on 13 July 1982. Cospas-1 had in fact been launched 30 June 1982.

Agreement on the Cospas-Sarsat MOU was the high point of the 1979 Leningrad meeting, but the second objective, agreeing on a detailed CSIP document, was not achieved. Actually, a fair number of meetings and the exchange of a considerable amount of documentation would be required before the CSIP could be finalised. It would also be regularly revisited afterwards.

2.4.3 First Launch and Early Success at 121.5 MHz with the Ziegleheim SAR Case

Cospas-1 (Kosmos 1383 according to the official USSR designation for the satellite) was launched 30 June 1982 and the D&E officially started 1 September 1982. The first actual rescue of distressed airmen accomplished with the assistance of Cospas-1 data was recorded on 10 September 1982 in Canada, two months and 10 days after the launch of the first satellite.

The First Rescue in British Columbia, Canada using Location Data Provided by Cospas-Sarsat
Photo courtesy of The International Cospas-Sarsat Programme

Widely publicised in the world media as "*the rescue from space by a soviet satellite*", the story is worth reporting in some detail as it is a text-book illustration of the role and benefits of satellite-aided detection and location of distresses.

In July 1982, a young pilot for a local airline and a nurse responding to a medical emergency disappeared near Dease Lake, in northern British Columbia, Canada, a remote mountainous area. The search for the missing plane was stopped four days later, after 1,800 flight hours, without any success. However, the father of the young pilot decided to continue the search for his son, renting a single-engine Cessna-172 airplane from an aero-club in Brampton, Ontario (near Toronto), with two pilots. For a week they flew between Dawson Creek and Dease Lake. Again, the search was unsuccessful and they decided to return home to Toronto. On 8 September 1982, flying back from Dease Lake to Dawson Creek over a mountain ridge, the Cessna-172 was suddenly faced with fast deteriorating weather and trapped below clouds. Following a river in a deep valley in the hope of reaching lower terrain, it faced a dead-end after a bend. Unable to clear the terrain, the plane brushed the top of trees in stall condition and crashed, hitting the ground almost vertically at about 40 miles per hour. The pilots Jonathan Ziegleheim and Gary VanAmelswoort, and their passenger George Heemskerk survived the crash, but were injured. Gary VanAmelswoort face was covered in blood from a split lip and a broken nose. In the crash, he had hit and broken off the control column. Johnathan Ziegleheim had a broken leg and was bleeding, George Heemskerk only had a painful wrist.

Fortunately, they could extract the 121.5 MHz ELT and its antenna from the broken aircraft and, climbing with some effort to reach clear ground, set it to operate.

The Cospas satellite 121.5 MHz repeater had been turned on a few days earlier by the Soviet controllers, after the satellite testing was completed. The ELT signal from the Dease Lake crash site, relayed by the satellite repeater, was received by the Canadian experimental receiving station at the Communications Research Centre in Ottawa, still in preliminary testing phase. The LUT provided a position for the source of the 121.5 MHz signal, soon passed to the Trenton Air Force Rescue Coordination Centre. For the first time ever, Cospas-Sarsat data was used to task SAR resources, in this case a Canadian Buffalo military transport, for a plane search.

With the Cospas-Sarsat position data, the Buffalo rapidly located the crash site and two paramedics parachuted in to assist the wounded men. The survivors were amazed they had been found so soon, on the morning after the crash. They were told about the Soviet satellite that had relayed their ELT signal, the system that had provided an alert and a location, and that Jonathan Ziegleheim was lucky it did work, as he would have bled to death within the next day. A helicopter was tasked to evacuate the crew.

The picture shows the track of the Cospas-1 satellite over Canada and the locations of the distress site of the Ziegleheim case in British Columbia and the experimental LUT in Ottawa, Ontario. As the crash site was at the edge of the satellite visibility area, the duration of mutual visibility between crash site, satellite and LUT was short, making a Doppler position determination challenging. With a single satellite in orbit, the distressed aviators were lucky to be detected and located so soon after the crash.

Picture coutesy of The International Cospas-Sarsat Programme

Without the Cospas-Sarsat location data, several days and many flight hours would have been required to find them, assuming the ELT signal was detected by overflying aircraft and reported to SAR authorities. Mr. Ziegleheim was the very first person saved thanks to the satellite system.

The successful launch of Cospas-1 had been exciting news and the announcement of the first actual use of the system in Canada, a complete surprise.

Cospas-Sarsat was in business and, at last, regarded internationally as a reality that could not be ignored

To all participants in the Cospas-Sarsat experiment, the successful launch of Cospas-1 had been exciting news, and the announcement of the first actual use of the system in Canada, a complete surprise. Although everyone was hoping for success, all were aware of the difficult challenge and the risks resulting from the technological innovations required to detect and process the weak 121.5 MHz signals. A cautious attitude had prevailed after the Cospas-1 launch, partially due to the uncertain political environment. The spectacular success in Canada, happening so soon after the beginning of the experiment and widely advertised in international media, demonstrated the value of the whole concept and extinguished all doubts about its feasibility. Cospas-Sarsat was in business and, at last, regarded internationally as a reality that could not be ignored.

2.4.4 Unexpected Results and Concerns for the 406 MHz System

The mood at the CSCG-4 Meeting held in Williamsburg, Virginia, USA in October 1982 was certainly uplifted by the first successful use of the 121.5 MHz system, but not all news was good news. At 406 MHz, the Cospas-1 satellite was producing a continuous flow of 'pseudo' 406 MHz alert messages generated from widespread interference in the frequency band. Although enhanced filtering on board future satellites could reduce the flow of pseudo messages, the interference situation was a very serious threat, as it could mask actual 406 MHz transmissions from real distress beacons in certain parts of the world, making the new system unusable. From that moment, the elimination of harmful interference from unauthorised transmissions in the 406 MHz frequency band became a challenging and frustrating task for the Cospas-Sarsat partners.

In the short term, with a single satellite in orbit, the prospect of rapid progress in the demonstration and evaluation of the 406 MHz system was somewhat compromised. A thorough characterisation of the interference situation was required and would necessitate the development of specific processing tools to locate the interference sources. The launch of the second Cospas satellite[29] and the first Sarsat satellite[30], both in March 1983, with appropriate adjustments to the on-board message filtering process to address the interference situation at 406 MHz, greatly contributed to this task and allowed a thorough demonstration of the system.

2.4.5 A Short Overview of the Demonstration and Evaluation Phase

A fairly detailed Demonstration and Evaluation Plan had been developed and approved prior to the launch of Cospas-1. It comprised a description of the technical and operational tests that each partner had planned to undertake separately, with 'real' or simulated beacon transmissions, to characterise the performance of its equipment and assess the operational value of the satellite alerting system for SAR authorities. The D&E Plan also included a description of 'joint tests' to provide the basis for a comparison of the performance of the various satellites and receiving stations used in the D&E, and to demonstrate the global coverage capability of the 406 MHz system. A detailed presentation of the D&E scope and its outcome is provided in Chapter 3.

The 18-month D&E phase was for all participants an intense and sometimes frustrating learning experience, with a few bright successes and some difficult issues that had to be addressed urgently. At 121.5 MHz the system exhibited performance in terms of detection probability and location

29/ Launch of Cospas-2 on 24 March 1983.

30/ Launch of NOAA E (NOAA 8) on 28 March 1983.

accuracy that met expectations, in itself a considerable success. However, the constant flow of false alerts due to non-distress transmissions, previously undetected by ground receivers or with too-brief durations to be reported by aircraft, was a real surprise and a cause for concern for SAR authorities. At 406 MHz, the interference situation and the pseudo alert messages generated by Cospas-1, which seriously impacted the operational prospects of the system, required quick reaction. The Cospas team modified the on-board filtering process of 406 MHz signals before the launch of Cospas-2 and the Sarsat team verified the performance of the Sarsat SARP [31] equipment in a severe 406 MHz interference environment prior to the launch of Sarsat-1. Fortunately, the CNES 406 MHz receiver-processor unit had a digital filtering system that eliminated most of the pseudo alert messages. Furthermore, it also featured a selectable 'unfiltered receiver mode' that allowed the continued reception of those pseudo-alert messages on command. This feature would later be used, together with the Canadian 406 MHz repeater mode also available on Sarsat spacecraft, to derive a method for locating the sources of 406 MHz interference and start international actions to request their elimination.

2.4.6 The Challenge of Real Distress Alerts

'Real' Alerts and Investigator Countries

At the CSCG-4 Meeting in Williamsburg, USA, Cospas-Sarsat jumped with little preparation into a world of inescapable operational responsibilities. Norway's Space Centre and the UK Department of Transport had signed a separate Memorandum of Understanding [32] with the Sarsat partners to become officially "*investigator countries*" in the planed D&E, using their own receiving stations. Bulgaria's State Shipping Company had signed an MOU with Morsviazsputnik to experiment with distress beacons at 406 MHz. Other partners were eager to join in. Investigator meetings would have to be organised in conjunction with the mandatory Sarsat or Cospas-Sarsat meetings to coordinate their participation.

The issue of real distress alerts, as illustrated by the Ziegleheim SAR case, required urgent attention. The matter essentially concerned the 121.5 MHz system as there were no operational 406 MHz beacons in the field. About 250,000 operational 121.5 MHz beacons were deployed around the world, most of them aviation ELTs in the USA and Canada, but also several thousand ELTs in Europe. Procedures for dealing with these alerts, whether 'real' or 'false', had to be developed, particularly with regard to their distribution to SAR services internationally. The matter had received little attention during the D&E preparation, which was essentially the responsibility of the space agencies. As the 121.5 MHz system provided only 'regional' coverage around the receiving stations, the huge expanses of territory of the USSR, Canada and the USA limited the chances that a receiving station would locate a distress transmission abroad.

The matter was rather different in Western Europe, and the experimental stations in Toulouse - France, Lasham - UK and Tromsoe - Norway, enjoyed fairly large coverage overlap. This meant that a 'real' distress alert at 121.5 MHz could be detected simultaneously by the three stations. Furthermore, the location of the distress could be in any one of the Western European countries

31/ SARP: the Search and Rescue receiver-processor and memory unit operating at 406 MHz on Sarsat and Cospas satellites.

32/ The Understanding between Sarsat (DOC of Canada, CNES of France and NASA of the United States) and the Norwegian Space Centre was signed in 1981, the Understanding between Sarsat and the UK Department of Transport (DOT) was signed by correspondence in October 1982.

included in the stations' coverage, which included almost all of Western Europe and part of Northern Africa. The international dimension of the issue was obvious, but not its solution as it required appropriate co-ordination and the consent of numerous SAR authorities, as well as of the competent international organisations.

The Transition to Operational Responsibilities

At the end of the D&E phase, the Cospas-Sarsat System performance had been adequately characterised, both at 121.5 MHz [33] and at 406 MHz, and the System was declared technically ready for use. Operationally, the matter was not so clear and difficult discussions were on-going regarding the principles to be followed for the international distribution of Cospas-Sarsat distress alerts. The concept of Mission Control Centres (MCCs) at each one of the main partners (Canada, France, the USA and the USSR) had been adopted and implemented to allow for the exchange of System or test data, as well as 'real world' alerts, between partners, including the Investigator countries operating receiving stations (the LUTs).

With more countries joining the Programme as Ground Segment Providers, i.e., operators of LUTs and MCCs, the matter of alert data distribution would become a central issue of the transition to global operations in the years following the conclusion of the D&E. Although the satellite system was declared 'ready for use operationally' at the CSSC-1 Meeting in Seattle, USA in 1985, it would take a number of years, and many heated debates, for Cospas-Sarsat to develop a comprehensive 'Data Distribution Plan' and harmonise its procedures to ensure an efficient and reliable distribution of Cospas-Sarsat distress alerts worldwide.

The matter was complex in all its aspects: technically, operationally and politically. In 1984, there was no inexpensive, secure, world-wide data communication system for swift and reliable distribution of distress alerts. Telex and its aeronautical equivalent AFTN [34] were the only options. Operationally, there were no agreed procedures or standards for the automatic exchange of computer-generated alert data. Politically, the new concept of MCC service areas with agreed boundaries was difficult to implement. The development and implementation of the 'Cospas-Sarsat Data Distribution Plan' required considerable effort from all participants, including the representatives of SAR authorities from the Cospas-Sarsat partners and LUT/MCC operator countries who took a leading role in this work. It was instrumental to the successful transition from an experimental satellite project into a global, operational, distress alerting and locating satellite system.

The burning issue concerned 'real' alerts (alert messages automatically generated by the System and not associated with programmed tests), when located by the System outside the national boundaries of the States operating the LUTs. These 'real' alerts could be either genuine distresses or 'false', non-distress alerts. An obligation to distribute distress alerts to SAR authorities in non-participating countries, unprepared to receive such alerts, would undoubtedly create an additional

33/ The performance of the 243 MHz repeater system on Sarsat satellites, provided by Canada, had also been tested with the Sarsat 1 satellite. This system was identical to the 121.5 MHz repeater system and exhibited similar results.

34/ AFTN the Aeronautical Fixed Telecommunication Network was available worldwide, with varying capabilities, but free of charge for authorised users. Its use was regulated by ICAO. It would gradually be open for use by Cospas-Sarsat MCCs after some years to become the backbone of data distribution in some parts of the world, before Internet network protocols became globally available.

burden as well as legal responsibilities for the distributor. The issue was significant mostly in Europe, due to the vast coverage areas of the LUTs and the relatively limited expanses of European countries' territories. The space agencies operating the System felt they had no such competences and would rather pass all data to their own national SAR authorities. The SAR authorities felt that they could not commit to such new responsibilities which had not been formerly debated at IMO and ICAO.

For Cospas-Sarsat partners, the challenge of alert data distribution would become particularly difficult when 406 MHz beacons began to spread among the fishing fleets. It would be further amplified when geostationary satellites with a 406 MHz repeater became operational, providing quasi-instantaneous detection of 406 MHz signals worldwide, most often without location data associated with the beacon transmission. The whole issue of alert data distribution is further discussed in Chapters 3 and 5.

2.4.7 The Second Cospas-Sarsat MOU

In 1984, the signatories to the 1979 Cospas-Sarsat MOU could declare the System technically ready for use and recommend its continuation, but they had no mandate to manage an operational system for search and rescue. Chapter 4 analyses the prerequisites that had to be satisfied for the international acceptance of the System and its formal adoption by IMO and ICAO. Chapter 4 also describes the long road that the Cospas-Sarsat partners followed before arriving at a consensus on the new institutional framework that would ensure the continuity of the Cospas-Sarsat Programme. That would take another four years. In the meantime there was an urgent need to manage the existing System and make reliable alert data available to SAR authorities.

A new MOU was required, but neither the DOC of Canada, nor NASA in the USA had a mandate to run an operational system. NOAA[35] was the U.S. agency responsible for operational meteorological satellites and DND[36] was the leading Canadian department for SAR. Therefore, the responsibility for continuing the project was effectively transferred to these administrations. Actually, NOAA had no specific mandate for operating a SAR satellite system, but no other US agency (Coast Guard responsible for maritime SAR and Air Force responsible for aeronautical SAR) was ready to take the responsibility, including the associated financial commitments. The fact that Dr. John McElroy, who had started the Sarsat project as Director of Communications Division in the Office of Space and Terrestrial Applications at NASA, was now Assistant Administrator for Satellites at NOAA, probably helped resolve the issue.

Dr. John McElroy
Assistant Administrator for Satellites, NOAA (1982-1985)
Photo courtesy of NOAA

35/ NOAA: the National Oceanic and Atmospheric Administration of the United States.

36/ DND: the Department of National Defence of Canada.

In the USSR, Morsviazsputnik was the mobile satellite communications branch of MORFLOT, therefore, the transition to an operational system did not raise issues. In France, the national space agency, CNES, had no responsibility for SAR and no mandate for maintaining an operational system, but there was no alternative. CNES was still enthusiastic at the prospect of participating in the establishment of a new international humanitarian satellite system and ready to continue funding its share for some years, until the system was internationally adopted.

The "*Memorandum of Understanding among the Ministry of Merchant Marine of the Union of Soviet Socialist Republics, the National Oceanic and Atmospheric Administration of the United States of America, the Department of National Defence of Canada and the Centre National d'Études Spatiales of France concerning Cooperation in the Cospas-Sarsat Search and Rescue Satellite System*" was signed at Leningrad, USSR on 5 October 1984. The agreed text, in three language versions, was signed by Mr. Yuri Zurabov, Deputy Director General of Morsviazsputnik for MORFLOT, Dr. John McElroy, NOAA's Assistant Administrator for Satellites for NOAA, Mr. Robert Dagenais, Sarsat Manager at the National SAR Secretariat for DND, and Mr. Daniel Levesque, Programme Manager Navigation and Data Collection Satellite Systems, for CNES.

Similar in its structure to the 1979 MOU, the 1984 MOU marked a clear change of objective. The first objective of the Parties to the MOU was now to "*establish the Cospas-Sarsat system as an international operational global search and rescue satellite system".* To this end, the Parties agreed to:

- *"assure the initial operational capability and the availability of the Cospas-Sarsat system to provide satellite services and information [...] for use in search and rescue operations"*; and
- *"actively encourage the operational use of the Cospas-Sarsat system by other countries.*"

The MOU was resolutely contemplating the long-term future of the Cospas-Sarsat system as the Parties "*agree to consider future enhancements [...] including the possible use of geostationary satellites in the future*". The parties also agreed to develop, "*as soon as possible, within the framework of the Cospas-Sarsat cooperative activity, the institutional basis for the establishment of an international operational global search and rescue satellite system [taking into account] relevant discussions in international organisations such as the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO) and the International Telecommunications Union (ITU).*"

The Cospas-Sarsat System was then described as three Sarsat satellites (NOAA E already launched, NOAA F and G to be launched) and three Cospas satellites (Cosmos 1383, 1447 and 1574 already launched), plus three more Sarsat satellites to be equipped with the SAR payload [37] (future NOAA H, I and J). The Cospas and Sarsat parties declared their intent to maintain two satellites in operation in orbit "*under normal operations*" (that is, except in case of total failure of the satellite bus or the payload). Under the 1984 MOU, the System was described as consisting of the interoperable space and ground segments (satellites, LUTs and MCCs). The continued participation of Norway and the United Kingdom was "*contemplated*" and the participation of

37/ A new Sarsat MOU between NOAA of the USA, DND of Canada and CNES of France was prepared in parallel and signed in 1984, whereby the three Sarsat partners commit to continue their cooperation and provide for three additional satellites with the Canadian and French SAR payloads.

other countries as ground segment operators welcome, subject to approval by the Parties to the MOU and the signing of an appropriate arrangement.

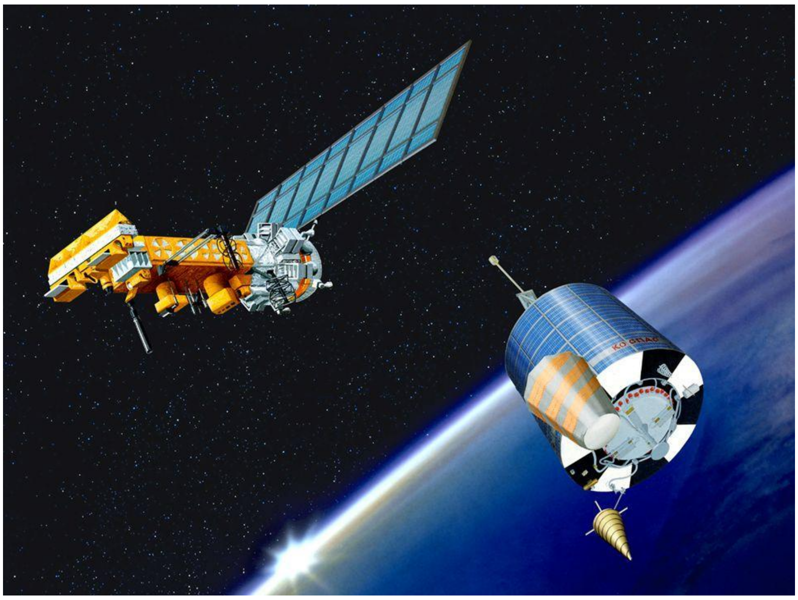
The new governing body for the management of the Cospas-Sarsat System was the Cospas-Sarsat Steering Committee (CSSC), which replaced the Cospas-Sarsat Coordinating Group (CSCG). The CSSC had broad authority for coordinating the cooperative activity, maintaining system interoperability and exchanging information as necessary for system operation. It was composed of two representatives for each of the Parties who took decisions by mutual agreement. Other participating countries "*may be invited to attend the meetings*" of the CSSC, but "*at the discretion of the CSSC*". The MOU also stated that "*normally, agencies operating LUTs and other ground segment equipment would be invited to attend.*"

The last innovation of the MOU was to contemplate the creation of a permanent secretariat "*to coordinate actions and assist the CSSC in administering [the] Understanding.*" For reasons explained in Chapter 4, the secretariat would not be established until 1987, when the parties had already agreed to a new instrument, the International Cospas-Sarsat Programme Agreement.

The other articles of the MOU were fairly standard and did not make significant changes to the provisions of the former MOU on liability, exchange of funds, settlement of disputes, etc. The MOU signed on 5 October 1984 became effective 180 days after its signature and confirmation by all Parties. The novelty in Article 14 was to foresee a termination date: "*31 December 1990, or until the Parties agree to some other international framework, whichever comes first.*"

The 1984 MOU was clearly aimed at preparing a transition toward longer term arrangements. The intention was clear, but the views of the partners quite different on what would constitute the future 'appropriate institutional framework'. For the space or communication agencies that had conducted the development and the evaluation and demonstration of the Cospas-Sarsat system, the establishment of an international global operational distress alerting system was a new proposition with no precedent.

Artist's view of NOAA/Sarsat satellite (left) and Tsikada/Cospas satellite (right) (image courtesy of CNES)



2.5 GEOSAR Systems

Good ideas often come to several people simultaneously. The idea of using a low-power radio transmitter, automatically or manually triggered in a distress event, to send a distress alert via satellites was not the exclusive ownership of Cospas-Sarsat partners. Good ideas can also be implemented in different ways. Therefore, it is not surprising that competing approaches to distress alerting using satellites would be proposed to potential users, at about the same time.

In the 1970s, the alternative to low-altitude polar orbiting satellites (also referred to as LEO: low-altitude Earth orbiting satellites) relaying signals in the 400 MHz part of the frequency spectrum was mobile communications satellites in geostationary (GEO) orbit operating in the L-band portion of the spectrum (1.6 GHz). As discussed above in Chapter 1, section 1.2, such satellites were being proposed for the Inmarsat maritime mobile satellite network and one MHz of bandwidth in L-band had been allocated by the ITU to distress alerting in the mobile satellite service [38].

The Cospas-Sarsat LEOSAR approach stemmed from the need to locate existing 121.5 MHz ELTs transmitting an analogue signal which could not be relayed via a geostationary satellite for any practical use. Doppler positioning was the only possible 121.5 MHz signal processing that could assist SAR services. Similarly, the 406 MHz system, which was derived from the Argos environmental data collection and Doppler positioning system, was tailored for LEO satellite operation. However, by the mid-1970s, IMO began discussing the components of the Future Global Maritime Distress and Safety System (FGMDSS) and most participating Administrations expected that voice and data communications in the maritime mobile satellite service operating through a geostationary satellite constellation would become a key component of the future system. A geostationary satellite constellation could provide continuous coverage of most ocean areas with no more than three or four satellites. In IMO, distress alerting using satellite EPIRBs operating through the future maritime geostationary satellite system was largely seen as an obvious choice.

2.5.1 Competing L-Band EPIRB System Designs

Maritime administrations in a number of countries (the Federal Republic of Germany, Japan, Norway, the United Kingdom, the United States and the Soviet Union) sponsored or encouraged research for the development of satellite EPIRBs. For IMO the major issue was to choose from among many proposals the design that would be selected as the GMDSS standard L-band satellite EPIRB. Considering the technology available in the 1970s, there was nothing straightforward in the proposal to decode a low-power digital signal, transmitted from a battery-operated, float-free transmitter thrown into heavy seas, after such signal had been relayed through a repeater on a satellite 36,000 km away from Earth. In 1982-1983, the various design concepts were assessed in a Co-ordinated Trial Programme (CTP) managed by CCIR Interim Working Party 8/7 (IWP 8/7), with predetermined test procedures and an agreed evaluation method, including real life tests of prototype equipment.

38/ Footnote 5.375 in RR Article 5 (Table of Frequency allocations) : The use of the band 1 645.5-1 646.5 MHz by the mobile-satellite service (Earth-to-space) and for intersatellite links is limited to distress and safety communications (see Article 31).

The German EPIRB design developed by the DFVLR [39] was recommended by CCIR, in 1984, as the most appropriate L-band system for use in the FGMDSS. Besides the disappointment of the losing competitors, the immediate consequence of the choice was that the Federal Republic of Germany was compelled to assume the role of champion of the L-band design during discussions on satellite EPIRBs in the FGMDSS, while the countries that had not prevailed in the design competition continued to provide support for the concept and its implementation, but with subdued enthusiasm.

To most delegations at IMO meetings, the Inmarsat geostationary mobile satellite communication system, whose availability and continuity was guarantied by an international convention, was expected to become the cornerstone of the FGMDSS. It was naturally the first choice for the provision of satellite EPIRB services. For that simple reason, few delegations to meetings of the Radio-communications Sub-Committee of the Maritime Safety Committee (MSC) of IMO expressed support for the 406 MHz LEO version of satellite EPIRBs introduced by the Cospas-Sarsat partners. All Administrations were aware of the L-band EPIRB development and eager to keep their options open. Furthermore, the leaders of the Sarsat project were space or research agencies with no direct connections to maritime administrations representing their country at IMO meetings. Morsviazsputnick, a branch of the Ministry of Merchant Marine of the USSR representing its country at IMO COM and SAR Sub-Committee meetings and also leader of the Cospas system, was the exception. Therefore, early proposals for inclusion of Cospas-Sarsat 406 MHz beacons as a possible component of the FGMDSS were met with polite scepticism at IMO.

2.5.2 Operational Issues and Technical Constraints of L-band Systems

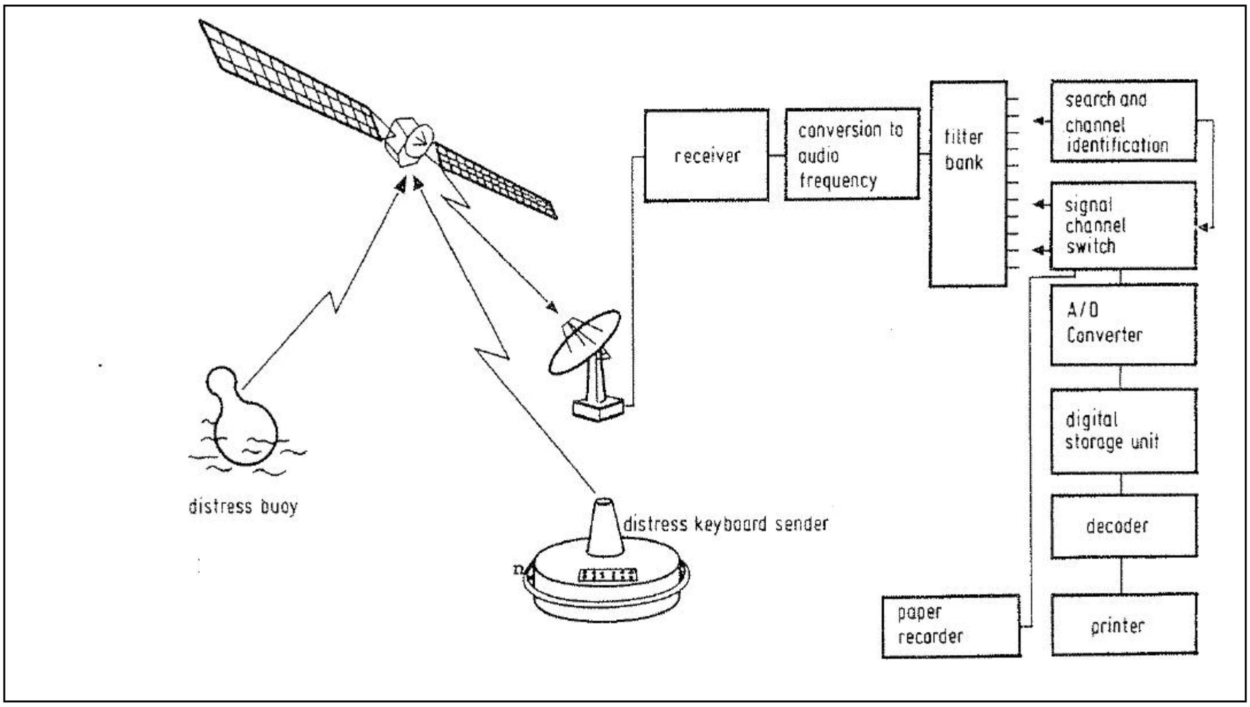
The major drawback of the 406 MHz Cospas-Sarsat design was the waiting time before a LEO satellite would fly in visibility of the EPIRB, which introduced delays in the transmission and the processing of the alert message. The major hurdle faced by the L-band design was the need to acquire position data and transmit this data in the alert message, as the independent location determination using the Doppler technique was not possible in a geostationary satellite system.

Manual input of ship position data directly into the EPIRB through a keyboard was seen as impractical for a float-free device. It was briefly considered (see picture next page) and swiftly rejected [40]. Remote input devices, whether a keyboard on the bridge of the ship or an automatic, periodic feeding of position data derived from the ship navigational instruments, would introduce failure points and risks of unreliable data. In particular, no remote device could ensure an update of the position data after a free-floating EPIRB had been released at sea in a distress incident, which raised the issue of finding the EPIRB, hopefully tied to a life-raft, after several hours drifting at sea. A navigation receiver coupled with the EPIRB was a possible approach, but no such device operating with terrestrial, ground based navigation systems providing long-range coverage could reasonably be considered for integration into a low-power, battery operated, float-free system of reasonable size. Due to the physics of radio-wave propagation, long range

39/ DFVLR: Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (German Research & Development Institute for Air & Space Travel)

40/ Joint IAF/IAA Working Group Report on 'Global Satellite Aided Search and Rescue' (1979) - Section 3.2 'Description of the Distress Radio Call System of the Federal Republic of Germany' - The DRCS included a portable "Distress Keyboard Sender" with an omni-directional antenna, separate from the satellite EPIRB, to be used to send the ship's position in case the main satellite radio station was inoperable.

terrestrial navigation systems would necessarily operate in the lower part of the frequency spectrum, imposing fairly large antennas for the receiver, incompatible with a compact float-free device, which was expected to remain ‘portable’ by a single person.



The satellite EPIRB and Distress Keyboard Sender configuration in the FRG L-Band Distress Radio Call System (DRCS) concept
Ref: 1979 IAF/IAA Report on Global Satellite Aided Search and Rescue

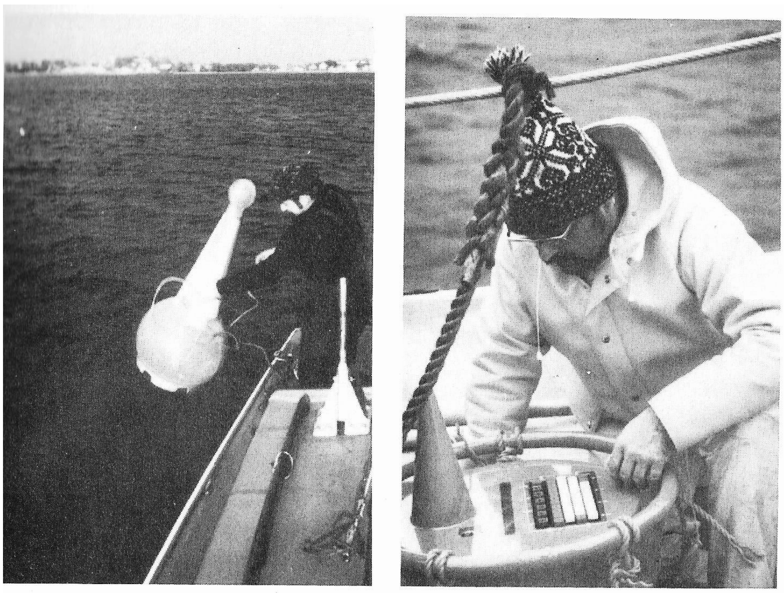


Illustration of a 1982prototype of L-band distress buoy and Keyboard Sender
(The CCIR-Recommended Satellite EPIRB system at 1.6 GHz - by Walter Goebel, DFVLR, in Satellite Aided Search and Rescue symposium proceedings, CNES 1984).

The only viable approach was to include a satellite navigation receiver (that is, a GPS receiver since at that time only the United States GPS system was operational) in the float-free EPIRB system. However, the GPS technology was not readily available to civilian applications, at least not at a cost affordable to mariners. As a consequence of this temporary technical impasse, after the selection of the German design in 1984, the full implementation of the Inmarsat L-band EPIRB system was delayed. The Inmarsat-E service, which featured L-band satellite EPIRBs with an integrated GPS receiver to determine the position of the float-free EPIRB after its release, did not begin full operation until January 1992, seven years after the start of operational use of Cospas-Sarsat 406 MHz EPIRBs.

2.5.3 Experts' Debate at IMO and ITU

At IMO, the discussion between the champions of the 406 MHz LEO and L-band GEO satellite EPIRB systems would continue for many years, with numerous twists. It was clear that any number of peripheral issues could affect the final decision in favour of a particular design. One issue of specific interest to mariners and rescuers was the 'homing device' attached to the EPIRB. Assuming that a position of the distress incident had been provided to SAR services on the coast, either via the Doppler position determination of the LEO system or via encoded data with the GEO satellite relay, this position would entail some computation uncertainty plus the effect of drift at sea, which could be significant. In all circumstances, a final location by rescuers with direction-finding equipment was necessary to 'home' on the disabled ship or the life-rafts.

For aviation 406 MHz Emergency Locator Transmitters (ELTs), the obvious solution would be to incorporate a low-power 121.5 MHz transmitter in the distress beacon, as direction-finding (DF) equipment was available to most aircraft and cheap portable direction finders could be made available to ground rescuers. At sea, for EPIRBs, the matter was more complex with a wide range of possible frequencies for direction finding, from 2,182 kHz to VHF (121.5 or 156.8 MHz) or UHF (406 MHz), including also sophisticated radar transponders (SARTs) operating at 9 GHz. The final choice would impact SAR services as well as ship owners because compatible devices would be needed on search aircraft and rescue boats. It would also impact the design and cost of the satellite EPIRB.

A 2,182 kHz homer, as initially proposed by the proponents of the L-band system, required a larger antenna, hence a bulky buoy suitable for large vessels but not for pleasure boats. Initial L-band EPIRB designs included a 30 kg buoy, 1.2 m high and 0.5 m wide (see picture on previous page). The driving consideration for this early design had been to avoid swift movements of the buoy antenna in choppy waters, which could result in Doppler shifts of the transmitted frequency. The concern was a possible severe impact of sudden frequency shifts on the detection probability at the receiving station. Following successful trials at sea of smaller designs and due to the impracticality of handling a large buoy, the buoy size and weight were greatly reduced when L-band EPIRBs reached the market, and the 2,182 kHz homing frequency was dropped.

Similarly, to be effective, the 9 GHz SART system required a reasonably stable antenna high above the water, imposing again a bigger and more expensive device than the 406 MHz EPIRB with a VHF homer. Each device had advantages and drawbacks and, without the feedback of real operational experience at sea to clarify issues and settle arguments, the debate at IMO between SART and VHF homers never came to a firm conclusion. A list of possible options was accepted, and costs and the marketplace would decide the ultimate winner. So far, in 2016, no Cospas-Sarsat EPIRB has been designed with a 9 GHz SART system and all approved maritime 406 MHz EPIRBs designs include a 121.5 MHz homer.

The discussion of the two proposed satellite distress alerting systems was not limited to IMO. At the 1983 'Mobile' World Administrative Radio Conference, the Federal Republic of Germany (FRG), as the L-band EPIRB champion, opposed the use of the 1,544 to 1,545 MHz frequency band by Cospas-Sarsat for the LEO feeder link to receiving stations. The band was allocated by the ITU for Space to Ground mobile satellite communications and reserved for distress and safety operations (RR 1982 Note 728 / RR 2012 Note 5.356). However, feeder link services were specifically excluded from the mobile satellite service in L-band (RR 2012 Note 5.351) and the FRG had plans for a system of alert broadcast to ships using this particular portion of the band.

Cospas-Sarsat proponents demonstrated that sharing the one MHz frequency band was feasible and the FRG move was not supported. The exception in favour of the Cospas-Sarsat feeder link was maintained for that particular portion of the L-band reserved for distress and safety.

2.5.4 Searching for the "Perfect" Distress Alerting Satellite System

Although often confusing, the debates at IMO MSC's Sub-Committees on radio-communications and SAR had the merit of pointing out why no single system, whether LEO or GEO, was entirely satisfactory and what the characteristics of a complete satellite EPIRB system should be.

IMO produced two requirements documents for the FGMDSS, applicable to ships over 300 gross tons. Carriage requirements would define the type of equipment to be on board ships for communications and automatic distress alerting, including satellite EPIRBs. Operational requirements stated the desirable functions and operational characteristics of the system. The need for immediate distress alerting was accepted by all IMO experts. However, this could be performed either by ship-borne communication equipment or by the float-free satellite EPIRB to be released in case the ship was in danger of sinking and/or had to be abandoned. The sole discussion in this regard was which type of equipment should be used. If the satellite EPIRB was required to perform this immediate distress alerting function, then the polar orbiting Cospas-Sarsat satellite system, at that time with no geostationary relay capabilities, could not be selected for sea areas A-1, A-2 and A-3 [41]. Alternatively, if only the ship's on-board communication system was required to perform this function, Cospas-Sarsat 406 MHz EPIRBs could be accepted in all sea areas of the FGMDSS.

The operational requirement for a method of updating the satellite EPIRB position after its release at sea emerged gradually, based on early experience obtained with the Cospas-Sarsat system, mostly from the use of 121.5 MHz beacons at sea.

During the Fifth Cospas-Sarsat Coordinating Group Meeting (CSCG-5, 20 to 24 June 1983) held in Toulouse, France, CNES proposed organising a symposium in Toulouse in the following year. All parties interested in the satellite-aided search and rescue project, including IMO, ICAO, ITU and Inmarsat as well as the L-band system developers, would be invited. The idea of the French representative, Gérard Brachet, was clearly to show the reality of the Cospas-Sarsat system, publicise its successes and promote the objective of its acceptance as part of the FGMDSS. The Toulouse symposium goals were also to make all parties aware of the expectations of other countries, system users, beacon manufacturers as well as international organisations.

By the time of the Toulouse Symposium on Satellite-Aided Search and Rescue (10-13 April 1984), the need for position updates had been accepted by most experts. During a round table session at the end of the Symposium on 13 April 1984, Captain E. Gilbert from the U.S. Coastguard stated:

"I think, of course, in this like other issues, we are looking for a balance [….]; obviously we would like an immediate alert and an exact location. […] But the importance of an updated, accurate location, I think has emerged as a more important requirement [during this Symposium] than we might have thought before. […] I suppose I should confess, as a former ship navigator, that ships often do not know where they are with any precision; and of course, much of our workload [in

41/ A description of the four FGMDSS 'sea areas' and the associated carriage requirements are provided at Annex 2.

SAR] involves yachts and smaller vessels and much of our search history in the Coast Guard verifies completely that these people, particularly in adverse circumstances, have a very poor understanding of where they are. So, if we are depending on ships, particularly smaller vessels, to provide some kind of position update into the system, we have to recognize that will not be especially precise."

Mr. Uwe Hammerschmidt, who represented the German Hydrographic Institute and was an active supporter of the L-band EPIRB system, disagreed with the above statement. He nevertheless concluded that "*if we can combine the efforts, we would have the geostationary L-band system for the initial alerting after the ship is sinking and the EPIRB floats free, then the position updating during the search phase would be provided using EPIRBs inside the life rafts operating through the polar orbiting satellite system, in this case Cospas-Sarsat, at 406 MHz"*.

This acknowledgement of the independent positioning capability of the polar system was actually a remarkable breakthrough for Cospas-Sarsat. In simple terms, the ideal, 'perfect' system should provide global and continuous coverage for quasi-real-time distress alerting and an independent location capability, ideally using a single satellite EPIRB type operating on a single frequency to provide all desired performance requirements.

2.5.5 The Cospas-Sarsat Strategy for a Combined LEO/GEO System

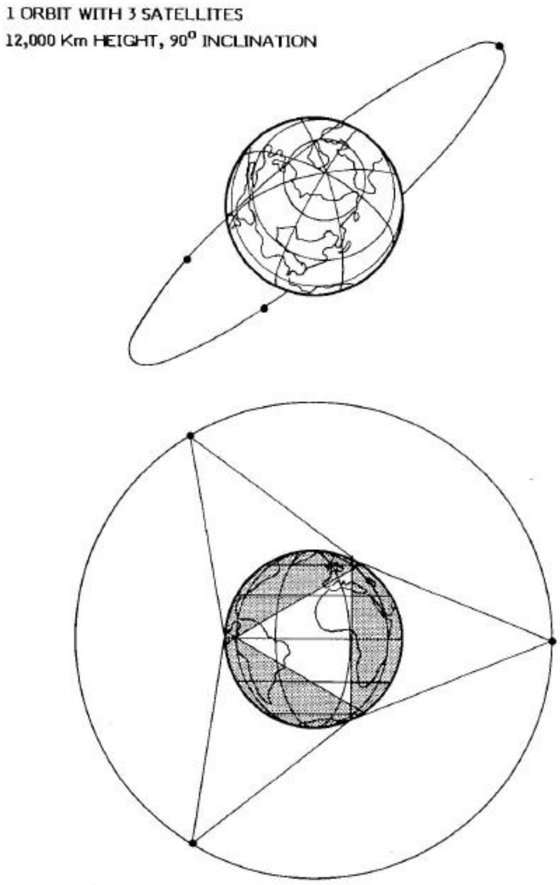
To achieve this ideal system, the Cospas-Sarsat partners followed two approaches. With early tests using the 402 MHz data collection channel on NOAA's GOES geostationary meteorological satellites, NASA had shown the feasibility of relaying signals with characteristics similar to operational Cospas-Sarsat beacon messages through a GEO system. In January 1983, at a Sarsat regional meeting in Toulouse, Bernie Trudell from NASA informed the Sarsat partners of the United States' decision to equip two future GOES satellites with a 406 MHz repeater "*for demonstration purposes*". This was followed in 1984 by trials using GOES-7, with the participation of Canada and France, confirming that low-power 406 MHz Cospas-Sarsat beacons messages could effectively be relayed by a GEO system and decoded on the ground.

Cospas-Sarsat was fully aware that providing global GEO coverage at 406 MHz would be a difficult challenge, and the GOES experiment results were initially intended to convince Inmarsat of the feasibility of a 406 MHz repeater on their future 'second generation' GEO satellites. The Sarsat partners and Inmarsat ran appropriate feasibility studies, but the approach failed to materialise because of costs involved and unresolved funding issues (see section 4.1). Adapting a fairly large, deployable 406 MHz receiving antenna on a GEO satellite dedicated to L-band communications (around 1.6 GHz) was a costly technical challenge. Furthermore, no institutional structure existed to share the costs of this additional on-board equipment, as Inmarsat signatories expected financial returns on their investments that free SAR alerting services could not provide.

The demonstration of the 406 MHz GEO capability was continued in 1985-86 to improve the ground processing system. Follow-on NOAA GEO satellites were equipped with enhanced 406 MHz repeaters, as a complement to the 400 MHz meteorological data collection payload. In 1986, at the CSSC-2 meeting, the Indian Space Research Organization offered to provide a 406 MHz repeater on their future INSAT spacecraft series to cover the Indian Ocean region, thereby furthering the goal of Cospas-Sarsat to provide continuous world-wide detection capability.

'Global' GEO coverage was achieved in 1995. Finally in 1998, after a two-year demonstration and evaluation of the GEO capabilities and more than 10 years after the initial trials of the concept, the GEOSAR complement to the 406 MHz LEOSAR system was formally declared operational by Cospas-Sarsat.

2.5.6 A Possible L-Band Polar System



SERES Polar system Concept

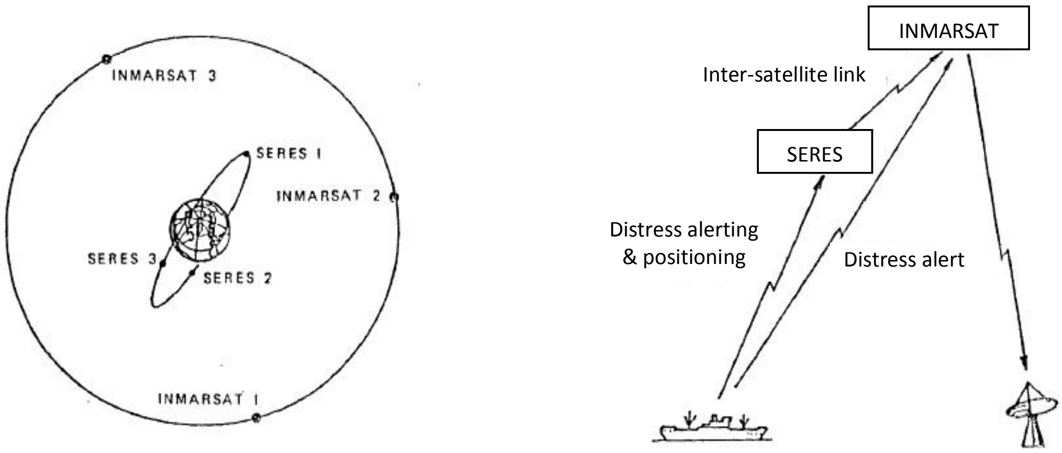
In 1984, the French Representative in the Cospas-Sarsat Steering Committee, Gérard Brachet, met the Director General of Inmarsat, Olof Lundberg, in London. While Mr. Brachet was advertising the merits of the 406 MHz frequency, Mr. Lundberg suggested that Cospas-Sarsat should consider installing L-band repeaters on their LEO satellites. Considering the available satellite platforms, i.e., the NOAA Advanced-Tiros spacecraft and the Russian Tsikada spacecraft, the technical challenge was probably as daunting as 406 MHz repeaters on Inmarsat's GEO satellites. Politically and financially, this was also a dead end as governments already sponsoring the 406 MHz system could not at the same time develop and fund a competing approach.

The German DFVLR, champion of the L-band EPIRB system, also thought of complementing the Inmarsat L-band EPIRB service with a polar-orbiting system at L-band which would have provided Doppler positioning and permanent coverage of polar regions.

An original concept, SERES, developed by the German company MBB/ERNO, which featured three satellites equally spaced on the same polar orbit at an altitude of 12,000 km, was presented to IMO and to the Inmarsat Council in 1982. The system would provide both communications and distress-alerting services in the Polar Regions, as a complement to Inmarsat's GEO satellites.

With this type of constellation, continuous coverage of the poles would be achieved with only three operational satellites, although the same number of spare satellites would probably be required to ensure the reliability of the continuous coverage. As in the case of Cospas-Sarsat, some Doppler shift of the received signal would be available for independent position determination. Additionally, the possibility of relaying SERES satellite transmissions to the ground using Inmarsat's geostationary satellite constellation was envisaged, thus achieving a quasi-real time alerting, even at the poles.

For the same reasons as noted above when considering 406 MHz repeaters on board Inmarsat GEO satellites, that is costs and funding, the SERES concept never achieved reality.



SERES Polar System Concept and Inmarsat Constellation

2.5.7 Termination of the L-band EPIRB System

The Inmarsat-E distress alerting service was free of charge to users. Operating costs were entirely borne by the Inmarsat Ltd. Company and national coast-Earth station operators. The initial investment for specific receiving equipment in Inmarsat's coast-Earth stations had been borne by the German government. When in 2004 the time came to replace this coast-Earth station equipment, Inmarsat and the national station operators were reluctant to fund the replacement and the question of the actual need for the service was raised.

406 MHz EPIRBs, which had been available since 1985, had already been adopted by large numbers of fishermen and pleasure craft sailors when L-band EPIRBs were finally made available on the marketplace in 1992.

In 2004, only 1,300 L-band EPIRBs were in use worldwide, of which only 100 were installed on SOLAS vessels pursuant to GMDSS requirements. The figure compared unfavourably with the 260,000 406 MHz EPIRBs in use at the time (with a total of about 380,000 406 MHz beacons, including aviation ELTs and PLBs[42]). The contrast was also striking with the success of other Inmarsat services (Inmarsat-A, -B and -C communication terminals) that had reached about 100,000 customers. Furthermore, Inmarsat acknowledged that the retail price of the L-band EPIRB, higher than the equivalent 406 MHz EPIRB with a GPS receiver, did not leave much hope for a positive evolution of the situation.

Finally, on 7 September 2004, Inmarsat announced that the service would be terminated on 1 December 2006. The 1,300 L-band EPIRBs were replaced by equivalent 406 MHz Cospas-Sarsat models, purchased by Inmarsat Ltd and offered to the Inmarsat-E service users in 2006.

42/ PLB: Personal Locator Beacons

Chapter 3

The Cospas-Sarsat System Design, Development, Demonstration and Evaluation

3.1 The LEOSAR System

The genesis of the Sarsat project in Canada, France and the United States, and the Cospas project in the USSR is presented in sections 2.2 and 2.3, respectively. Both systems were designed as low-altitude Earth orbiting (LEO) systems, using operational satellite platforms of opportunity:

- NOAA meteorological satellites in sun-synchronous, quasi-polar orbits [1] at an altitude of about 850 km for Sarsat payloads; and
- Tsikada Doppler navigation satellites in quasi-polar orbits [2] at an altitude of 1,000 km for Cospas payloads.

3.1.1 Principle of Operation

Illustration of the footprint of a LEO satellite in polar orbit.
Photo courtesy of the International Cospas-Sarsat Programme

LEO Satellites

At an altitude of 850 km, a satellite typically travels at a velocity of 7 km per second. The orbital period is about 101 minutes. The satellite has a visibility circle of roughly 5,000 km in diameter. When viewed from the Earth, the satellite crosses the sky in less than 15 minutes, depending on the maximum elevation angle of the particular satellite pass.

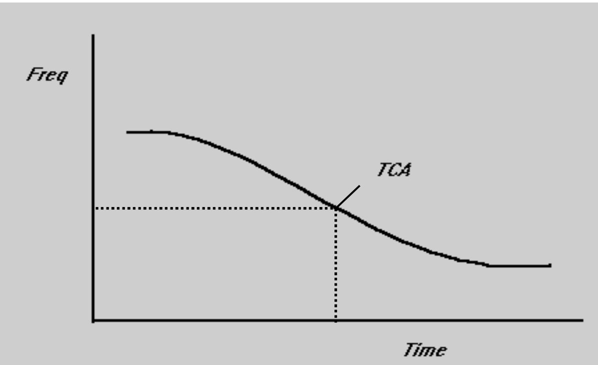
As the Earth rotates under the fixed orbital plane of the satellite, the complete surface of the globe is scanned in less than 12 hours by each satellite. The poles are scanned at each orbit, while at lower latitudes the average waiting time for two successive satellite passes in visibility of a specific location increases. It can reach a few hours at the equator, depending on the number of satellites in the constellation. At mid-latitudes, the waiting time for the nominal constellation of four LEO satellites is typically less than one hour on average. The average waiting time is further reduced when more satellites are available in the operational constellation.

1/ The nominal inclination of the satellites in the NOAA polar system was 98.7°. A sun-synchronous orbit is an orbit that crosses the equator at fixed local times: the orbit plane axis rotates slowly (360° in one year) to keep a fixed angle with the direction of the Sun. This feature allows sun-synchronous Earth observation satellites to view the Earth always under the same illumination angle.

2/ The nominal inclination of the satellites in the Tsikada system was 83°. These satellites were not sun-synchronous. Therefore, Cospas satellite orbit planes and Sarsat orbit planes drifted relative to each other in time, reducing the operational benefit of multiple satellites during periods when the Sarsat and Cospas satellite orbit planes exhibited small ascending node separations.

The Sarsat payloads carried on U.S. NOAA satellites consist of a 121.5 MHz, 243 MHz and 406 MHz repeater system with a 1,544.5 MHz downlink transmitter (the Search and Rescue Repeater - SARR - channels), all provided by Canada, and a 406 MHz receiver-processor-memory unit (the Search and Rescue Processor - SARP - channel) provided by France. The Cospas payloads on the Nadejda satellites of the Tsikada system comprise a 121.5 MHz repeater (SARR) and a 406 MHz receiver-processor-memory unit (SARP), with the 1,544.5 MHz downlink transmitter, all designed and provided by Russia (or the former USSR prior to 1992).

The beacon signals received by the 121.5 MHz repeater [3] and the data generated by the 406 MHz processor are broadcast continuously on the 1,544.5 MHz downlink, providing a 'local-mode' coverage around Local User Terminals (LUTs) that receive and process the downlink signal when satellites are in view. Processed data from 406 MHz beacon transmissions stored in the satellite memory are also broadcast continuously at high speed (2.4 kbps), thus providing the 'global-mode' coverage, each LUT receiving a complete memory dump at each pass of the satellites they are tracking [4].



Doppler frequency shift versus time of the signal received at the satellite antenna

Doppler Effect - Doppler Ambiguity

Satellites orbiting the Earth at low altitude move at high speed. The velocity of the satellite relative to the distress beacon causes a shift in the radio frequency of the beacon signal received at the satellite antenna, called the 'Doppler effect', as illustrated in the diagram.

The Doppler curve characteristics - time of closest approach (TCA) and slope - are used to compute the location of the transmitter [5]. The Doppler location technique always generates pairs of predicted locations, one on each side of the satellite sub-track, resulting in a position ambiguity since one is the real location and the other a mirror image. The ground station can try to assess which position is the most likely, using the skewing of the Doppler curve caused by the rotation of

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3/ In the Sarsat system, the composite downlink spectrum also includes the repeated 243 MHz and 406 MHz bandwidths.

4/ The 406 MHz SARP (Search and Rescue Processor) payload on the first three Sarsat satellites did not have a dedicated memory unit. The data was broadcast in real time on the 1544.5 MHz downlink and stored in the spacecraft tape recorders, with the stored data from the various satellite instruments, to be dumped to the NOAA stations at Wallops Island, Maryland and Fairbanks, Alaska. The 406 MHz SARP data was then forwarded to the USMCC at Suitland, MD for processing and distribution to U.S. SAR services or the other Cospas-Sarsat partners as appropriate. In this configuration, alert data was not necessarily recovered after every orbit, but in no cases did the wait last more than three orbits. This global operation mode with the USMCC processing of 406 MHz stored data, continued until 1996 when the Sarsat-2 satellite was decommissioned. This system architecture introduced additional delays in the ground processing of Sarsat global-mode data. Starting with Sarsat 4, the SARP included a dedicated memory and all SARP data (stored and real-time) was broadcast via the 2.4 kbps data stream in the 1,544.5 MHz downlink, directly received by LUTs. Post pass processing would only take a few minutes.

5/ The TCA marks the position on the satellite track, where the satellite is closest to the beacon. The beacon is on a line of position perpendicular to the track. The slope of the Doppler curve at TCA varies with the distance of the beacon to the satellite track. The two possible Doppler positions are symmetrical on each side of the satellite track.

the Earth. However, both possible locations produced by the Doppler computation are always forwarded to the competent SAR authorities, with a calculated probability for each.

The 'true location' versus 'image location' assessment process was always difficult with 121.5 MHz signals, which usually did not have a 'clean' carrier frequency spectrum. At 406 MHz, when the pass geometry is good, the ambiguity resolution typically yield 75% versus 25% probabilities. The ambiguity resolution is confirmed after a second pass of a satellite in view of the beacon, as the two image positions are far apart while true positions match.

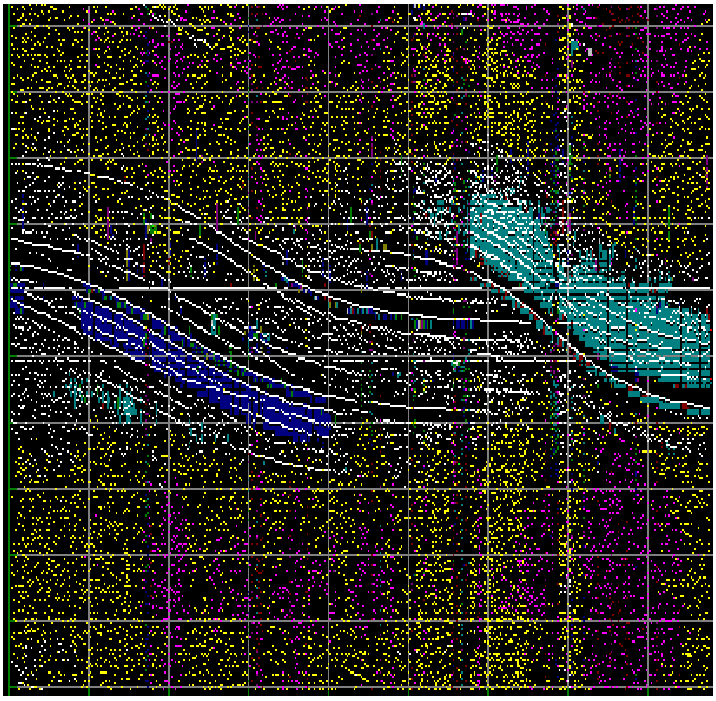
3.1.2 The 121.5 MHz Search and Rescue Repeater (SARR) System

The operational use of 121.5 MHz ELTs prior to Cospas-Sarsat is addressed in Chapter 1, section 1.3. The analogue distress beacons developed in the 1960s were required to meet national specifications based on ICAO standards, but were not initially designed to work with a satellite system. Such beacons transmitted only a fraction of a Watt (about 0.05 to 0.1 Watt EIRP[6]), the signal having swept tone, amplitude modulation, which produced a warbling sound in a nearby aircraft receiver, similar to today's car alarms. The carrier frequency of the beacon was not very stable and was significantly affected by ambient temperature variations.

121.5 MHz SARR Processing and 'Local Coverage'

On the ground, the spectrum of the signals repeated through the satellite SARR channel had to be analysed to identify Doppler curve patterns that would yield a location. However, the matter was complicated by noise, interference from strong voice transmissions and the untidy spectrum of the weak beacon signal, which sometimes exhibited sidebands and an unstable carrier frequency (see picture). Performance parameters such as the system multiple access capacity, ambiguity resolution and location accuracy were significantly impacted by these characteristics[7]. Furthermore, no information could be provided about the operator's identity.

Finally, the 121.5 MHz repeater (SARR) mode of operation required simultaneous visibility of the satellite by the beacon and the ground receiving station (LUT). Therefore, coverage was only 'local', around LUTs, and average waiting times for a suitable satellite pass in view of both beacon and LUT increased with the distance of the beacon to the LUT.

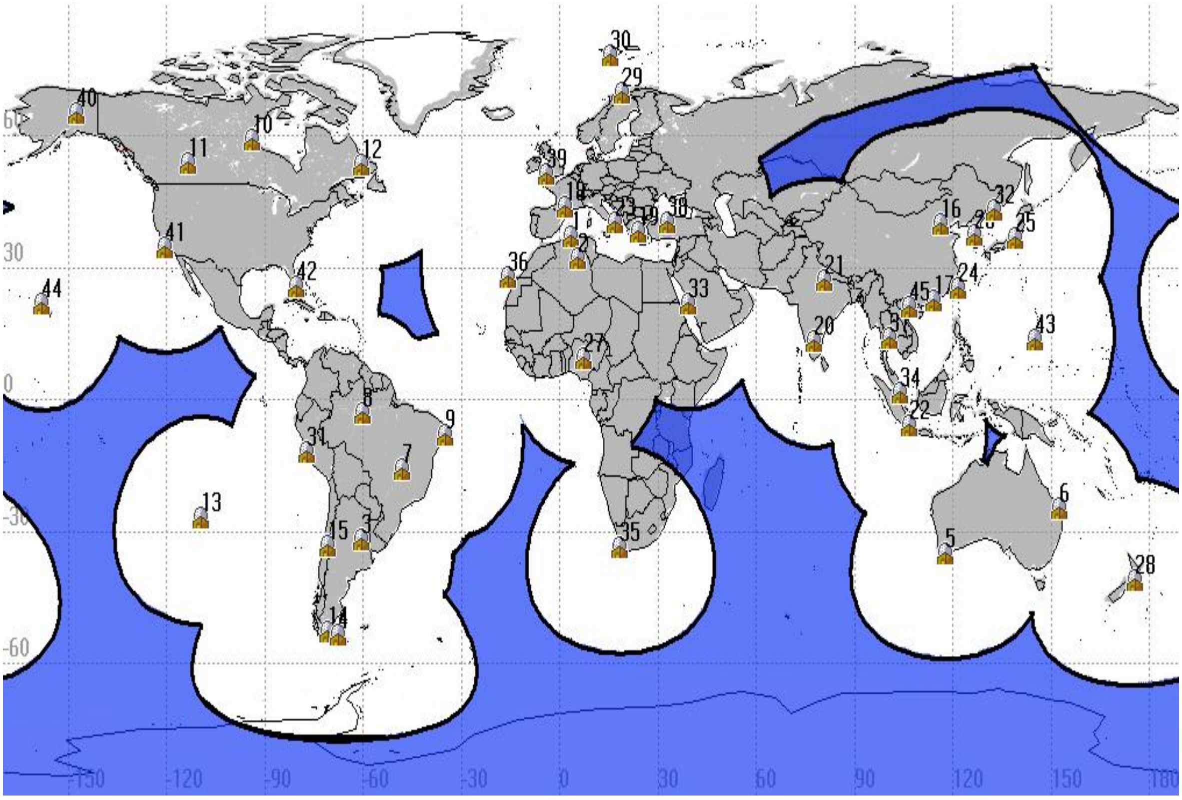


Spectrum Plot (frequency versus time) of the Repeated 121.5 MHz Band showing Noise and Doppler Patterns from Beacons and Interferers
Photo courtesy of the International Cospas-Sarsat Programme

6/ EIRP: Equivalent Isotropic Radiated Power.

7/ See section 3.2.1 on 121.5 MHz system performance.

Nevertheless, even with these limitations, 121.5 MHz beacon monitoring was greatly enhanced with the introduction of satellite detection and Doppler location techniques.



LUTs:

1 Algiers, Algeria
2 Ouargla, Algeria
3 Parana, Argentina
4 Rio Grande, Argentina
5 Albany, Australia
6 Bundaberg, Australia
7 Brasilia, Brazil
8 Manaus, Brazil
9 Recife, Brazil
10 Churchill, Canada
11 Edmonton, Canada
12 Goose Bay, Canada
13 Eastern Island, Chile
14 Punta Arenas, Chile
15 Santiago, Chile
16 Beijing, China
17 Hong Kong, China
18 Toulouse, France
19 Pentelli, Greece
20 Bangalore, India
21 Lucknow, India
22 Jakarta, Indonesia
23 Bari, Italy
24 Keelung, ITDC
25 Gunma, Japan
26 Incheon, Korea
27 Abuja, Nigeria
28 Wellington, New Zealand
29 Tromsoe, Norway
30 Spitsbergen, Norway
31 Callao, Peru
32 Nakhodka, Russia
33 Jeddah, Saudi Arabia
34 Singapore
35 Cape Town, South Africa
36 Maspalomas, Spain
37 Bangkok, Tailand
38 Ankara, Turkey
39 Combe Martin, UK
40 Alaska, USA
41 California, USA
42 Florida, USA
43 Guam
44 Hawaii, USA
45 Haiphong, Vietnam

Satellite:
Altitude 850 km
Elevation angle 5 deg

Illustration of Cospas-Sarsat SARR Local Mode Coverage

The map shows the satellite visibility area of the 45 operational LUTs as at the end of 2008.

The actual SARR coverage extends beyond the 'clear' circles but with increased average waiting times for a suitable satellite pass to achieve simultaneous beacon/satellite/LUT visibility.

(Cospas-Sarsat Secretariat System Data No. 34 - Dec. 2008)

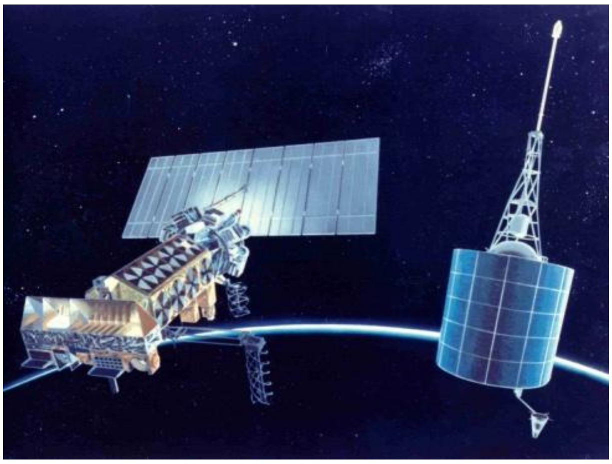
Technical Challenges of the 121.5 MHz System Development

Since there were already 250,000 beacons in service when Cospas-Sarsat was starting up, the new satellite system had to accommodate whatever signals they generated. The first challenge for the developers of the 121.5 MHz system was obviously the very weak signal emitted by ELTs. Fifty milliwatts (0.05 Watt) EIRP, radiated by a quasi-hemispherical antenna, after propagation in space over a distance of 1,000 km, resulted in a $5x10^{-15}$ Watt [8] signal reaching the satellite antenna. The following sections describe some of the technical challenges that the 121.5 MHz system developers had to address. The performance of the 121.5 MHz system is presented in section 3.2, together with a few examples of the actual use of the system for SAR operations during the D&E phase.

8/ $5x10^{-15}$ Watts = 0.000,000,000,000,005 Watts.

EMI Gremlins on NOAA Satellites

A very sensitive SAR receiver/transmitter was clearly necessary on the satellite. The Canadian SAR repeater was designed, built and tested to ensure it did not generate interfering signals (also designated 'electromagnetic interference' or EMI) in other frequency bands, particularly in its own SAR receive bands. All the other payloads and weather instruments onboard the host NOAA-E spacecraft (renamed NOAA-8 once in orbit) were also designed and tested to have very low EMI emissions meeting U.S. military standards' requirements. Most of those same instruments had successfully flown together on several previous NOAA satellites. Therefore, it was assumed that the host spacecraft would provide a good home for the new SAR payload. However, the 121.5 MHz SAR receiver was much more sensitive (about 1,000 times or 30 dB) than the emission levels permitted for the other satellite instruments.



Artist view of a NOAA/Sarsat Satellite (left) and a Tsikada/Cospas Satellite (right)
(Photo courtesy of CNES)

The team was shocked when the first SARR payload was installed on the first Sarsat satellite (NOAA-E) and the SAR antennas were connected to perform the routine EMI tests. High broadband noise levels and dozens of unexpected signals appeared in the 121.5 MHz receive band on the downlink signal. Many of those signals were much stronger than distress beacon signals would be, so would mask real distress signals. The SAR mission could be doomed. Fortunately, such emissions were not observed in the 243 MHz or 406 MHz receive bands of the Canadian instrument.

Initially, since the satellite factory was not far from several major airports and three large cities (New York, Newark and Philadelphia), it was assumed that all those interfering signals were coming from outside sources, such as local FM radio and television stations, aircraft and air traffic control centres. However, further testing was done. The normal spacecraft-level EMI tests were always done in a large 'anechoic room', which prevented reflections of radio signals off the walls and ceiling, but that room only provided partial blockage of outside signals. The only way to effectively block signals from the outside world was to put the entire satellite (which was almost the size of a small delivery van) with its antennas deployed into a large steel vault (actually a thermal-vacuum chamber) and repeat the test. The interference levels were much reduced, but, unfortunately, they were still too high for the SAR mission to be successful. Analysis[9] showed that low-level 121.5 MHz signals were generated within many of

> It took us some time to convince both ourselves and NASA that the EMI problem was real. If the problem hadn't been discovered prior to launch of Sarsat-1, the 121.5 MHz system would likely have worked very poorly, if at all, and the story this Report is now telling might have been significantly different!
>
> Ted Hayes, CRC Canada,
> Sarsat Systems Manager
>
> Investigating and resolving the EMI issues on this complex, multi-mission NOAA spacecraft that was already completely built was one of the biggest technical challenges I had ever faced.
>
> Jim King, CRC Canada
> Sarsat Systems Engineer

9/ King, J.V., Master of Engineering Thesis "*Determination of the Effects of Spacecraft-Generated Electromagnetic Interference on the 121.5/243 MHz Sarsat Mission*", University of Ottawa, Canada, April 1986.

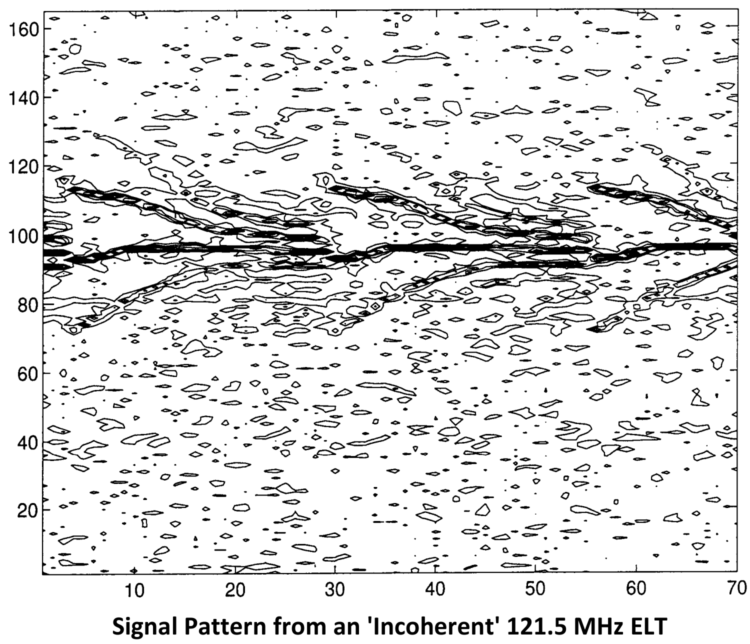
those instruments. They were emitted by interconnecting cables on the spacecraft and picked-up by the SAR receive antenna a few metres away. The onboard interference would not have any Doppler shift, so it permanently cluttered the entire SAR bandwidth.

The only solution was to install tiny radio frequency (RF) filters, called ferrite beads, on every wire coming or going to each instrument, and wrap RF shielding around almost all the spacecraft cables and connectors. After months of painstaking spacecraft rework and retesting, the SAR receive band was finally made quiet enough for the mission and the launch to proceed. Some low-level interference was still present[10], but this was later traced and rectified on subsequent NOAA satellites. Much credit goes to RCA Astro-Electronics management, engineers and technologists who pursued and rectified this catastrophic interference issue. Without the EMI fix on this and subsequent NOAA satellites, the 121.5 MHz SAR mission on Sarsat satellites would have failed.

The same EMI interference issue also had to be addressed by RISDE scientists who developed the Cospas 121.5 MHz SARR payload in Moscow. However, the Nadejda spacecraft was not as crowded as the NOAA bus, which had nine different instruments. Aside from the Cospas payload, only the Doppler navigation Tsikada mission receivers and transmitters were hosted on the bus, which limited the possible sources of EMI. However, the Tsikada system frequencies at 150 MHz and 400 MHz were very close to the SAR receiver frequencies, which was certainly a concern for RISDE designers. The Cospas spacecraft actually provided a very quiet, sensitive receiver that easily picked up faint distress signals at 121.5 MHz.

Analysing a Very Messy Spectrum

The incoming signal amplified by the satellite with the background noise, re-modulated on the 1,544.5 MHz downlink, was received on the ground, at a LUT some 1,000 km below. After filtering and amplification of the useful 121.5 MHz bandwidth, the LUT processor had to sample the energy in the band to create a frequency/time plot, then analyse the result to identify possible beacon Doppler curves. Unfortunately, in addition to being very weak, the emissions of some first generation 121.5 MHz beacons exhibited an untidy spectrum, sometimes with an unstable carrier frequency, or no component for the carrier frequency, or with strong sidebands, which could seriously confuse the analysis (see picture[11] at left).



Signal Pattern from an 'Incoherent' 121.5 MHz ELT
The sweep tone modulation sidebands are clearly visible, while no stable carrier frequency can be identified.
Picture courtesy of the International Cospas-Sarsat Programme

10/ CRC Report SAR 82/2, Issue 1, June 1982 - King, J.V., "*Analysis of the NOAA-E EMI Test Tape After All Fixes Incorporated on Spacecraft*" (data recorded 15-16 March 1982 at RCA, NJ, USA),

11/ Cospas-Sarsat 2000 Seminar - Document WP2/4 "*Advantages of a Combined LEOSAR/GEOSAR System*" - D. Hill, EMS Technologies, Ottawa, Canada

Processing Unprecedented Amounts of Data in the 1970s

Several studies were undertaken in Canada and the USA to assess various processing techniques for the 121.5 MHz signals. These studies were presented at an international meeting of the Sarsat partners in Ottawa in May 1978 [12]. Michael Stott and Richard Renner of Canadian Astronautics Ltd. demonstrated the performance of their all-digital Constant Bin Correlator (CBC) algorithm that was able to automatically track and extract very weak signals received from 121.5 MHz distress beacons. The company was later contracted to build an Advanced Development Doppler Processor (ADDP), as a precursor of a complete satellite ground receiving station.

Computers in the 1970s did not have the power of today's laptops. To run the CBC algorithm, a large external Array Processor box was required to quickly perform mathematical calculations that were too complex to be performed by the main computer. The processor had to collect and digitise all the signals in the 121.5 and 243 MHz bands during the 15-minute satellite pass, then process all that data for about another 20 to 30 minutes after the pass and eventually produce beacon locations. This processing time was adequate in the early days of Cospas-Sarsat, since there were gaps of 1 to 2 hours between satellite passes, as only a few satellites were in orbit. In the 1980s, newer, faster processing hardware became available, allowing post-pass processing to be completed in just a few minutes.

Real-World 121.5 MHz Beacons, LUT Performance and RCC's Worries

During technical tests, where stable, coherent signals were used, the LUTs performed not too badly at resolving ambiguity *[assessing the true versus the image solution of the Doppler position, by assigning a different probability to each solution]*. However, the real world was quite different. Invariably, when an off-the-shelf *[121.5 MHz]* ELT/EPIRB was activated, the probabilities assigned by the LUTs were usually 50%/50% for the true and mirror locations.

To complicate matters, due to poor modulation techniques, the audio side bands associated with the ELT/EPIRB often produced multiple solutions scattered around both the true and image locations calculated by the LUTs. This caused a dilemma for RCCs. Previously, RCCs had to contend with ELTs that were activated in non-distress situations. Now they were confronted with (and swamped by) LUT-generated false solutions.

Major Herbert Edward (Ted) King,
Officer in Charge of the first Canadian MCC
in Trenton, Ontario Canada

The First 'CAL' LUT

The Canadian Astronautics Limited (CAL) company founded by Jim Taylor pioneered the development of 121.5 MHz signal processing. Michael Stott led this development. Richard Renner, Lloyd Green, Denis Hill actively participated and continued for many years to support the many evolutions of the Cospas-Sarsat Programme. After demonstrating the capabilities of its algorithm, CAL was contracted to develop the prototype Sarsat LUTs used during the D&E. The Cospas LUT was developed independently in the USSR by RISDE (Research Institute for Space Devices Engineering).

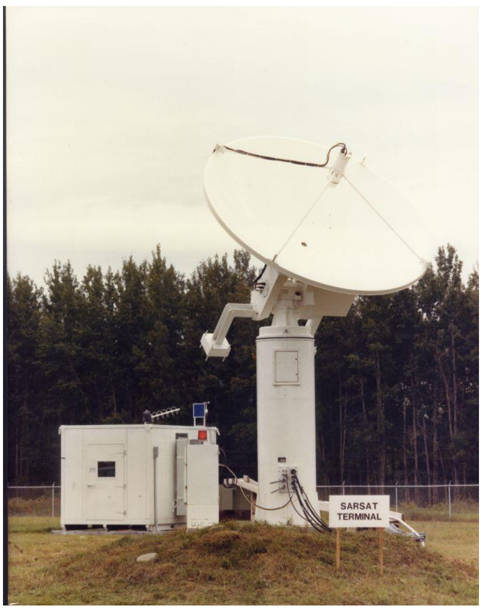


Photo courtesy of the International Cospas-Sarsat Programme

12/ Winter, A.E., "*Assessment of Potential Ground Stations*", Communications Research Centre, Memorandum, May 1978, Ottawa, Canada.

3.1.3 The 406 MHz Search And Rescue Processor (SARP) System

406 MHz distress beacons were designed specifically for satellite detection and Doppler location. In contrast with 121.5 MHz beacons, the 406 MHz design featured:

- high peak power output (5 watts) and low duty cycle (1/2 second burst every 50 s);
- improved radio frequency stability (carrier frequency phase-modulated with digital data);
- a digital message with a unique identification code transmitted by each beacon; and
- an option to include in the beacon message location data derived from a navigation device.

These design parameters made the 406 MHz system far superior to the older 121.5 MHz system, providing the following enhanced performance features:

- increased system capacity, the 1 % duty cycle provided a multiple-access capability of more than 90 beacons operating simultaneously in view of a polar orbiting satellite, versus 10 beacons for the 121.5 MHz system;
- improved location accuracy, typically to within 2 km versus 20 km for the 121.5 MHz system, and better ambiguity resolution;
- unique identification of the transmitter and, if the beacon was properly registered, an identification of the user in distress; and
- global coverage.

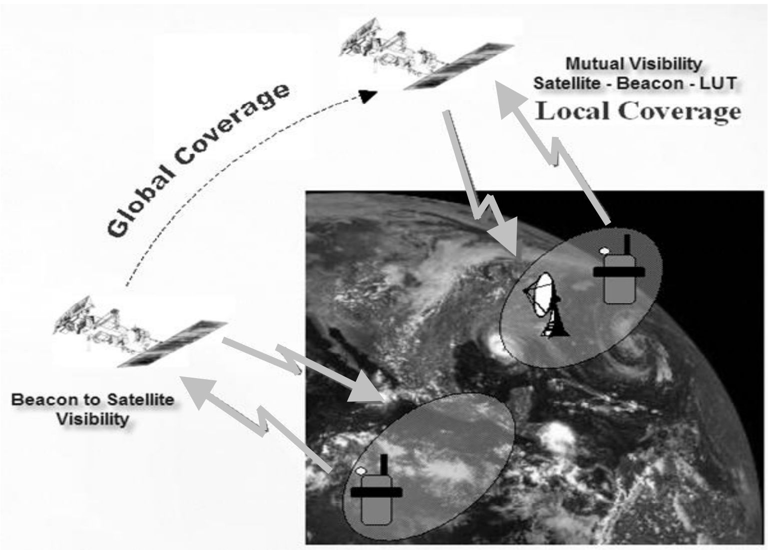


Illustration courtesy of the International Cospas-Sarsat Programme (Doc. C/S G.007)

406 MHz SARP Processing Methodology

A frequency measurement is performed by the SARP instrument for each 406 MHz beacon burst received by the satellite. The beacon message data, including its unique identity code, is decoded and stored in the satellite SARP memory, together with the frequency measurement result. Stored data is continuously broadcast on the 1544.5 MHz downlink, interleaved with real-time data generated by the SARP from incoming beacon bursts. Each LUT tracking the satellite receives the complete memory dump in a 2.4 kbps data stream, which includes all 406 MHz data points collected during the last orbits. For each active beacon, the LUT creates a string of data points (measured frequency, time of measurements for same beacon identity) that is matched to a Doppler curve template to derive the beacon location.

The 406 MHz SARP system design provides complete Earth coverage, although with some additional waiting time, since the Doppler location processing of stored data is delayed until a LUT enters the satellite footprint. Another consequence of the design is that every LUT ultimately generates the same global alert data. This is beneficial in terms of system redundancy, but requires a sophisticated data exchange network together with appropriate filtering algorithms (see Chapter 5, section 5.1).

406 MHz SARR Processing

On Sarsat LEO satellites, 406 MHz beacon bursts are also available to LUTs via the 406 MHz Canadian repeater (the 406 MHz SARR channel). Burst detection, data recovery and frequency measurements are performed by the LUT and can be merged with the SARP stored data to improve Doppler location processing. 406 MHz SARR data can also be processed independently, but with the constraints of the local coverage mode.

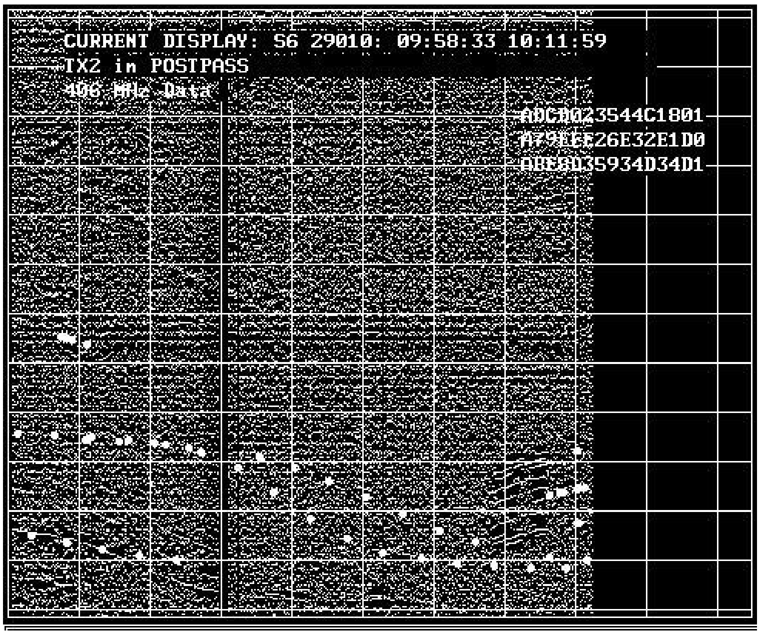


Illustration of a 406 MHz Repeater-Mode Dot Plot

Beacon bursts forming several Doppler curves can be identified around 406.025 MHz (bottom of the 406 to 406.1 MHz band).

The time interval between successive bursts from the same beacon is 50 s.

A partial Doppler curve is seen at the bottom left of the picture and in-band interference to the right, above the Doppler curves.

(NASA Picture, Texas 2 LUT, Sarsat 6)

A Few Nagging Issues with the 406 MHz Processing

The choice of high power bursts for beacon transmissions rather than the continuous, weak signal of the 121.5 MHz beacons had clear advantages as highlighted above. However, it also meant that the Doppler curve had to be reconstructed by the LUT using a small number of data points. A minimum of four points was desirable, roughly corresponding to passes lasting no more than 4 minutes in view of a beacon at the edge of coverage (about a 5° elevation angle).

On high elevation satellite passes (when the satellite passes overhead) up to fifteen beacon bursts could be collected, providing enough measurements for a good adjustment of the plot and the Doppler curve template. At lower elevation angles, a smaller number of measurements was received and interference or obstacles/terrain masks could further reduce the number of available data points. The Doppler location computation could then become problematic or even impossible. After some processing optimisation, LUT manufacturers proposed three-point Doppler solutions, which on occasion would be the only location data available to rescuers, but sometimes also led to large location errors, particularly when the inflection point of the Doppler curve (the TCA) was not bracketed by the sample of available data points.

For a similar reason, when a beacon was activated at the end of a satellite pass, a partial Doppler curve was generated, potentially making the location computation challenging. Furthermore, the beacon bursts transmitted during the beacon oscillator warm-up time exhibited an unstable carrier frequency, which directly impacted the Doppler location accuracy. For this reason, special attention was paid to the specification of the 406 MHz beacon oscillator stability, particularly during warm-up time and when the beacon experienced thermal shocks.

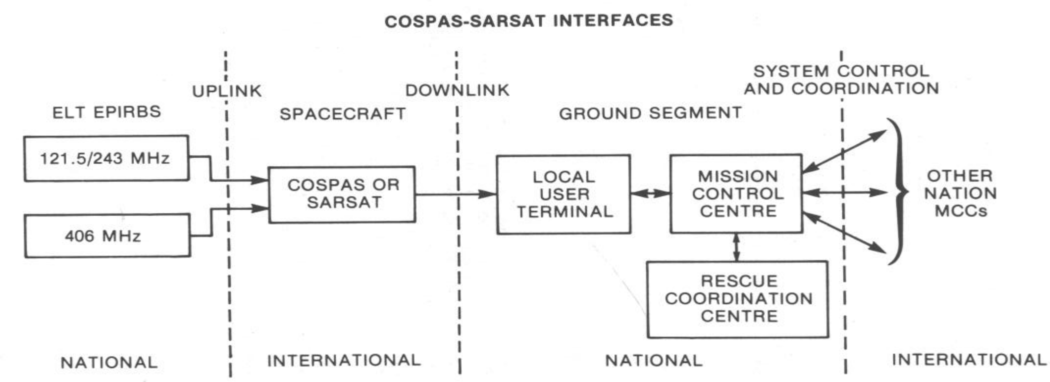
3.1.4 The Cospas-Sarsat Implementation Plan (CSIP)

'Interoperability' was the keyword defining the ultimate objective of the Cospas-Sarsat system design coordination. In the context of the 1970s, since any exchange of technology between Eastern and Western partners was ruled out, the solution was not straightforward.

The partners agreed at their meeting in Ottawa, Canada, in July 1979, that a detailed coordinating document, the Cospas-Sarsat Implementation Plan (CSIP), should be developed for review at the following meeting in Leningrad, USSR scheduled for November 1979. The document would have to set out the requirements for compatibility and interoperability of different satellite designs, beacon signals, alert data and System information messages transmitted among the System components and participants.

The schedule was clearly ambitious. At the Leningrad meeting the Morflot representatives noted that they had not had time for a thorough review of the initial document draft provided by the Sarsat partners in the English language, a few weeks before the meeting. However, the representatives were able to reach agreement in principle on major interoperability parameters for the satellite systems.

The partners continued to work diligently by correspondence and the first issue of the CSIP was signed on 22 May 1980 during the Lanham, MD meeting in the United States. Leadership in development of the CSIP was provided by Vladislav Rogalsky (USSR), Bernie Trudell (USA), Harvey Werstiuk (Canada) and Daniel Ludwig (France). The CSIP was significant as the first internationally coordinated 'System' document agreed by the Cospas-Sarsat partners. Many updates would be required to track evolutions during the development phase of the satellite systems. The CSIP actually established the basis of the future LEO system's technical documentation.



LEOSAR System Block Diagram showing the Segments Interfaces

Diagram courtesy of the International Cospas-Sarsat Programme

Interoperability: Mostly a Technical Approach with Few Operational Considerations

Arguably the most important chapter of the CSIP document was Chapter III dealing with interoperability. This chapter was drafted to specify all of the interfaces, critical system parameters and pre-launch testing required to assure the interoperability of the Cospas and Sarsat systems. Using a LEO system block diagram description, each interface point was identified and accompanied with the corresponding values and comments. Descriptions of the Cospas and Sarsat L-band spectrum downlink and alert data formats were provided. The specification for system control and coordination was also detailed, including information needed for exchange between the Cospas Mission Centre (CMC) in Moscow and the United States' Mission Control Centre (USMCC) in Suitland, MD. Finally, Chapter III provided the general principles for verification of interoperability that included:

- a common system of units and definitions;
- methods of measurement;
- exchange of raw test data, test standards and test results.

Chapter II of the CSIP consolidated the descriptions of the Cospas and Sarsat components as they existed. These descriptions covered the technical details of ELTs/EPIRBs, satellites, and LUTs, and the operational expectations for ground segment control and coordination. While the description of the technical components, existing and planned, was relatively straightforward, it was clear that no plan was yet in view as to how any long-term operational system coordination was to be conducted, or how distress alert data was to be distributed globally. To the space agencies, system interoperability was primarily a technical issue and SAR operational considerations were not a priority.

As detailed in the CSIP, each Sarsat LUT would send its distress alert data to its national MCC for distribution to that country's SAR service; likewise, information from the Soviet LUT would be sent to the Cospas MCC for distribution to the USSR SAR service. The USMCC and the CMC would act as the single points of contact for system coordination between the Sarsat and Cospas experiment operations. These MCCs would exchange orbital and time calibration data needed for satellite tracking and position location processing, with the USMCC relaying the Cospas system data to the other Sarsat partners. Additionally, during the initial D&E phase and until Sarsat 2 was decommissioned in 1996, the USMCC would receive and process global 406 MHz alert data from the NOAA command and data acquisition (CDA) stations and distribute that data to the appropriate partner[13]. The arrangements set out in the CSIP were suitable for the initial demonstration and evaluation phase of the two interoperable systems, but far from the global operation that would be required to meet SAR needs for timely and reliable alert data distribution.

Working and Meeting Arrangements

Managerial and working arrangements were also set out in the CSIP, including the organisation and procedures for the Cospas-Sarsat Coordinating Group (CSCG) meetings. The two main phases of the joint project were described:

a) the definition and development phase in which the cooperative system would be further defined and the hardware developed, and

b) the demonstration and evaluation (D&E) phase, which would include active participation by SAR services.

13/ See note 4 of section 3.1 on page 3-2. The 406 MHz SARP payload on board the first three Sarsat satellites did not have a dedicated memory unit. Sarsat 406 MHz global mode data was processed only by the USMCC before distribution to U.S. SAR services or the other Cospas-Sarsat partners as appropriate.

3.2 The LEOSAR System Demonstration and Evaluation

From the early days of the implementation of the experimental satellite aided search and rescue system, the partners realised the necessity of involving the eventual system users in a demonstration of its employment. As with any new system, a plan was developed to perform and report on a technical evaluation. In addition, the plan also aimed to demonstrate to the SAR services, government agencies and beacon users the capability of the new system to greatly improve the life-saving alert and position determination of persons in distress.

The demonstration and evaluation (D&E) activities were planned to start after the launch and in orbit engineering tests of the first Cospas or Sarsat satellite. The objectives were straightforward – to confirm the performance of technical components as developed, determine the operational characteristics of each sub-system, and make recommendations on the possible use of the experimental system operationally. The D&E plan outlined in the CSIP did not define the specific tests to be conducted. Detection probability and position determination accuracy were clearly a part of it, but the CSIP architects also specified that the evaluation should include assessments of operational aspects, such as various geographical conditions, accuracy of drift velocity measurements of EPIRBs over several satellite passes, time between beacon activation and SAR service notification, and system reliability.

It was left to each D&E participating country to further develop and put in place their own D&E plans. Each partner defined test activities according to their national needs and, for the most part, conducted D&E activities, collected data, and summarised results individually.

Fishing Vessel in Urgent Need for Assistance
Photo courtesy of the International Cospas-Sarsat Programme

The D&E phase of the Cospas-Sarsat system officially began in February 1983, with the active participation of national agencies or administrations[14] that had operational responsibility for search and rescue. By this time the Cospas-1, Cospas-2, and Sarsat-1 satellites had been launched. Cospas-3 was launched in June 1984 and Sarsat-2 in December 1984. The System performance tests were concluded in late 1984. The national test reports were later combined into a final D&E summary document entitled 'Cospas-Sarsat Project Report' issued in September 1985.

Post-launch tests on the Cospas-1, Cospas-2, Sarsat-1, and Cospas-3 satellites confirmed that all four spacecraft were operating nominally and were compliant with the interoperability requirements of the CSIP.

14/ In Canada: Department of National Defence, Transport Canada, Canadian Coast Guards and the Dept. of Fisheries and Oceans. In the United States: the U.S. Air Force, U.S. Coast Guards and the Federal Aviation Administration. In France: State Secretariat for Transport, State Secretariat for the Sea, Defence Ministry. In the USSR: Ministry of Merchant Marine, Ministry of Civil Aviation, Ministry of Fishing and the Academy of Science. In addition, Administrations in Norway (Dept. of Justice and Police) and the UK (Ministry of Defence, Dept. of Transport, HM Coastguard and the Civil Aviation Authority) actively participated in the Sarsat D&E. Bulgaria's Shipping Corporation also carried out tests in conjunction with the Cospas D&E.

To assess the overall System performance, the following five parameters were considered:

- location probability
- detection threshold
- location accuracy
- ambiguity resolution
- multiple access (system) capacity

The two following sections address each of these performance parameters for the two main areas of evaluation: the 121.5 MHz system and the 406 MHz system.

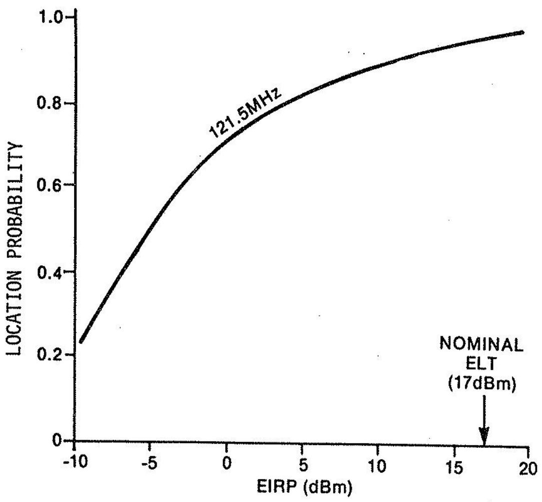
3.2.1 121.5 MHz System Performance

121.5 MHz Location Probability

The location probability was defined as the ratio of the number of instances in which a location was derived for a given beacon, relative to the total number of tracked passes that allowed a possible location of the beacon.

The location probability was dependent on the spectral characteristics of the 121.5 MHz ELT. For convenience, ELTs were generally classified into two categories:

- coherent ELTs that had a spectrum containing a clearly identifiable, stable frequency carrier component; and
- incoherent ELTs that had no predominant carrier component in its spectrum (see section 3.1.2).



121.5 MHz Cumulative Location Probability Determined in the D&E
(Cospas-Sarsat Project Report C/S R.001)

In the D&E tests, the location probability for a nominal coherent ELT at 121.5 MHz was greater than 0.95 for a single satellite pass. A nominal ELT was defined as one that had a power output of 20 dBm (100 mW) and an average antenna gain of -3 dBLi, hence a 17 dBm EIRP [15]. The location probability for a nominal incoherent ELT was approximately 0.80.

The figure to the left shows a graph of location probability versus ELT EIRP obtained during the D&E.

121.5 MHz Detection Threshold

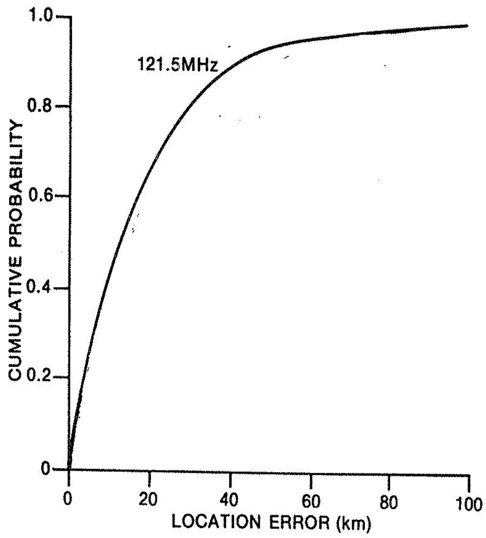
The detection threshold performance observed during the D&E (the lower beacon transmitted power that allowed a detection of the signal by the LUT), which was also highly dependent on the ELT spectral characteristics, is summarised in the following table.

15/ EIRP: Equivalent Isotropic Radiated Power.
mW: milliwatt; dBm: decibel relative to 1 mW (20 dBm = 100 mW).

ELT type	Nominal ELT	ELT Threshold	S/No	System Margin
Coherent	50 mW EIRP	0.5 mW EIRP	20 dBHz	20 dB
Incoherent	50 mW EIRP	3 mW EIRP	28 dBHz	12 dB

In this table the S/No values represent the signal-to-noise density ratios at the LUT processor input. The ELT Threshold column shows that the lower emitted signal level that allowed a detection was 0.5 milliwatt for a coherent ELT. The values given in the fifth column represent the estimated signal margin with respect to a nominal ELT (50 mW EIRP). These results illustrate the remarkable sensitivity of the receiver on board the satellite, which also explains the severe impact of interference on the 121.5 MHz system.

121.5 MHz Location Accuracy and Ambiguity Resolution



121.5 MHz Cumulative Location Error Probability Determined in the D&E
(Cospas-Sarsat Project Report C/S R.001)

The results of various field tests using real ELTs showed that the position location error was less than 20 km at least 68 percent of the time for a nominal ELT. The figure at left shows the cumulative probability distribution for the position location error. The data in this figure was derived from the same data set used to determine the location probability.

For each real signal the Doppler location algorithm generates two solutions which are symmetrical on each side of the satellite sub-track. Ambiguity resolution refers to the ability of the LUT processor to select the position that corresponds to the true location. D&E test results indicated that the LUT was successful in resolving this ambiguity approximately 75 percent of the time for coherent ELTs.

121.5 Multiple Access Capacity

During simulations, the LUT signal processor was demonstrated to have the capability of locating at least ten simultaneous ELT signals at 121.5 MHz.

3.2.2 406 MHz System Performance

Because of the burst transmission mode of 406 MHz beacons, the following probabilities were assessed:

- Message detection probability - the ratio of the number of received message bursts to the number of expected message bursts - ranged from 0.42 in Europe to 0.62 in North America, for all satellite geometries. [16]

16/ This performance parameter was significantly impacted by the presence of unwanted interference in the 406 MHz frequency band which is discussed separately. The Project Report noted that this less-than-optimal message detection probability did not normally degrade the overall system performance because on nominal satellite passes, ten to fifteen opportunities existed to acquire messages and only three or four messages were required to determine a location. However, a smaller number of detected bursts could affect the location accuracy.

- Beacon detection probability - the probability of detecting and correctly decoding at least one message burst during a satellite pass - was 0.99. A single burst detection would provide the beacon identification, which was already valuable information for SAR.
- Beacon location probability - the probability of detecting and correctly decoding at least three (or four [17]) individual message bursts during a single satellite pass so that a Doppler position estimate could be generated by the LUT - ranged from 0.82 in North America to 0.87 in Northern Europe, for all satellite geometries. For satellite elevation angles greater than 10°, the beacon location probability was measured to be 0.98 in North America.

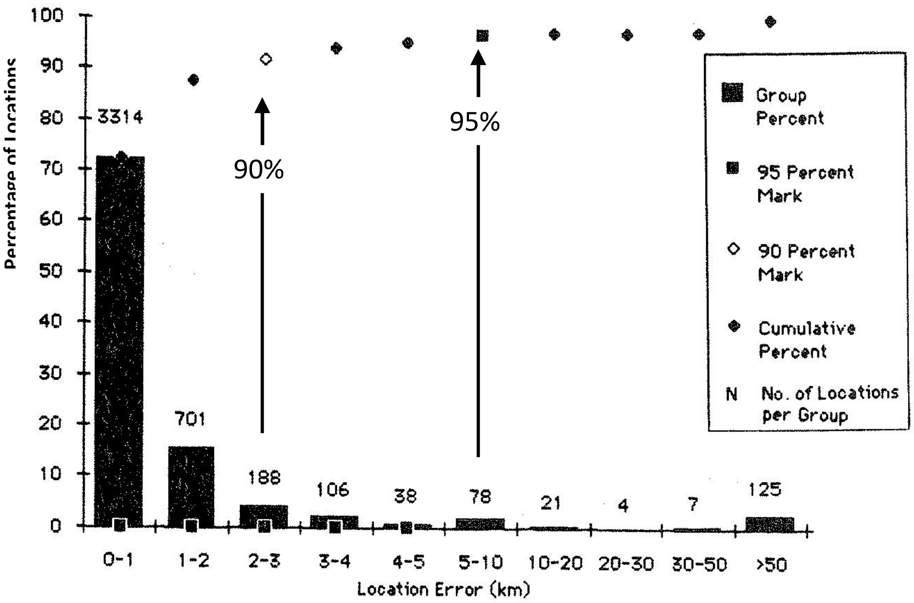
406 MHz Detection Threshold

Tests in North America showed that when the output power of a nominal 5 Watt beacon was attenuated by 13 dB, the beacon location probability, on passes above 10° elevation, decreased by 10 %. If all pass geometries were considered, the ten percent decrease occurred at 6 dB attenuation. On this basis, it was estimated that, in the absence of interference, a nominal 406 MHz beacon was operating with a margin of about 10 dB. Tests in Europe showed that, due to severe interference experienced at the time, the 406 MHz system had virtually no margin.

406 MHz Beacon Location Accuracy

The figure at left shows a histogram of position location errors observed during the D&E and the corresponding cumulative probability.

These System test results indicate that typically over 70% of the Doppler location solutions had errors less than 1 km, 90 % had errors less than 3 km and 95 % had errors less than 10 km.



Histogram of 406 MHz Beacon Location Errors and Cumulative Probabilities during D&E
(Cospas-Sarsat Project Report C/S R.001)

406 MHz Ambiguity Resolution

Because the medium-term frequency stability of the 406 MHz beacon is very good, the LUT signal processor was able to correctly resolve the ambiguity between real and image locations more than 95 % of the time. [18]

17/ A satellite pass was considered 'nominal' if its duration would normally provide for the detection of at least four beacon bursts. This pass geometry would normally be achieved with a maximum elevation angle over the horizon ≥ 5°. During the D&E some LUTs also provided a location with only three bursts.

18/ In real life situations, the ambiguity resolution performance at 406 MHz could be affected by the beacon oscillator instability during warm-up time, if the beacon was turned on during a satellite pass.

406 MHz Multiple Access Capacity

The 406 MHz system was designed to be capable of processing ninety beacons simultaneously in the field of view of a LEO spacecraft, during a single satellite pass. The verification of this capacity was performed in 1984 using a special test facility located in France. Capacity tests using the Cospas-2 satellite demonstrated that even with interference present, the onboard processor could process more than seventy 406 MHz beacons simultaneously.

406 MHz interference

As reported in Chapter 2, section 2.4.4, the unexpected presence of severe interference in the 406 MHz frequency band, particularly in Europe, Central America and Africa, resulted in a continuous flow of pseudo-alert messages when the Cospas-1 satellite was tracked by the LUTs. The on-board receiver processor did not adequately filter out interfering signals and interpreted the random data generated by the processor as possible 406 MHz beacon bursts, which filled the satellite memory with useless data. Furthermore, interference could jam the satellite SARP Data Recovery Units (DRUs) for durations of 10 to 15 minutes, masking actual beacon transmissions.

In contrast with the 121.5 MHz system, SAR services would not be impacted by false alerts generated from interference at 406 MHz, since this type of pseudo-message could not be confused with the digital signature of a 406 MHz beacon and, therefore, could be removed by the LUT processing. Improved filtering at satellite level eliminated most of the pseudo-message problem on later satellites. Nevertheless, the interference had a severe impact on the 406 MHz system performance and the matter required urgent action.

Based on work at CAL and CRC [19], and at CNES, the 406 MHz interference situation was reported to the 1983 World Administrative Radio Conference (WARC-83). This action resulted in a WARC resolution for the protection of the 406.0 to 406.1 MHz frequency band and the International Frequency Registration Board (IFRB) was requested to initiate a monitoring programme. Using the pseudo-data relayed by the satellites, special algorithms were developed by the Cospas-Sarsat partners to locate the interference sources [20]. The locations were reported to the IFRB and to competent Administrations in the countries where the source had been located. The continuous effort of many years resulted in the elimination of numerous sources, greatly improving the interference situation at 406 MHz.

3.2.3 System Operational Performance during the D&E

The System tests had shown that, despite severe interference in both 121.5 MHz and 406 MHz frequency bands, the 121.5 MHz and the 406 MHz systems performed as expected. The second phase of the D&E consisted of a variety of tests in real-world environment: on land, in mountainous areas, at sea, in the Arctic and the Antarctic regions; using off-the-shelf 121.5 MHz

19/ King, J.V. "Effects of 406 MHz Interference on the Cospas-1 Processor", CRC Report SAR 83/9, April 1983.

20/ King, J.V. "Techniques for Locating 406 MHz Interference Signals Using the Cospas-Sarsat Satellite System", CRC Report SAR 83/18, June 1983

ELTs/EPIRBs as well as prototype 406 MHz beacons. A large number of results are reported in the Cospas-Sarsat Project Report [21], confirming the expected operational performance.

Over 250,000 beacons operating on 121.5 MHz were already in service at the time of the D&E. Therefore, there was no lack of real-world events to demonstrate the usefulness of the System to SAR authorities. The search for a small aircraft in British Columbia, Canada (the Ziegleheim SAR case on 10 September 1982), two months after the launch of Cospas-1, is reported in Chapter 2, section 2.4.3 of this document. It was followed one month later (10 October 1982) by the first rescue at sea of the crew of a trimaran sailing boat in the Atlantic (the Gonzo), which had overturned (see the text box on the next page: *SAR after the first Cospas-Sarsat launch (3)*).

SAR after First Cospas-Sarsat Launch (1)

The second rescue took place on 29 September, 1982. A MAYDAY report was heard in Quebec by overflying aircraft. Shortly thereafter, an ELT was heard. It was late afternoon, and darkness was approaching.

The Trenton SAR Region (SRR) Commander (Col. Dave Garland) was present in RCC Trenton getting his end of day briefing when the incident occurred. We quickly determined that a Cospas 1 satellite would soon be making an orbit within the vicinity of Quebec. A search airplane was launched and told to head east. "Where?" the crew asked. We told them to head towards Montreal and they would be updated enroute. Shortly thereafter, the Ottawa LUT provided a solid location for the crew to use.

The crash site was found before darkness set in, and rescue specialists parachuted in to the site to help the occupants. Meanwhile, the search aircraft directed a rescue helicopter to evacuate those on the ground. This rescue demonstrated the benefits of close coordination between RCC and MCC personnel. At that time only one satellite was available. The timeliness of this rescue was only possible by chance and the need for a full satellite constellation was quite apparent.

Major Herbert Edward (Ted) King,
Officer in Charge of the first Canadian MCC
in Trenton, Ontario Canada (1982)

A major contributor to the success of the D&E was the direct involvement of the SAR services in the tests. In all participating countries, SAR personnel were involved in the test development, conduct, data collection and analysis. Actual 121.5 MHz distress alert messages processed by the experimental LUTs were transmitted through the MCCs to national RCCs to be evaluated and used if possible in real distress events. By the end of the test phase, in May 1985, Cospas-Sarsat had provided alert and location data in 194 distress incidents world-wide, involving 527 persons of whom 473 were rescued. All these 'saves' were achieved with the 121.5 MHz system as there were no operational 406 MHz beacons in the field at the time of the D&E.

The major concern of SAR personnel was the considerable number of false alarms generated by 121.5 MHz ELTs. Over 90% of all 121.5 MHz alerts generated by Cospas-Sarsat were not genuine distress cases. These false alerts resulted from ELTs triggered inadvertently in non-distress situation and from interference. In both circumstances, this was a direct consequence of the large field of view of the satellite and its monitoring capability (see the text box: *SAR after the first Cospas-Sarsat launch (2)*). A number of non-distress ELT transmissions previously undetected, therefore ignored, were now notified to RCCs.

21/ See Document C/S R.001: Cospas-Sarsat Project Report (September 1985), Appendix A, for detailed results of tests performed by Canada, France, the United States, the USSR, Norway, the UK and Bulgaria. A list of real distress events for which Cospas-Sarsat provided support from September 1982 to June 1985 is also provided.

The second lesson noted from the D&E regarding operational matters was the need to enhance communications on the ground and organise the distribution of alert data internationally.

SAR after the first Cospas-Sarsat launch (2)

One other challenge was discovered early during the D&E testing. When flying at normal aircraft altitudes, the 121.5 MHz frequency is fairly quiet. However, at satellite altitudes, a much larger area is visible, and the band becomes more noisy.

Two contributors to the problem were evident. Firstly, a strong voice transmitter some distance away can have a disruptive effect on satellite detection. Secondly, as more modern communications devices were introduced into consumer service, harmonics or spurious signals were appearing in the distress band. The Local User Terminals (LUTs) could not distinguish between what was an ELT and what was a spurious signal or interference. As a consequence, solutions that were sent to MCCs included a high volume of trash.

Major Herbert Edward (Ted) King

Despite the inevitable growing pains and the concerns over false alerts, the positive results of the experimental Cospas-Sarsat System demonstration and evaluation encouraged participants to continue the System implementation, undertake enhancements, and pursue mitigation efforts regarding the 406 MHz interference environment.

SAR after the first Cospas- Sarsat launch (3)

The third rescue was a maritime incident that occurred in the Atlantic ocean in October 1982. A 60-foot trimaran named "**Gonzo**" had overturned. Its EPIRB had been activated and the signal was being picked up by overflying aircraft.

At that time, the Ottawa LUT was the only LUT that provided coverage of the area. The communication link between the CMCC (Canadian MCC) and the USMCC was not working at the time of the incident, so the USA was not receiving any of the satellite data. A request was made to the CMCC to identify possible locations for the source of the signal and forward them to the appropriate Rescue Coordination Center (RCC). This was quickly accomplished, thanks to the good bilateral relations between Canadian and American RCCs. A Liberian tanker was sent to the site of the overturned boat and acted as a breakwater (sea state 6) while a US Coast Guard boat rescued the three sailors.

This incident demonstrated the importance of good, reliable communication links and the need to have backup communication links when outages occur. It was evident that the Canadian LUTs eventually would be detecting events in other jurisdictions in Denmark, the UK and Portuguese SRRs. In time, some bilateral meetings were held with North Atlantic RCCs to further discuss how this should evolve. The results of these deliberations eventually made their way into Cospas-Sarsat meetings and helped to shape the handling of operations.

Major Herbert Edward (Ted) King

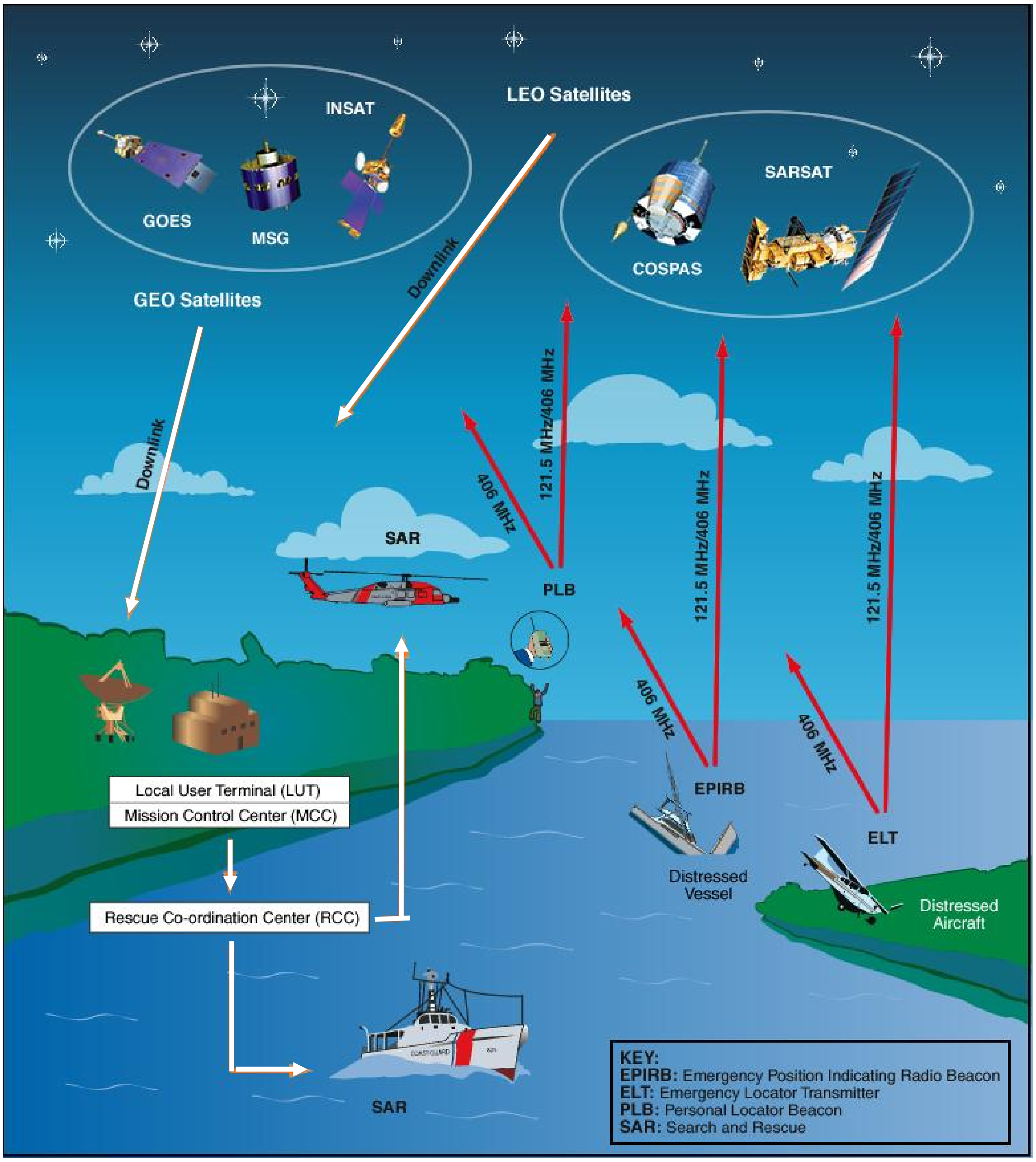
Photo courtesy of the International Cospas-Sarsat Programme

The Gonzo SAR Case

The Gonzo trimaran sailing from Portland, Maine to England, capsized about 300 NM south-east of Cape Cod, on 10 October 1982 with three people on board (see text box at right).

3.3 The Combined 406 MHz LEOSAR-GEOSAR System

The LEOSAR demonstration and evaluation phase had shown the considerable benefits of satellite distress alerting and locating. However, in 1984, the competition between the 406 MHz LEOSAR concept and the L-band EPIRB system operating with the Inmarsat geostationary satellite system was on-going at IMO. The GEOSAR concept which provided quasi real-time alerting had many supporters (see Chapter 2, section 2.5) and the Cospas-Sarsat partners were aware of the need to propose a 406 MHz GEOSAR capability to win over doubters and ensure that Cospas-Sarsat would remain relevant to maritime users.



The picture above illustrates the principle of combined LEO-GEO operation at 406 MHz.
121.5 MHz beacon transmissions are not relayed by the GEOSAR satellites.
(Courtesy of Cospas-Sarsat secretariat)

3.3.1 406 MHz GEO System Design and Development

The LEO versus GEO initial design option for a satellite system relaying the emissions of low-power, battery-operated radio transmitters, at the end of the seventies, commanded several basic system features.

Because of the low transmit power available at beacon level, the need to use antennas with quasi-hemispherical radiation patterns and the considerable propagation losses affecting the signal arriving at a GEO satellite more than 36,000 km away, the L-band - GEO system designers chose a low bit rate for the beacon digital message. With a low data bit rate, an acceptable energy-per-bit ratio could be achieved using only one watt of beacon emission power. The drawback was that low bit rates meant longer transmission durations and, in a random access communication system, more carrier frequency spreading to achieve the required capacity. Fortunately, a full 1 MHz bandwidth was available at L-band for satellite EPIRBs operating with the Inmarsat GEO system (see Chapter 2, section 2.5).

406 MHz System Architecture Constraints

With a LEO satellite system, a higher bit rate was feasible, due to lesser propagation losses. It was also desirable since a satellite pass in visibility of the beacon would last no more than 15 to 20 minutes. Furthermore, short messages and higher repetition rates were beneficial to the Doppler location technique as they would provide a greater number of frequency shift measurements during the satellite pass, hence higher location computation accuracy. The Cospas-Sarsat 406 MHz LEO system with short burst transmissions (less than half a second) and a high repetition rate (at about 50-second intervals) could achieve a reasonably accurate Doppler location with less than 4 minutes of satellite visibility.

The consequence of this choice of design parameters was a high capacity (over 90 beacons in the LEO satellite visibility area) with less than one tenth of the L-band system bandwidth requirement (i.e., 100 kHz at 406 MHz instead of 1 MHz at L-band). However, there were also drawbacks: the need for a fairly high power burst, about 5 watts for 406 MHz beacons against 1 watt for the L-band design, and a rather severe constraint on the length of the beacon message, hence the amount of data that could be encoded.

The Cospas-Sarsat 406 MHz system high bit rate meant that the available energy per bit would be particularly low for message decoding through a GEO relay. This would impose high performance repeaters at the satellite level as well as high quality receivers in the receiving stations of the GEO system (the GEOLUTs). Although the feasibility had been demonstrated in 1983 and 1984 through experiments by NASA, DOT and CNES [22], this issue would be the first challenge to be met by manufacturers of operational GEOLUTs.

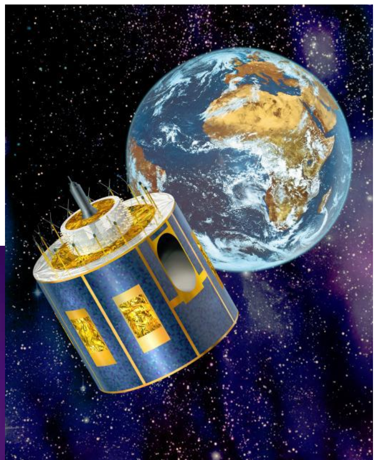
Operational GEO Platforms of Opportunity

The second biggest hurdle to the implementation of a global GEO 406 MHz system was to find operational satellites to host the 406 MHz repeater, adequately positioned in longitude to provide

22/ See Chapter 2, section 2.5.5: The Cospas-Sarsat Strategy for a Combined LEO/GEO System.

complete GEO coverage. After Inmarsat had declined to host such a capability on their second generation space segment, the choice was extremely limited, particularly as the funding of this capability could not be provided through customer fees. The only available government-owned, operational GEO satellites were the United States' GOES meteorological satellites, already equipped with a data collection system at 402 MHz, not very different from the required 406 MHz repeater. The adaptation of an additional repeater system using the same receive antenna was therefore rather straightforward, which limited the additional costs incurred. The United States' decision to proceed with this addition to their GEO system was a considerable boost to Cospas-Sarsat ambitions, but still short of the required global coverage.

Top: NOAA Geostationary Operational Environmental Satellites (GOES)



Centre: EUMETSAT's Meteosat Second Generation (MSG)

Bottom: ISRO's INSAT-3A

Photos courtesy of NOAA, EUMETSAT and ISRO

The Indian Space Research Organisation (ISRO) proposal, in 1986, to install a 406 MHz repeater on their future INSAT satellites would provide the required global coverage by 1994. The only constraint was that, to limit additional on-board power requirements, the INSAT-2 satellite would only provide a narrow beam downlink received by the INSAT GEOLUT in Bangalore. This feature prevented other countries from installing their own GEOLUTs to directly receive INSAT-2 alert data, introducing a weak point in the operational 406 MHz GEOSAR system.

In addition to the United States' GOES and India's INSAT satellites, the GEO coverage was later completed with additional operational and spare satellites provided by EUMETSAT [23] from 2003 (the MSG satellite series) and from 2011 with Russia's Luch and Electro satellites.

The Need for a Longer 406 MHz Beacon Message

By definition, geostationary satellites have no velocity relative to a fixed point on the Earth. There is no Doppler effect and location techniques using a triangulation methodology [24], although possible in theory, would not be particularly accurate. The only viable option for locating a beacon with a GEOSAR system was to make the beacon capable of acquiring its own position, using an integral GNSS receiver, and transmit the data in its alert message.

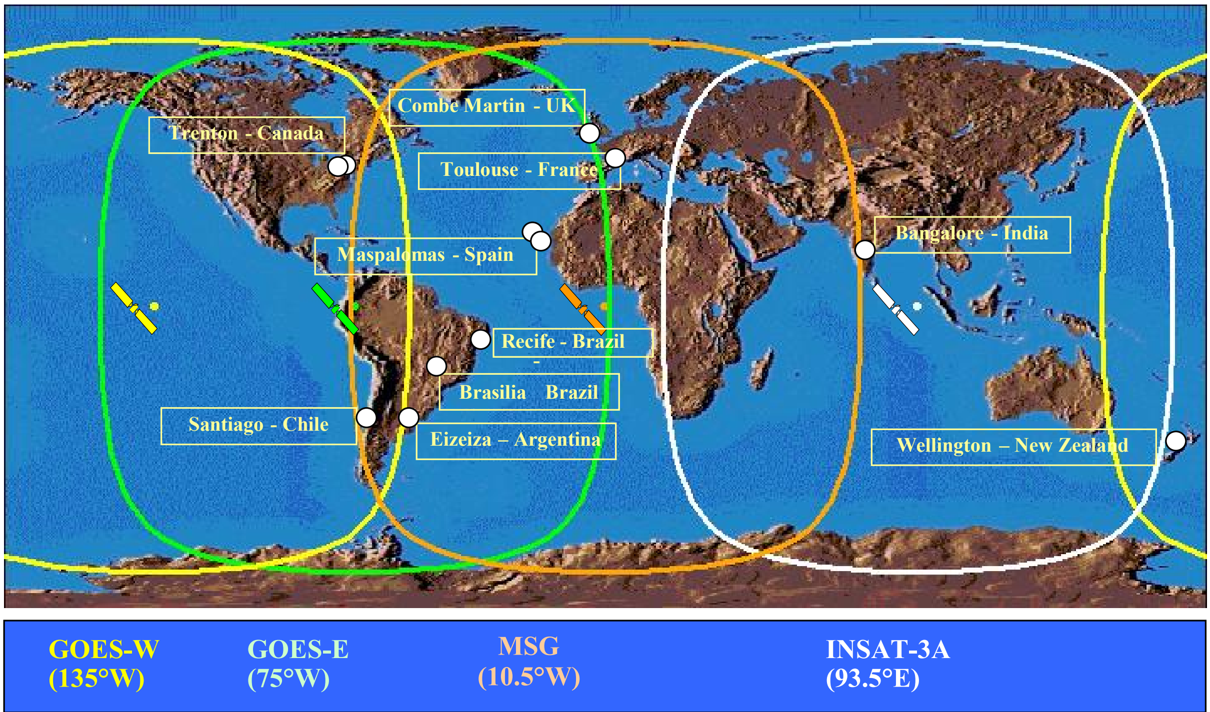
23/ EUMETSAT: the European Meteorological Satellite Organization (see also Chapter 4, section 4.4.4).

24/ Measuring a time difference of arrival of beacon bursts relayed via two GEO satellites would provide two positions, one in each hemisphere. However, the difficulty of time measurements on 406 MHz beacon bursts and the geometry of the problem (satellites in the equatorial plane) did not leave much hope for an operationally viable solution.

Fortunately, the option for additional bits in the 406 MHz beacon message, which was not part of the initial LEOSAR system design, had been introduced in October 1981 upon the insistence of CNES, on the grounds that the 'short' 406 MHz beacon message did not have any spare capacity for possible evolution [25]. This was accepted by CNES' partners with some reluctance as the design of the Sarsat and Cospas 406 MHz payloads had been frozen and manufacturing had started. The 'long message' format with 32 additional data bits was backward-compatible with the initial SARP design, as the additional message bits could be ignored by the satellite processor. However, to become effective in the LEOSAR system global mode of operation, the change required a redesign of the 406 MHz SARP payload, which was implemented only in the third batch of LEO satellites, starting with NOAA-K (Sarsat-7) and Nadezhda-7 (Cospas-10), launched in 1996 and 1998, respectively.

3.3.2 406 MHz GEOSAR Demonstration and Evaluation

Prior to officially introducing the 406 MHz GEOSAR system as a new Cospas-Sarsat capability, between July 1996 and February 1998, a thorough demonstration and evaluation (D&E) of the 406 MHz GEOSAR capabilities and the enhancements provided by combined LEO-GEO operations was performed. Three satellites GOES-8, GOES-9 and INSAT-2A were used for the GEOSAR D&E, together with experimental GEOLUTs in Canada, France, India, the UK and the United States. Australia, Spain, Algeria, Chile, Japan and Russia contributed data and analyses to the GEOSAR D&E. The D&E Report was published in October 1998 as document C/S R.008.



2003 GEOSAR Coverage with 12 Operational GEOLUTs.

In 1998, the GEOSAR system comprised two U.S. GOES satellites and India's INSAT-3A. The EUMETSAT MSG-1 satellite was launched in 2003. The Russian GEOSAR satellites Electro and Luch were launched after 2011. (Picture courtesy of the Cospas-Sarsat Secretariat)

25/ The need for an extended coding capability in the beacon message was not clear at that stage. There were no talks yet of a 406 MHz GEOSAR capability, and coding a position in the beacon message seemed far fetched, particularly as the system was designed for Doppler location processing.

The major conclusions of the D&E were reported as follows:

- The GEOSAR system could recover beacon messages down to an elevation angle of 0º. A 4º elevation angle provided a conservative estimate of the coverage area where reliable reception of alerts was assured.
- On average, the GEOSAR alert was received 46 minutes before the first LEOSAR alert for the same beacon. The median time advantage was 21 minutes.
- The GEOSAR system was a good complement to the LEOSAR system as 85% of all alerts in a GEO satellite visibility area to 0º elevation were detected by the GEOSAR system and undetected alerts could be explained by circumstances such as ground obstacles and masks, or weak beacon signals. In addition, a large number of short-duration 406 MHz beacon transmissions, previously undetected by the LEO system as the LEOSAR coverage was not continuous, were recovered by the GEOSAR system.
- When the 406 MHz beacon message did not include a GNSS position, the early GEOSAR alert was still a benefit to SAR, provided the beacon was correctly registered. SAR services could use the beacon identification to enquire on the circumstances of the registered owner and either rapidly eliminate false alerts or start to plan the rescue mission.

3.3.3 406 MHz Beacon for the Combined LEO-GEO System

406 MHz Beacon Registration

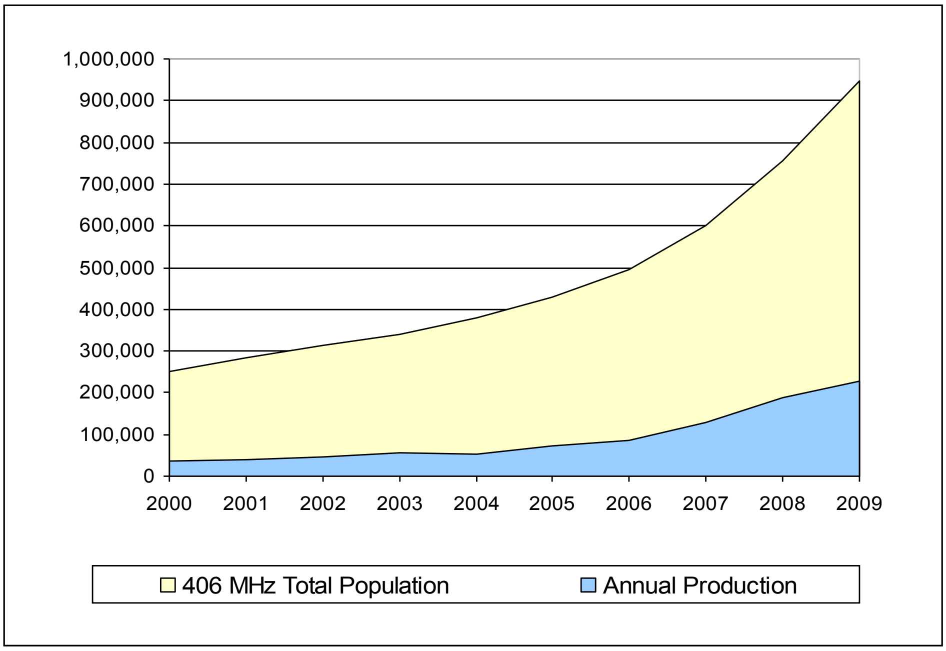
The benefits outlined above also highlighted the need to further educate ELT/EPIRB users. Many short-duration transmissions generated by unauthorised beacon testing, using operational mode transmissions instead of the authorised beacon test-mode, were now detected by the GEOSAR system and were passed to SAR authorities. In all cases, proper beacon registration was essential for efficiently processing alerts, genuine or false. This last point led Cospas-Sarsat to implement an International Beacon Registrations Database (the IBRD). Although setting up beacon registration regulations was a national responsibility, many countries failed to implement effective registration facilities, precluding national users from properly registering their beacon. The Cospas-Sarsat IBRD was set up in 2006 and made available to States and individual beacon owners that did not have the opportunity to register beacons in their country.

Various types of 406 MHz EPIRBs, ELTs and PLBs (circa 1990)
Photo courtesy of the International Cospas-Sarsat Programme

406 MHz Location Protocol Beacons

Detailed specifications for the digital message in self-locating beacons also called 'location protocol beacons' were introduced in 1997, before the GEOSAR system became officially a component of the Cospas-Sarsat LEO-GEO System in 1998.

The option to include GNSS position data as part of the 406 MHz distress message gradually became a common feature in many of the newer beacons. The total population of beacons (ELTs, EPIRBs and PLBs) reached about 945,000 in 2009. 30% of the 2009 production (229,000 beacons of all types produced by 45 manufacturers) were Location Protocol Beacons.



Total Population and Annual Production of 406 MHz Beacons - 2000 to 2009
(source Cospas-Sarsat Secretariat)

Fishing Vessel Incident At Sea, off the California/Oregon Border, United States

On 1 December 1996, the 40-foot fishing vessel Beach King capsized when hit by a large wave. The vessel was fishing in 20 to 25-foot seas near the California/Oregon border. The crew of three was not able to transmit a mayday call or signal a distress in any way; however, the vessel's 406 MHz EPIRB activated automatically when the vessel capsized.

The transmission from the 406 MHz EPIRB was relayed via the GOES-9 satellite to the USMCC and then on to RCC Seattle […]. The alert did not include a location. The RCC called the emergency point of contact listed in the beacon registration database. Upon learning that the Beach King was fishing off the Klamath River, the RCC dispatched a rescue helicopter to search the area.

The helicopter located the capsized vessel and hoisted two crew members from the cold (11° Celsius) water. The third crew member was never found. The crew members were flown to a local hospital where one of the crew received intensive care treatment for hypothermia. Post analysis of the case confirmed that the crew members were not wearing survival suits or flotation devices and would have perished had they remained in the water much longer.

The first notification of distress was an unlocated alert from a geostationary satellite, which arrived at the USMCC 47 minutes before a located alert from a LEO satellite. The Coast Guard was able to investigate the alert (that is, call the point of contact, check the harbour, make radio call-outs, and launch a helicopter) so that rescue forces could proceed to the vicinity of the distress immediately, even without the located alert data. This resulted in saving the lives of two people.

Summary Report of the 406 MHz Geostationary System
Demonstration and Evaluation (Document C/S R.009, October 1999).

Chapter 4

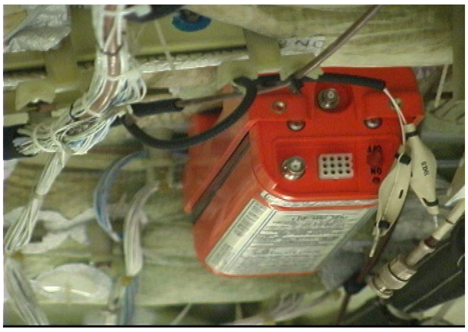
The Long Road towards a New International Organisation

4.1 International Acceptance, a Global Objective

A global SAR system, whether for mariners or for airmen, on land and at sea, cannot be truly effective without global assignment of SAR coordination responsibilities and standardisation of the complete system, including on-board equipment and communications, alerting procedures, SAR resources and SAR response planning. At a time of global trading, it would be unwise for a ship to be equipped with a system not recognised when sailing on the other side of the world, or for authorities to set-up a system suitable only for a portion of potential users. The same is true for airliners. Obviously, specific requirements can be set up locally for limited user populations, for example pleasure craft not sailing the high seas or light aircraft that do not cross borders. However, when considering global satellite systems, standardisation and global acceptance are basic requirements.

Therefore, it was rather obvious that, in the longer term, a single satellite EPIRB system would become the world standard. A selection had to be made among the proposed satellite systems operating at 121.5 MHz, 406 MHz or 1.6 GHz (the L-band system) to ensure cost effectiveness and facilitate global acceptance.

4.1.1 Cospas-Sarsat Acceptance in the Aviation Community



406 MHz Aircraft ELTs Installations

Photos courtesy of the International Cospas-Sarsat Programme

In the aviation domain, the International Civil Aviation Organization (ICAO) is the international body responsible for standardisation of safety requirements, procedures and operations. By 1979, 121.5 MHz Emergency Locator Transmitters (ELTs) had been made mandatory in some countries on general aviation aircraft, first in the United States and later in Canada and in France. ICAO mandated the installation of the equipment in airliners on international voyages in 1967, before the Cospas-Sarsat project was launched. As a result, the rather inexpensive 121.5 MHz ELTs spread rapidly in the aviation community and, when Cospas-Sarsat was declared operational in 1985, a large user community welcomed the enhancements provided in terms of alert monitoring and locating, at no additional cost to users.

In 1986, ICAO published Circular 185 describing the Cospas-Sarsat System and encouraging States to avail themselves of its distress alerting and locating capability. Although ICAO also invited States to issue appropriate regulations to allow the use of new 406 MHz digital ELTs, the organisation did not go as far as recommending a switch to the new frequency. It would do so only in 1999, allowing Cospas-Sarsat to terminate the satellite processing of 121.5 MHz distress signals by the year 2009. The transition to 406 MHz ELTs is addressed in more detail in Chapter 5, sections 5.4 and 5.5.

4.1.2 The Maritime Community Expectations and Concerns Regarding Satellite EPIRBs

In the maritime domain, satellite EPIRBs were a new thing and there was no consensus on which type should be used in the Future Global Maritime Distress and Safety System (FGMDSS)[1] developed by the International Maritime Organization (IMO); either Cospas-Sarsat beacons operating with the polar-orbiting satellite system or L-band EPIRBs operating with Inmarsat's geostationary satellites (see Chapter 2, section 2.4 on the Inmarsat-E system). The only commonly accepted view at IMO was that 121.5 MHz beacons, which could not be automatically identified, should not be used at sea. The high false alarm rate of automatically activated beacons and the uncontrolled development of cheap 121.5 MHz personal locator beacons (PLBs) were considered significant threats to maritime SAR services, which could rapidly be overwhelmed by a flood of 121.5 MHz alerts from the Cospas-Sarsat System, with no means of sorting out real from false distress alerts.

The L-band EPIRB system operating through Inmarsat's geostationary satellites was the easy choice as it did not entail additional funding for the space system, except dedicated ground-based receiving equipment installed in Coast-Earth Stations. Furthermore, the L-band EPIRB system was developed with the active support of IMO and would be operated by Inmarsat, a major service provider in the GMDSS, established as an international organisation, which provided all necessary guaranties of continuity. The Cospas-Sarsat polar-orbiting system was in a weaker position as no international treaty was in place to guarantee its long-term operation. It was developed, funded and maintained by a group of agencies, active either in space research and development or in meteorological applications, with the exception of Morsviazsputnik clearly associated with MORFLOT, the Soviet merchant marine regulator and operator. As a result the IMO response to Cospas-Sarsat supporters' request to include the developing system as part of the future GMDSS was not entirely positive. Some national delegations openly opposed that request.

4.1.3 High Hopes and Uncertainties for Cospas-Sarsat International Acceptance

The 1979 Cospas-Sarsat MOU provided for an experimental system comprising a series of three U.S. satellites, NOAA-E, F and G, with Canadian and French instruments, and a similar number of Cospas satellites provided by the USSR, all with payloads designed to repeat 121.5 MHz signals and process 406 MHz transmissions. Assuming a nominal life-time of only two years for Sarsat and Cospas satellites, continuity was not assured after the completion of the Demonstration and Evaluation (D&E) phase, beyond 1986. In 1982, U.S. budgetary concerns led to uncertainty concerning the continuation of a dual polar satellite system for meteorology. In a single polar orbiting satellite system scenario, the Sarsat contribution to the Cospas-Sarsat system would be reduced to a single operational satellite and launches of follow-on satellites (NOAA-H, I and J) would be delayed by several years. This situation would be contrary to the commitments laid-out in the MOU and would obviously raise questions as to the actual operational availability of the system and its value for distress alerting in the GMDSS. This particular matter was resolved in 1983 when NOAA's budget for a dual polar satellite system was restored, but the episode clearly showed that the continuity of the Cospas-Sarsat endeavour was far from being guaranteed and would have to be addressed by the Cospas-Sarsat partners as a prerequisite to achieving international acceptance.

1/ FGMDSS: IMO's 'Future Global Maritime Distress and safety System'. The acronym would change to GMDSS in 1999, date of the full implementation of the system.

However, at the fifth meeting of the Cospas-Sarsat Coordinating Group (CSCG-5) held at CNES Toulouse Space Centre in France from 20 to 23 June 1983, the early successes obtained with the Cospas-1 satellite in September 1982 and the launch of Cospas-2 and Sarsat-1 satellites in March 1983, lifted the hopes of the Cospas-Sarsat partners for international acceptance of their System. Furthermore, funding seemed assured for the NOAA-H, I and J satellites with their Canadian and French SAR payloads, as well as additional Cospas satellites, allowing the CSCG to start drawing plans for a 'transition phase' towards a fully operational System.

At IMO, the report of over 40 lives saved in various incidents where Cospas-Sarsat provided actual assistance to SAR authorities had somewhat changed the attitude of delegations to the Radio-Communications Sub-Committee. For the first time, at the Sub-Committee's 25th session, "*EPIRBs operating in the polar-orbiting satellite system*" were included, alongside L-band EPIRBs of the Inmarsat system, in the draft FGMDSS requirements for ships over 1,600 gross tons sailing in sea areas A-3 and A-4 [2], beyond VHF and MF DSC coverage. The rationale was that L-band EPIRBs operating through a geostationary satellite system would not be detected in polar regions while the alerting service could be provided by a polar-orbiting system, as demonstrated by Cospas-Sarsat. Staunch supporters of the L-band system still refused to name Cospas-Sarsat as the provider of the 'polar' or 'POL' EPIRB service, arguing that Cospas-Sarsat was a brand name not acceptable for an international requirements document. The objection did not apply to Inmarsat, clearly identified as the L-band EPIRB service provider. Furthermore, hopes for an L-band polar-orbiting system were still alive (see Chapter 2, section 2.4).

At the end of the CSCG-5 session restricted to the four Cospas-Sarsat Partners, an 'Open' CSCG meeting was held on 24 June 1983 with representatives of 'Investigator' countries (Norway and the UK who were associated with the Sarsat evaluation) and with observers from IMO and Inmarsat. ICAO had also been invited, but was not represented. After the usual welcome address and participants' reports, a courteous but tense discussion followed on the future of Cospas-Sarsat in the FGMDSS.

The IMO representative, Mr. de Goede, indicated that, if Cospas-Sarsat wished to provide its System as part of the GMDSS, Cospas-Sarsat must regularly submit information and status reports for consideration by IMO. Clearly, Cospas-Sarsat was not IMO's 'baby' and its adoption by the international organisation would require some effort by the Cospas-Sarsat partners who were reminded of IMO's prerogatives with respect to maritime SAR management.

The Inmarsat representatives, Paul Branch and Keith Thacker informed the group that, following an investigation of the feasibility of carrying a 406 MHz repeater on Inmarsat's second generation satellites, and due to cost issues and funding uncertainties, Inmarsat's Director General, Olof Lundberg, would not be in a position to recommend the inclusion of 406 MHz repeaters on future Inmarsat satellites at their forthcoming Council meeting in July 1983. This decision jeopardised Cospas-Sarsat hopes of soon achieving a dual polar and geostationary satellite system operating at 406 MHz.

Yuri Zurabov, the leader of the USSR delegation and Morsviazsputnik's Deputy Director General, expressed his discontent and disagreement with the Inmarsat Directorate conclusions, stating that he was keen to discuss the feasibility of merging Cospas-Sarsat operations and future operational

2/ The concept of GMDSS sea areas is presented in Annex 2, section 1 on 'Maritime SAR'.

system management with Inmarsat's, under some form of agreement with the organisation. The USSR had previously submitted several documents to the Inmarsat Council[3] on the feasibility of such a scheme.

The USA Representative, Tom McGunigal from NASA, indicated that, in his opinion, Inmarsat was making a mistake, but other options were available to Cospas-Sarsat for a GEO complement to its polar system, namely meteorological geostationary satellites like NOAA's GOES series. Tests using the GOES data collection channel at 401 MHz had already demonstrated the feasibility of a geostationary relay of Cospas-Sarsat 406 MHz beacon transmissions.

The UK delegate, David Pope from HM Coastguard, stated that IMO had requested Inmarsat to "*urgently consider combining polar and geostationary satellite systems*" for the satellite-EPIRB alerting function, to which Keith Thacker replied that Inmarsat was effectively considering an L-band polar system concept (the SERES proposal described in Chapter 2, section 2.4) and Inmarsat would follow its Council decisions on the matter.

The French Representative and Chair of the meeting, Gérard Brachet from CNES, always eager to keep-up the momentum, stated that the Cospas-Sarsat polar-orbiting system future was assured and that, on the face of Inmarsat's Council expected decision, Cospas-Sarsat should pursue the meteorological geostationary satellite option.

Don McKinnon, the Canadian Representative, indicated that other options, including dedicated satellites, were also open to Cospas-Sarsat.

This debate illustrates the various stakeholders' positions at this turning point in the decision making process. It also reveals the upbeat mood of the Cospas-Sarsat partners, or at least their representatives in the Programme, as it is unclear how much support the idea of pushing ahead with a GEO complement to the Cospas-Sarsat polar system actually enjoyed at the top level management at home. Implementing the plan for an operational dual polar and geostationary 406 MHz system without the support of Inmarsat would be a long and convoluted struggle of many years. The USSR's hopes to merge Cospas-Sarsat with the Inmarsat system had clearly suffered a setback, but were not entirely dead. The possibility of association with Inmarsat would resurface when discussing future institutional arrangements for the operational Cospas-Sarsat system.

4.1.4 The Moving Horizon of International Acceptance

On 5 October 1984, after the successful completion of the Demonstration and Evaluation Phase, the Cospas-Sarsat partners signed a new Memorandum of Understanding (MOU) at the CSCG-7 session held in Leningrad[4], USSR, declaring their intent to continue the system "*at least until year 1990*" and to make it available to all countries. This was confirmed in 1985 by a formal declaration that the system was operational and ready for use[5], which was made during the first

3/ Council/11/59 (USSR-1982): Possible Incorporation of the Search and Rescue System into INMARSAT
Council/15/57 (USSR-1983): Possibilities of integrating the Cospas-Sarsat System with INMARSAT
Council/18/47 (USSR-1984): Possible Venues of Integration of Cospas-Sarsat with INMARSAT

4/ Leningrad: today Saint Petersburg, Russia

5/ In the final conclusion of the Summary of Discussion of the Seattle meeting (CSSC-1, July 1985) the Cospas-Sarsat Steering Committee declared that "the 406 MHz system [was] ready for initial operational use". Acceptance of the 121.5 MHz system as 'operational' did not raise issues, but there was a debate among Cospas-

Cospas-Sarsat Steering Committee[6] held in Seattle, USA. Because of the stated purpose to maintain, manage and operate an operational system, the United States and Canadian signatories to the second MOU changed, from NASA to NOAA in the United States and from the Department of Communications (DOC) to the Department of National Defence (DND) in Canada.

The new MOU stated the commitment of the signatories at department/agency levels, not State or Governmental level, and none of the partners could realistically take on commitments beyond the expected life-time of the satellites already budgeted or planned. To administrations responsible for adopting and implementing regulations such as the FGMDSS, the year 1990, the expected termination date of the MOU, was barely a beginning. Although satellite EPIRBs became mandatory equipment on SOLAS vessels from 1993, a sign of the urgent need and their demonstrated efficiency, the target date for operational implementation of the complete GMDSS was actually set as 1999.

In 1984, the USSR submitted to the IMO Maritime Safety Committee MSC-49 session a draft Assembly Resolution on "*The Use of the Cospas-Sarsat Low Polar Orbiting Satellite EPIRB System*". Adoption of the draft resolution was deferred until MSC-51 in 1985 and finally approved by IMO at its 24th Assembly in November 1985. This was a very encouraging result for Cospas-Sarsat, though yet short of what could be considered full acceptance.

Opinions were still diverging at the Radio-communications Sub-Committee level on the final choice of the satellite EPIRB frequency. While a group of countries including France, the UK and the USSR proposed to use a single frequency, 406 MHz, for all satellite EPIRB alerting functions, the Netherlands proposed 406 MHz for float-free satellite EPIRBs and L-band for the on-board alerting function, while others refused to make a final choice.

At the Maritime Safety Committee MSC-51 session (20 to 24 May 1985), the USSR delegation supported by Canada and several other delegations, "*proposed that the Committee endorse the [Radiocommunications] Sub-Committee's opinion to use the frequency 406 MHz as the single frequency for a satellite EPIRB system*". The following are extracts of the MSC-51 session report:

"The delegation of China, supported by the delegations of Australia, the Federal Republic of Germany, Greece and Japan considered that a decision on the use of the Cospas-Sarsat system in the FGMDSS should be deferred until the following had been resolved:

.1 whether use of the system after 1990[7] would be charged to users;

.2 whether users would be required to contribute to the cost of launching additional satellites; and

.3 the organisation, management and procedure of that organisation."

Sarsat partners on the exact meaning of declaring the System 'operational' at 406 MHz and the resulting responsibilities for the Parties. Additional work was still needed on several issues, particularly the distribution of alert data, to achieve the expected operational efficiency and provide effective assistance to SAR authorities worldwide.

6/ When the '1984 MOU' became effective, after the CSCG-7 session held in Leningrad, Cospas-Sarsat Coordinating Group meetings were replaced by Cospas-Sarsat Steering Committee (CSSC) meetings. The change reflected the transition to an operational system with new management responsibilities for the Cospas-Sarsat partners.

7/ 1990 was the termination date of the second Cospas-Sarsat MOU signed in 1984.

"The delegation of Greece, taking into account that the cost and funding had not yet been resolved, expressed its concern with regard to the recommendation of the Sub-Committee to use the 406 MHz frequency for float-free EPIRBs in the FGMDSS. The delegation of Norway considered it premature to take a final decision on the choice of EPIRB frequencies until the questions regarding operational, technical and economic matters with respect to EPIRBs, both in the polar orbiting and in the geostationary satellite systems, had been resolved."

The MSC-51 report extracts quoted above are a good reflection of the dilemma that delegations to IMO were facing. On the one hand, Cospas-Sarsat was an operational system that had already demonstrated its value for distress alerting and its affordability to users. On the other hand, the system developed by space agencies had no firm, long-term funding basis, and the Cospas-Sarsat partners themselves could not explain how this unique cooperative space programme would be managed in the future. In short: who would pay for the service and who would be making the decisions? Although Cospas-Sarsat was still far from a mature operational system available worldwide, the institutional issue was the major concern of Administrations represented at IMO, including maritime Administrations from countries actively involved in the Cospas-Sarsat project.

The 1984 Memorandum of Understanding (MOU) between the Cospas-Sarsat partners, which entered into effect on 9 July 1985, stated that the MOU would remain in effect "*until the Parties agree to some other international framework, as appropriate, or until 31 December 1990, whichever comes first*". The stage had been set for the development of 'an appropriate international framework' and the clock started to run for the 1990 deadline.

The International Maritime Organisation Large Conference Room in London, UK
(IMO website: www.imo.org)

4.2 Highlights of the Negotiation of the International Cospas-Sarsat Programme Agreement

The 1984 Memorandum of Understanding between DND in Canada, CNES in France, NOAA in the United States and Morsviazsputnik in the USSR, clearly acknowledged that "*the development of an institutional framework at the international level, as appropriate, would be desirable*" to achieve the objective of "*the adoption of Cospas-Sarsat as the basis for an international operational global search and rescue satellite system*". However, the vagueness of the terms (*institutional framework at the international level, as appropriate)* actually reflected the absence of a clear consensus among the parties to the MOU on what could be considered an appropriate international institutional framework. If the need for a clear and solid international foundation of the Cospas-Sarsat System in a shape similar to the Inmarsat convention was obvious to most IMO members, it was not so obvious to some of the Cospas-Sarsat partners. Furthermore, each partner had to meet a variety of national objectives and policy constraints, often incompatible with the objectives or policies of the other partners.

4.2.1 National Views and Policies of the Cospas-Sarsat Partners

Canada

The Canadian Department of National Defence was the signatory to the 1984 MOU. However, Canada was subsequently represented in the meetings of the Cospas-Sarsat Steering Committee (CSSC) by the recently established National SAR Secretariat (NSS), responsible for coordinating the development of national SAR policy in Canada. Recognising the need for long-term commitments for the procurement of the Canadian SAR payloads carried on Sarsat satellites, DND had not, in the early going, expressed strong opinions concerning the required international framework. The Cospas-Sarsat system was seen in Canada as effective and a real safety improvement for all residents, workers and travellers in the far-north region of the country, an area covering about 10 million square kilometres, sparsely populated and quite inhospitable due to difficult terrain and extreme weather. The benefits of satellites for distress alerting had already been demonstrated by the first successful rescue accomplished with the help of Cospas-Sarsat location data, in 1982, in British Columbia.

Canada was the provider of the 121.5/243 MHz portion of the Sarsat payload and the first beneficiary of the alerting capabilities of Cospas-Sarsat. Therefore, selling the 121.5/243 MHz Sarsat mission to federal budget authorities in Ottawa was seen as an achievable objective, particularly if the system could be adopted internationally. However, with regard to the 121.5 MHz system which provided a response to urgent Canadian needs, the resolution of the institutional issue was not initially viewed as a prerequisite to the continuation of Canada's participation in the Sarsat team with the United States and France. This may perhaps be attributed to the fact that National Defence, as principally a military entity, had little interface with IMO as the body tasked with ensuring effective SAR response measures for international shipping. The assumption of responsibility by the NSS facilitated Canada's recognition of the value of an institutional framework, as a prerequisite to the inclusion of Cospas-Sarsat in the Global Maritime Distress and Safety System (GMDSS).

France

In France, CNES, the national space research centre, was the leading agency for the Sarsat project, specifically in charge of the development and procurement of the 406 MHz instruments carried on Sarsat satellites. The future of the 406 MHz system would clearly be compromised by an IMO refusal to accept it for the GMDSS. To CNES, international acceptance of the 406 MHz system was a priority.

The view of CNES management was also that the future operational satellite system for SAR should be entirely supported by its prime users, the national administrations responsible for SAR, which were the recipients of Cospas-Sarsat alert and location data. From CNES' point of view, long-term funding of France's contribution to the 406 MHz Sarsat payload would not be possible using CNES annual budget allowances, as the maintenance of an operational system was not consistent with its mandate for space system research and development. Furthermore, the development of a satellite system for distress alerting and locating was perceived as a promising technology, particularly the 406 MHz system developed with French expertise, but there was no commanding need at the national level that could make it a funding priority that France should assume alone.

French aeronautical and maritime administrations had been involved in the Cospas-Sarsat demonstration and evaluation phase from 1982 to 1984 and were represented at Cospas-Sarsat meetings. However, none of them wished to take responsibility for the follow-on operational phase, firstly because of their lack of expertise on space matters and also largely as a result of budgetary constraints and the scarcity or lack of specific resources for SAR. The French administrations already committed to providing SAR services over vast oceanic regions considered that receiving Cospas-Sarsat distress alerts located anywhere on the globe, and particularly the African continent, could mean a significant increase of their own operational burden, with no compensation in terms of new resources. As a consequence of these recurring cost and funding concerns, there was a common view among French stakeholders that, at a minimum, an intergovernmental agreement among all countries wishing to use the system would be needed to provide a form of cost sharing and to secure the long-term future of the satellite system.

USSR

The USSR position championed by Morsviazsputnik was clear. Cospas-Sarsat was effective, available to all and should be managed by an international organisation that would provide the required framework for the long-term international funding of the service. All feasible options could be considered; the international organisation could lease the satellite capacities provided by the Cospas-Sarsat partners through an appropriate agreement, or directly procure the required space system from the same partners and operate it under its own responsibility. To achieve this, Inmarsat was the obvious choice. It was the unique international organisation already established under the auspices of IMO to provide and operate a satellite system for maritime mobile communications and this system was expected to become a cornerstone of the FGMDSS. It was also the only international satellite organisation in which the USSR and other Eastern block countries were full members. Furthermore, Inmarsat was a satellite communications service provider that already had in place the appropriate financial and accounting expertise that would be required to organise and manage any shared funding mechanism for the Cospas-Sarsat distress alerting service.

In a document submitted to the 18th session of Inmarsat's Council in 1984 (document Council/18/47), the USSR acknowledged that the establishment of a Cospas-Sarsat Department within the existing organisational structure of Inmarsat would require some adjustments for the organisation's management of polar-orbiting satellite services, as well as the adoption of different funding principles for that specific portion of its space segment. However, from the USSR perspective, the only missing institutional instrument was an international funding and cost-sharing agreement between Administrations that would benefit from the satellite system, as actual alerting costs could not be charged to occasional users in distress. Funds should be channelled through States' contributions, according to a formula to be debated. To offset their financial contribution, States could in turn choose to charge registration fees for national EPIRB users or absorb these costs as government expenditures, actually funding the system through taxes.

If the Sarsat partners decided not to pursue the current cooperation, the USSR was prepared to provide the four satellites required, equipped with the desired SAR instruments, provided its expenditure could be compensated via a proper international funding mechanism.

United States

The views in the United States on the future of the Sarsat system were rather different from the above positions. The Reagan administration had made efforts to achieve budget savings and was eager to explore private sector interest in private operation of some areas of space technology. The Landsat Earth observation system, from their perspective, was a good example of a promising space technology sponsored by the government that should be considered for privatisation, possibly developing into a successful new industry. The United States also had reservations about the creation of new international organisations that could entail increased national costs and restrict national control. Moreover, the U.S. State Department was concerned that if the political profile of the Cospas-Sarsat programme was raised by a move to institutionalise it in a new intergovernmental organisation, politicians would target it as another example of uncontrolled government growth and bureaucratic expansion. Finally, to some U.S. political circles at the time, international cooperation with the USSR was not seen in a positive light[8] and raising the programme's political visibility could subject a successful technical endeavour to volatile political considerations.

> The Reaganauts had been in power nearly five years and the President had just gotten a mandate for another four. The Reaganauts were riding high; their philosophy or ideology (take your pick) had become conventional wisdom in Washington and much of the country. Reagan and his people firmly believed not only that government was dangerous, but, more important, that it was incompetent. "Bureaucrats" (they fairly spat the word out) could not manage complex programs and should not try.
>
> **Lisle Rose, U.S. State Department (retired), negotiator of the ICSPA**
> Quoted from "*How'd you like to go to Moscow - I wouldn't - Well you're going anyway*"

NOAA, the U.S. team leader and signatory to the '1984' MOU, had a long experience of international cooperation in the field of meteorology and specifically the collection and distribution of meteorological data from satellite systems. The exchange of meteorological data was performed on a voluntary basis and free of charge, under the auspices of the Coordination Group for Meteorological Satellites (CGMS) group, a structure rather similar to the Cospas-Sarsat Coordinating Group established under the initial Cospas-Sarsat MOU. In the view of NOAA-NESDIS[9] management at the time, the existing structure of cooperation was adequate and the newly established Cospas-Sarsat Steering Committee sufficient for the management of the

8/ On 8 March 1983, President Ronald Reagan had branded the USSR "*an evil empire*". Aeroflot could not land at U.S. airports and the USSR delegation to Cospas-Sarsat meetings had to fly to Canada before reaching Washington, D.C.

9/ NESDIS: National Environmental Satellite, Data and Information Service of NOAA.

operational satellite system. Because of the specific nature of distress alert data distribution and the fact that other countries would wish to be involved, the advantage of a permanent secretariat was acknowledged, but this function could be implemented without a new international body, either under the sponsorship of one of the parties or by an existing organisation.

Apart from the political concerns regarding East-West cooperation in space, two basic legal principles governed the U.S. policy concerning NOAA satellites:

- the NOAA polar weather satellite system or part of it, could not be placed in any circumstances under private, or foreign or international control;
- because of their public-good nature, these assets could not be used in any form of commercial application, hence sold or leased to a foreign entity, and consequently must be made available to users free of charge.

These principles are embedded in U.S. law, which declares:

51 U.S.C. § 60161 *Neither the President nor any other official of the government shall make any effort to lease, sell, or transfer to the private sector, commercialize, or in anyway dismantle any portion of the weather satellite system operated by the Department of Commerce or any successor agency.*

51 U.S.C. § 60162 *Regardless of any change in circumstances subsequent to the enactment of the Act, even if such change makes it appear to be in the national interest to commercialize weather satellites, neither the President nor any official shall take any action prohibited by section 60161 unless this title has first been repealed.*

These formal and non-negotiable principles, in clear opposition to the views of the USSR and of France, left little room for manoeuvre. NOAA's commitment to "*carry Sarsat instruments on the U.S. civil operational meteorological satellites on a permanent basis, or until such time as U.S. search and rescue mission agencies determine that their search and rescue satellite data requirements can be met otherwise*" [10] was certainly seen as a positive move in the right direction, but clearly not sufficient to alleviate the concerns expressed by the other Cospas-Sarsat partners or IMO member States.

4.2.2 Possible Models for the "Appropriate Institutional Framework"

The goals of the 1984 Toulouse Symposium on Satellite Aided Search and Rescue (see section 2.4.4) were to publicise the results of the D&E phase, promote the work done in preparation for the future operational system and make all parties aware of the expectations of other countries, administrations, system users and beacon manufacturers, as well as international organisations. The Symposium was also used to kick-off discussions among the partners on the institutional issue.

There was a clear reluctance of the U.S. party, voiced by NASA, to address the issue formally within the framework of the Cospas-Sarsat Coordinating Group, which had no mandate beyond the coordination of the demonstration and evaluation phase. Discussions were open on a second MOU

10/ Cospas/Sarsat - An Overview (T.E. McGunigal - NASA, USA; D.J. McKinnon - DND-DREO, Canada, G. Brachet - CNES, France, Y. Zurabov - Morsviazsputnik, USSR) in CNES Colloque, Toulouse 1984: Satellite Aided Search and Rescue- experimental results and operational prospects.

to prepare for a transition to the operational system, but tying the continuation of the cooperation and the future of the system to the resolution of the institutional issue was considered a risky path.

The Symposium, however, could not ignore the compelling calls by many stakeholders for Cospas-Sarsat to propose a long-term scheme for system funding and management, or a least to produce a road map for the development and implementation of 'an appropriate institutional framework'. Therefore, a paper was prepared at the request of Mr. Brachet, the CNES Director for Programmes and organiser of the Symposium, to review the possible institutional models, taking examples from existing organisations and analysing their suitability for the Cospas-Sarsat System[11]. After a review of the existing structure of Cospas-Sarsat cooperation and of the Inmarsat organisation, the paper briefly analysed the role, management structure, governance, and funding arrangements of organisations in the field of meteorology which could be used as models:

- CGMS (Coordination Group for Meteorological Satellites);
- WMO (World Meteorological Organisation);
- EUMETSAT (European Organization for the Exploitation of Meteorological Satellites).

In summary, the analysis concluded that none of the above models entirely satisfied the objectives of the SAR community or the needs of a global operational satellite system for SAR. CGMS, a voluntary non-binding coordination group of national technical agencies, was in nature similar to the structure proposed in the second Cospas-Sarsat MOU. This model did not appropriately address the long-term funding concerns of IMO. The WMO model, a UN specialised technical organisation was considered to be not adapted to the management of an operational satellite system for SAR, difficult to implement and probably costly to maintain. A structure along the UN specialised organisations' type would also raise coordination issues with IMO and ICAO due to possible duplication of competences on SAR matters. EUMETSAT, an intergovernmental organisation formed to operate European meteorological satellites, was probably the model closest to the desired institutional framework, but its implementation would require the ratification of a new intergovernmental agreement open to all States wishing to contribute to the system.

If existing organisations were to be considered for hosting the future institutional structure for Cospas-Sarsat, Inmarsat was perceived to be the best candidate, as the international satellite organisation was already serving IMO and the SAR community. However, a specific funding mechanism and the appropriate management structure for the SAR space segment and its operation would still be required. The major advantage of the Inmarsat option was that it did not entail the creation of a new international organisation and would avoid inevitable delays linked to the establishment of a new structure. It would also save the overhead costs of establishing and running a new independent structure.

No immediate conclusions could be derived from the Toulouse Symposium, except the clear preference of stakeholders for avoiding establishing a new costly international institution. The outline of the discussion had been drawn, and all actors were aware of its necessity.

The Toulouse symposium was followed by a two-day ad-hoc experts' meeting, held at CNES Headquarters in Paris (16 to 17 April 1984), with the aim of kicking off discussions among

11/ The Development of an Institutional Structure for the Future Global Satellite System for Search and Rescue (D. Levesque - CNES Sarsat Program Manager, France; K. Hodgkins - NOAA International Affairs, USA; P. Drover - DND, Canada) in CNES Colloque, Toulouse 1984: Satellite Aided Search and Rescue.

Cospas-Sarsat partners and share ideas regarding the creation of a permanent secretariat and the future institutional framework. Despite rather conflicting views and constraints highlighted in the discussion, a minimal understanding prevailed on a few basic principles that would guide future debates:

a) The future institutional arrangements should primarily concern the provision of the satellite constellation (i.e., the space segment of the system) and allow for some degree of participation by other countries providing receiving stations. However, the four partners, as current providers of the space segment, should retain a leadership in the management of the operational system, at least as long as they remained the major contributors to this system.

b) Options for cost sharing could be considered, particularly if small, dedicated satellites could be used to provide the service in the longer term. However, if payloads continued to be accommodated on NOAA's satellites, 'contributions in kind' would have to remain an option.

c) No new international body with independent legal status should be established, if avoidable, and the priority should be to use an existing international organisation to host the permanent secretariat required for the management of the operational Cospas-Sarsat system.

4.2.3 The Elusive Secretariat

During the three years that followed the signing of the second '1984' MOU at CSCG-7 in Leningrad (November 1984), from 1985 to 1987, the Cospas-Sarsat partners focussed intense activities in two main directions:

- transforming the Cospas-Sarsat system from a successful R&D project into a truly operational system available world-wide; and
- searching for a solution to the institutional issue, acceptable to all parties, which could meet the expectations of IMO member States and, specifically, address the expectations of those countries that were not party to the MOU, but were already actively participating in the operation of the system with their own ground receiving stations (Local User Terminals or LUTs).

These two goals translated into a number of ad-hoc meetings on the sidelines of the formal annual Cospas-Sarsat Steering Committee meeting enlarged to 'investigator countries' and observers, which was held in accordance with the provision of the 1984 MOU. No less than eight 'ad-hoc experts meetings' or 'special sessions' were held during these years to address the institutional issue and the secretariat [12].

12/
- 08-11/07/1985 Ad-hoc experts meeting - Suitland, Maryland, USA
- 21-22/10/1985 Informal meeting with Inmarsat, London, UK on Secretariat services
- 7-10/01/1986 Ad-hoc experts meeting - Moscow, USSR
- 28-30/04/1986 Ad-hoc experts meeting - Paris, France
- August 1986 Ad-hoc experts meeting - Annapolis, Maryland, USA
- 17-21/11/1986 Ad-hoc experts meeting - Moscow, USSR
- 09-20/02/1987 CSSC-3 session - Quebec City, Quebec, Canada
- 24-28/08/1987 CSSC special Session - Inmarsat, London, UK

Although consensus existed on the need for an international institutional framework and a permanent secretariat to help administer the future operational system, progress was almost non-existent during 1985 as the parties to the MOU gradually developed national positions that reflected the diverging expectations described above. The establishment of a permanent Cospas-Sarsat Secretariat was accepted by all as an urgent need revealed by the frustrating experiences of the hosts to formal CSSC meetings and the growing number of delegates and observers attending these meetings. Clearly, Cospas-Sarsat was becoming a victim of its own operational success. The organisation of meetings was becoming more complex. To limit travel requirements of large delegations, sessions would last up to two weeks, with a variety of technical, operational, as well as formal management meetings running in parallel with different participants. At a time when personal computers and the Internet were still in their infancy, reports, working documents and technical specifications had to be exchanged in paper form during meetings. The amount of copying was a true nightmare for the host. All this was extremely challenging to manage effectively with an improvised team from the host country and in premises rarely adequate for an international meeting with simultaneous interpretation in three languages.

The first meeting of the newly established Cospas-Sarsat Steering Committee was held in Seattle, USA (CSSC-1; 15 to 19 July 1985). It was preceded in the previous week by the last Sarsat-only meeting held in Victoria, BC, Canada (Sarsat Steering Group-11, no USSR participants). In Seattle, CSSC-1 ran beyond the five working days allowed and was concluded with the approval of the report around 03:00 in the morning of the sixth day. Pizzas were ordered in the middle of the night to feed delegates, most of whom had missed dinner.

The formal CSSC-2 meeting in Villefranche, France (21 to 25 April 1986), was preceded by three meeting days on technical and operational matters (16 to 18 April 1986), with representatives of the four partners plus 'investigator' and 'observer' countries. During the second week, technical, operational and policy matters were addressed in parallel, with 'plenary' meetings of all participants to coordinate the work. The long sequence of meeting days in Villefranche ended with the approval of the CSSC-2 report in the early morning on the day after the scheduled end of the session. As in Seattle, the preparation of a complete Summary of Discussions, its printing and distribution to a large number of participants, all of which was the responsibility of the host country, followed by the joint review and final approval of the document in the last plenary meeting, was an almost impossible challenge. The limits of improvised arrangements and untrained staff were obvious. For the host country, in addition to gruelling management problems, the cost of the CSSC meeting was growing out of control.

The proposed temporary solution to the secretariat issue, in the shape of a small dedicated secretariat formed with seconded staff from each party and hosted by one of the leading organisations, never took off. It was repeatedly postponed until 1987, when a new inter-governmental agreement began to take shape among the four Cospas-Sarsat Parties. The institutional issue did cast a long shadow on the Cospas-Sarsat System, which made some urgent decisions difficult to reach.

4.2.4 The Long Road to a Consensus among Partners

July 1985 - Suitland, Maryland, USA

At the ad-hoc experts' meeting in Suitland, MD, USA (8 to 11 July 1985), the need for a new formal agreement was acknowledged by the four partners and options for the Secretariat were reviewed. France repeated its proposal to host it on a temporary basis, with seconded staff from the Cospas-Sarsat partners. The proposal was acceptable to the United States and Canada, but the USSR insisted on a Secretariat provided by Inmarsat, probably concerned that, if no solution was found to the institutional matter, the Sarsat partners would choose to maintain the *status quo* and the temporary solution would become permanent.

Regarding financial compensations for the provision of the space segment of the System, the United States agreed that both in-kind and financial contributions would be acceptable, opening the door for possible financial compensations by other States for the USSR Cospas satellites and the Canadian and French Sarsat instruments, but maintaining the U.S. NOAA satellites out of the financial scheme. The USSR, again concerned by the untidiness of a proposal which would make the USSR and possibly two other partners look for financial compensation while the United States refused them, insisted on the discussion of a leasing agreement with Inmarsat for the complete space segment. The United States objected, pointing to the prohibition stated in U.S. law.

No breakthrough was achieved, each party holding its position. At the CSSC-1 session in Seattle, USA (15 to 19 July 1985), the partners agreed:

- "*that the system was ready for operational use;*
- *to explore further the feasibility of an inter-governmental agreement and mechanisms to allow for contributions by other countries;*
- *to pursue discussions with Inmarsat on the establishment of a secretariat; and*
- *on the importance of obtaining international approval for the system, specifically its acceptance as part of the FGMDSS".*

At first unconvinced of the need for a new institutional arrangement, NOAA had made a concession to its partners, but this was still quite short of Morsviazsputnik and CNES expectations. The above agreements were publicised at the IMO MSC-52 session held in January 1986, together with estimates concerning the annual costs for maintaining the space segment (10 M.US$/year) and the expected price range of operational 406 MHz EPIRBs (500 to 1,000 US$), to support IMO's discussions on the choice of the satellite EPIRB frequency. This show of progress among the partners was not sufficient to convince IMO delegates to adopt 406 MHz as the single frequency for satellite EPIRBs.

October 1985, London, UK

At a meeting with Inmarsat's Directorate in London in October 1985, the principle of a Secretariat provided by Inmarsat under a contract with the Cospas-Sarsat leading agencies was informally agreed among participants. Inmarsat was tasked with preparing a draft Understanding to be signed by the four Cospas-Sarsat partners and Inmarsat, outlining the contractual relationship for the provision of secretariat services. Inmarsat was also asked to prepare cost estimates and a scope of services that would be requested from the Secretariat.

January 1986, Moscow, USSR

An 'ad-hoc experts meeting' in Moscow in January 1986, held close to the Red Square, allowed the four partners' and Inmarsat's representatives to further progress the preparation of the secretariat agreement. A tentative schedule for the establishment of the Cospas-Sarsat Secretariat in 1987 was considered.

The other major discussion topics were the inter-governmental agreement and the basic questions concerning funding mechanisms and a possible management structure.

The USSR representative, Yuri Zurabov, insisted that the most expedient way to satisfy requirements for funding, system continuity and international recognition was a straightforward integration into the Inmarsat organisation, which would most certainly alleviate any concern of IMO and ICAO regarding the use of the 406 MHz frequency. Robert Dagenais, the Canadian representative noted that the U.S. legislation made the proposed integration into Inmarsat almost impossible and Canada was developing proposals for a continuation of the system under the assumption that a new inter-governmental agreement would be prepared to address management and funding issues. The French representative, Daniel Levesque, outlined CNES' difficulty in continuing cooperation within the existing framework beyond 1994 and noted that the French administration considered that changes to the Inmarsat Convention would be necessary to implement the USSR proposal, which might create additional problems. Therefore, France's preferred approach was to develop a new international instrument as soon as possible. James Bailey, the United States representative, reiterated the U.S. position excluding the transfer of any portion of NOAA satellite system to any entity, whether through a sale or leasing agreement. Mr. Bailey also confirmed that the United States did not rule out the establishment of a Cospas-Sarsat Secretariat at Inmarsat.

No real progress on the institutional issue had been achieved, but all parties reaffirmed their intent to support long-term System operation and Canada announced their intention to prepare the outline of a possible inter-governmental agreement.

April 1986, Villefranche and Paris, France

The next opportunity for progress was the CSSC-2 session in Villefranche, France (21 to 25 April 1986). However, before the Villefranche meeting, a move by Morsviazsputnik's Director General, Yuri Atserov, to secure a recommendation at IMO in favour of the integration of Cospas-Sarsat into the Inmarsat system provoked a firm response by the U.S. State Department, who forbade NOAA to follow up with the option of a secretariat at Inmarsat. At Villefranche, the United States refusal to pursue the Inmarsat option for the secretariat, conveyed to CSSC-2 by NOAA's Representative, James Bailey, triggered an equally firm response from Morsviazsputnik's Deputy Director General, Yuri Zurabov, who ostentatiously began to read a newspaper, ignoring the on-going discussion. Mr. Zurabov finally requested a break, considering that further discussion of the issue was pointless.

After an afternoon of one-to-one consultations around coffee tables under the Mediterranean sun, the decision was made to postpone any discussion of the issue until the following week. An 'ad-hoc meeting of experts' of the four Cospas-Sarsat partners was already scheduled at CNES Headquarters in Paris, starting on the following Monday (28 to 30 April 1986). Although there was little hope of breaking the deadlock, it was urgent to continue the discussion and review fall-back options. Despite the serious spat, the CSSC-2 session resumed the next day with the remaining agenda items.

In Paris the mood was rather sombre and every participant could feel the tension. No real progress could be achieved in the current context, but all delegates agreed that further effort should be made to patch differences and build on whatever common basis could be found. A decision was made to plan for another meeting in Annapolis, Maryland, USA in August 1986. In the mean time participants would consult with IMO on the feasibility of a secretariat under the auspices of that organisation. The four partners were also invited to prepare proposals for the 'appropriate international framework'.

CSSC-2 Meeting in Villefranche, France (1986)
Signing the Summary of Discussions and the Data Distribution Plan, from left to right:
Sitting: Yuri Zurabov, Jim Bailey, Daniel Levesque, Robert Dagenais
Standing: Arnold Selivanov, Fred Flatow, Daniel Ludwig, Jim Robinson

Photos courtesy of the International Cospas-Sarsat Programme

All along during this sequence, Norway and the UK, officially participating as 'investigator countries' that had invested significant efforts in the demonstration phase and resolutely supported the Cospas-Sarsat System in international circles, had been kept informed of progress or, rather, the lack of an actual break-through. Mr. Ken Anderson for the UK and Mr. A. Rundberget for Norway had joined the four partners in Paris on the last day of the meeting. They reiterated the need for a solid international framework addressing long-term funding to achieve the desired international recognition and urged the parties to show actual progress before the end of the year as the window of opportunity to secure acceptance for Cospas-Sarsat at IMO could soon be closed.

August 1986 - Annapolis, Maryland, USA

By August 1986, the United States' reluctance to discuss a secretariat at Inmarsat had partially eased, and the message passed to the USSR was that the matter could be reconsidered if sufficient legal guaranties were provided precluding any move to integrate the Cospas-Sarsat System to the Inmarsat organisation. After review of other options for the Secretariat, the Inmarsat solution appeared to be the most practical of all possible solutions.

However, in Annapolis no noticeable progress was achieved regarding the institutional issue despite the very pleasant setting of the venue at the U.S. Naval Academy. Options and national positions were reviewed, showing little change, except that the path of a new inter-governmental agreement was recognised as the only possible way forward. An additional meeting was convened in November 1986 in Moscow, USSR.

November 1986 - Moscow, USSR

Each of the four partners came to the Moscow Ad-hoc Experts Meeting (17 to 21 November 1986) with a carefully stated national position. Preliminary drafts of a possible intergovernmental agreement had been prepared by the USSR and the United States, based on the general principles outlined in Annapolis. In addition, prior to the Moscow meeting, a meeting of the Canadian and U.S. representatives with Inmarsat in London had revived the plans for a secretariat hosted by Inmarsat, including the draft Understanding initiated in 1985.

The remaining issues regarding the establishment of the secretariat were rapidly dealt with and consideration given to a detailed implementation schedule, including staff positions and procedure for staff recruitment by Inmarsat. The signing of the Understanding was planned at the following CSSC meeting (CSSC-3) to be held in Canada in February 1987.

As expected, the meeting moved on to the major discussion topic: the intergovernmental agreement. Although different on a number of ancillary matters, the draft documents submitted by the USSR and the United States were converging on major topics:

- the existing system provided by Canada, France, the USSR and the United States would form the basis of the future Cospas-Sarsat System;
- the agreement would be exclusively among space segment providers and space segment assets would remain under the exclusive control of the provider;
- additional contributions in the form of space hardware could be accepted; however, to ensure the overall consistency of the system, such contributions would be subject to approval of a council consisting of representatives of the space segment providers; and
- ground segment providers (countries providing and operating ground receiving stations) and other contributors could be formally associated and participate in the management of the system in ways to be determined.

Participation by other countries in the form of financial contributions was explicitly provided for in the USSR draft. It was not excluded in the U.S. draft, but remained hazy. Such funding would be on a voluntary basis and distress alerts would be provided to all States free of charge.

These principles were acceptable to Canada and France. However, France, with the support of the USSR delegation, insisted on establishing a specific mechanism for collecting financial contributions, which was clearly absent from the U.S. proposal. Although a compromise could be built in theory, if the United States and Canada stayed out of a global funding arrangement whereby other countries would be invited to contribute financially, France and the USSR would actually be left to fight a difficult and uncertain battle to secure other countries' contributions. The complexities of a two-tier approach proposed by France were obvious. If space hardware procurement did not follow the usual open market competitive approach, a specific methodology would be required to assess the value of space hardware contributions and decide on their suitability. Furthermore, any financial compensation scheme would be difficult to organise, manage and impose internationally. To close the debate, the United States announced that, if

France or Canada could not continue the provision of the Sarsat SAR payloads for integration into NOAA's spacecraft, the United States would consider providing these payloads themselves, thus matching the level of the USSR contribution to the system.

To keep the door open for new contributors to the space segment and the complexities of managing 'financial contributions' at a reasonable level, it was agreed that such contribution should be in the form of at least one 'basic unit' of the space segment; that is, a satellite platform or a SAR instrument to be carried on a polar orbiting spacecraft. A group of countries could propose to contribute one or several space segment units, such as an additional satellite fully equipped with the required instruments for processing 121.5 MHz and 406 MHz distress beacon transmissions. Subject to approval of the proposed contribution by the existing Parties to the intergovernmental agreement (the current providers of the space segment), they would accede to the Agreement to become a full Party. In practical terms, the scheme for additional contributions reproduced the existing arrangements, actually requiring 'financial' contributions to take the form of contributions 'in kind' acceptable to the existing partners. Rather than encouraging other States to contribute, the proposed scheme seemed to build safeguards against undesired additions to the system.

At the end of the Moscow meeting, the outline of a new intergovernmental agreement had been adopted. The United States and Canada had confirmed that they were prepared to continue with their contribution to the space segment in the long term. The representatives of the USSR and France agreed to report to their governments and further investigate whether their contributions could be continued 'in kind' in a long-term perspective. The provision by other countries, or a group of countries, of portions or 'units' of the space segment remained in theory open, but in practical terms difficult to implement and therefore rather unlikely.

In France, CNES' reluctance to commit to a long-term operational programme was eased by the unambiguous support of the French Ministry of Foreign Affairs, which took a positive view of France's contribution to a unique humanitarian international space endeavour and called for CNES to continue the French contribution. CNES Director General, Frederic d'Allest, decided that CNES should continue as the French leader of the project and accept the corresponding financial commitment. With a similar view of the international prestige attached to a continuous involvement and its role as primary contributor to the Cospas-Sarsat system, the USSR also decided to follow along and commit to the long-term provision of two satellites with 406 MHz and 121.5 MHz instruments.

How Did Cospas-Sarsat Survive?

First, it was a relatively inexpensive, low political visibility project. Second, it was humanitarian in character; when it did make headlines, they were about lives being saved, not about cost overruns, schedule slips or transfer of advanced technology from West to East. Third, the USA and USSR were not the only nations involved - the project's multilateral character meant that a number of other countries had invested in, and were deriving benefits from, the system. Their national and regional search and rescue capabilities would have been seriously compromised if either the USA or the USSR had withdrawn their satellites from the system. For these reasons political judgements were made in Washington and in Moscow that continuation of this modest collaboration served US and Soviet national interests better than cutting it off.

Jennifer Clapp, International Affairs, NOAA
(*Space Policy*, 1995)

4.2.5 The Fast Track Negotiation and Signing of the International Cospas-Sarsat Programme Agreement

February 1987 - Quebec City, Quebec, Canada

With the deadlock now broken, detailed negotiations of the International Cospas-Sarsat Programme Agreement (ICSPA) would then proceed extremely fast. At the CSSC-3 meeting (9 to 20 February 1987) in Quebec City, QC, Canada, a draft text of the inter-governmental agreement was adopted by the representatives of the four partners, seconded by representatives of their Foreign Affairs Departments. The exceptionally bitter cold of the season (even the Norwegian delegation admitted to never having experienced these kinds of cold temperatures) did not slow the pace of the meeting, which also addressed other urgent technical and operational issues.

A decision was made to proceed as soon as possible with the establishment of the Cospas-Sarsat Secretariat at Inmarsat and the contract with the four co-operating agencies, DND, CNES, NOAA and Morsviazsputnik, was finalised. Inmarsat was tasked with the selection of the Head of Secretariat plus one technical officer among candidates presented by the four partners, with the caveat that Inmarsat's selection should be vetted by them *in fine*.

The discussion of the Secretariat staff positions was an interesting illustration of the different perspectives of the Cospas-Sarsat partners and Inmarsat regarding the Secretariat arrangement. Inmarsat proposed a secretariat with about five staff members at a fairly junior level. The Cospas-Sarsat Secretariat would just be a 'secretariat' fully integrated to the Inmarsat administrative structure, with limited autonomy and closely monitored by Inmarsat's Directorate. On the other hand, all Cospas-Sarsat Parties wished to retain close control of the Secretariat actions on a daily basis. The Head of Secretariat should therefore maintain a close liaison with the Cospas-Sarsat Parties and enjoy a large autonomy within the Inmarsat structure, directly reporting to the Director General. After some discussion a compromise was reached. The position level of the future Head of Secretariat was raised to the highest position for 'professional' staff, with Inmarsat's Director of Administration as the direct reporting authority.

August 1987 and November 1987 - Inmarsat, London, UK

A special session of the CSSC was convened at Inmarsat Headquarters, London from 24 to 28 August 1987 under the Chairmanship of J.R. Hodgson (Canada). Dr. O. Lundberg, Director General of Inmarsat, welcomed the Cospas-Sarsat partners for the first of a long series of meetings to be held in London. The newly appointed Head of Secretariat, Daniel Levesque from France, assisted the Chairman. Mr. Levesque, formerly at CNES, had been the leader of the French delegation to Coordinating Group and Steering Committee meetings since 1983, and to the 'ad-hoc experts meetings' convened from 1985.

Besides urgent administrative arrangements to be made between the Cospas-Sarsat partners and Inmarsat, the meeting was entirely devoted to the discussion of the draft intergovernmental agreement. The Heads of delegations (J.R. Hodgson for Canada, Isaac Revah for France, Jim Bailey for the United States and Yuri Zurabov for the USSR) were assisted by career diplomats, M.M.K. Nash - Canada, Olivier de Saint Lager - France, Lisle Rose - USA and Ludmilla Abramova - USSR, who provided invaluable advice during the preparation of the draft agreement. With a few exceptions, delegations to the numerous ad-hoc meetings had been remarkably stable. This probably explains how in spite of hot discussions and conflicting views, trust and understanding gradually developed among participants, allowing a swift conclusion of the work after a basis of consensus was reached. In addition to those mentioned above, the contributions of a number of individuals also deserve to be recognised. They were: Jennifer Clapp and Ken Hodgkins from NOAA, Konstantin Ivanov from Morsviazsputnik, Daniel Ludwig and Pierre-Henri Pisani from CNES and Robert Dagenais from NSS.

The enthusiasm of participants at the London meeting was obvious. However, probably because of a desire for rapid conclusion by some delegates, interesting moments flared up early in the discussions. At the start of the formal session addressing the draft intergovernmental agreement, the U.S. State Department representative, aiming clearly at a request from the French Foreign Affairs Ministry representative to re-examine some text tentatively agreed in Quebec City, expressed 'regrets' that newly appointed delegates unfamiliar with the negotiation process had to be brought up to speed, which actually slowed down the discussion. The new French delegate quickly returned the compliment, pointing to the undiplomatic attitude of the U.S. diplomat and noting that, although the draft English text was certainly good, there might be room for improvements.

The U.S. delegation had cleared the draft Agreement with the U.S. State Department and was reluctant to revisit preliminary English text tentatively agreed in Quebec City. Any changes would have to be explained and cleared again with the State Department. France, the USSR and Canada, aware of the importance of the document being discussed for the future of the programme, wished to carefully review, and where possible improve, the draft text prepared in Quebec City. Major issues also had to be finalised, particularly with regard to the possible future evolution of the System, the rules for accession of other parties to the agreement, and the role and status of 'non-Party participants' in the Programme, those States that already provided ground receiving stations (Local User Terminals or LUTs) or had already declared their intent to do so, and those States that wished to participate in the management of the system, but did not wish to procure and operate a LUT.

At the conclusion of the meeting held at Inmarsat Headquarters near Euston station in London, which would become the regular venue for most Cospas-Sarsat meetings in years to come, a draft English version of the International Cospas-Sarsat Programme Agreement (the ICSPA) had been tentatively agreed by the four partners. It was still incomplete, but all major items had been cleared and agreed. At last the permanent Secretariat was in operation, although still with a single member of staff. The breakthrough was quickly publicised to IMO and ICAO, but the draft text of the ICSPA, under formal review by the four parties, was not released. Translation in the French and Russian languages had yet to be prepared, reviewed and formally agreed. There was great hope, but no guarantee yet of final success.

The devil always hides in the details, and translations often reveal ambiguities that go unnoticed in a single language version. Further fine tuning of the English text and harmonisation of the French and Russian language versions were accomplished during subsequent months and at the fourth Cospas-Sarsat Steering Committee meeting held in London in November 1987.

In the end I had the feeling that the steadily strengthening loyalties of each party to the CSSC team, and the collective, mutual pride that emerged among all the players in what we were striving to achieve, was a critical factor in carrying the project through to its final successful outcome.

Dick Hodgson, Executive Director, National Search and Rescue Secretariat, Canada (1986-1988)

The CSSC-4 meeting (2 to 13 November 1987), reproduced the mild chaos of previous CSSC meetings with technical, operational, system exercise, plenary and 'restricted' sessions running in sequence or in parallel with a variety of participants, or convened on a short-notice decision by the Chair. The meeting was attended by delegations of the four parties to the draft Agreement, Canada, France, United States, and USSR, plus the United Kingdom and Norway with the status of 'investigator country'. In addition, representatives from Chile, Denmark, India, Italy, Japan, Sweden and Switzerland attended as observers from 10 November 1988. Representatives of IMO, ICAO and Inmarsat also attended the plenary session. Seven other countries had indicated their interest in the System and had been invited, but fortunately did not attend CSSC-4.

A second officer had joined the Secretariat: Jim King from Canada, formerly with the DOC. Jenny Ray, Inmarsat's Conference Officer with considerable experience of this type of gathering, also helped organise and administer the meeting. However, Cospas-Sarsat still had to create the organisation and procedures required to run smooth and efficient international meetings.

June-July 1988 - Paris, France

The decision was made in London to sign the International Cospas-Sarsat Programme Agreement at the earliest opportunity, possibly at a special meeting of the CSSC in April 1988 or, alternatively, during a USA-USSR summit meeting scheduled in May 1988 in Moscow. However, these plans were overly optimistic as they underestimated the time required for governmental review of new international agreements. At the CSSC-5 meeting in April 1988, with attendance limited to the four parties to the 1984 MOU, further fine tuning of the three language versions of the Agreement was still required. However, progress would be made on preparation for the signing, the choice of depositaries of the Agreement and the procedure for other States' association with the Programme. The Secretary General of the International Civil Aviation Organization (ICAO), headquartered in Montreal, Canada, and the Secretary-General of the International Maritime organisation (IMO) based in London, UK, had agreed to act as joint Depositaries of the International Cospas-Sarsat Programme Agreement. Rules of procedure for the future Council of the Programme were drafted. A new meeting was scheduled in July 1988 in Paris at the invitation of CNES who, on behalf of France's Foreign Affairs Ministry, offered to host the signing ceremony at the Quai d'Orsay. The Cospas-Sarsat Secretariat was tasked with preparing seven original copies of the three language versions of the Agreement.

The meeting in Paris, France was held as planned from 27 June to 1 July 1988, culminating with the signing ceremony of the Agreement on 1 July 1988 with the expected solemnity in the grand 'Salon de l'Horloge' at the Quai d'Orsay in Paris. Appropriate speeches by the signatories highlighted the exceptional nature of the humanitarian project, which was now made available to all countries, and the remarkable spirit of cooperation that prevailed among the four partners.

The climax of years of efforts by numerous dedicated delegates was nevertheless preceded by the customary moment of secretariat panic, when alterations to the Russian language version of the Agreement were requested by the representative of the USSR Ministry of Foreign Affairs, who was unsatisfied with the quality of the Russian version. Although minor, these changes presented a delicate logistical problem, as each original copy of the Agreement had been printed on special and expensive 'treaty' paper provided by France. Spare sheets were available, but printing of the text could only be accomplished in London using the same word processor for the Russian language that had been used originally, to remain consistent with the unchanged portion of the original prints of the document. The day before the signing ceremony, corrections in Russian language were passed to London, printed in the exact same format on plain paper, and carried to Paris on the last flight of the day by Jim King for transfer onto the special treaty paper using a photocopier at CNES Headquarters. During the night, replacement pages were hastily inserted and the original copies rebound, thus avoiding a last-minute diplomatic incident.

The minor incident reported above illustrates a specific aspect of the negotiation concerning the International Cospas-Sarsat Programme Agreement. Despite the exceptional character of this international East-West cooperation on a humanitarian satellite system, the whole project was intentionally kept at the lowest possible profile to avoid political controversies. The negotiation of the Agreement was delegated to junior or lower rank diplomats. Lisle Rose, from the U.S. State Department, reported that "*Just a few people got concerned, […] my Deputy Office Director said: In effect, it kind of went under the radar, really our Office Director or even Deputy Assistant Secretary of State should have negotiated it"*. The late reaction of the USSR Ministry of Foreign Affairs' representative can be seen in the same light. Cospas-Sarsat was politically good-to-have and was regularly mentioned in joint statements after East-West political summits, but it was a modest, low cost space programme with no obvious strategic significance. It did not raise awareness and scrutiny at the higher levels of government. Considering the political context of East-West relations at the time, this may have been a benefit, as the final negotiation, translation, review and approval of the text of this new international agreement were accomplished within less than 18 months (February 1987 to 1 July 1988). This, in itself, can be seen as an unusual achievement.

Photo courtesy of the International Cospas-Sarsat Programme

Fire on Board

At approximately 11:42 local Newfoundland time on 14 April 2008, JRCC Halifax was made aware that COSPAS-SARSAT had detected an unregistered Canadian 406 EPIRB. One position was off the east coast of Newfoundland and a mirror position in James Bay area. Since the James Bay area was frozen, search efforts were concentrated off Newfoundland where there was an active fishing fleet.

A Canadian Coast Guard Ship and helicopter and CF Cormorant were tasked to proceed to the area to investigate. […] At 13:00 COSPAS-SARSAT formed a composite position approximately 20 nautical miles east of the original position. Resources were re-tasked to the new COSPAS-SARSAT position and shortly thereafter the Cormorant observed smoke on the horizon.

Upon arrival on scene, the helicopter saw the fishing vessel Lacey May one nautical mile away from the COSPAS-SARSAT composite position. The vessel was engulfed in flames and five sailors were standing on a nearby ice flow, EPIRB in hand.

A fire had started in the engine room and the Captain ordered the evacuation into the work boat before any voice radio distress was sent. The Cormorant hoisted the uninjured sailors off the ice flow and proceeded to Gander, NL, 90 nautical miles away.

Reported by Capt. Marco Plasse,
RCC controller at Halifax MRCC - Canada.

4.3 The International Cospas-Sarsat Programme Agreement (ICSPA)

The first objective of the ICSPA was to ensure the continuity of the Cospas-Sarsat System, specifically the funding, deployment and operation of its space segment, which initially consisted of low-altitude polar orbiting satellites (the LEO system). As shown in section 4.1, establishing the system on an intergovernmental basis rather than a mere inter-agency understanding, was a prerequisite to its international acceptance and its inclusion as part of the Future Global Maritime Distress and Safety System (FGMDSS).

National objectives and policy constraints of the four parties to the ICSPA (Canada, France, the United States and the USSR) were reviewed in section 4.2. These national objectives and policy constraints led to the creation of an original institutional structure: the "*International Cospas-Sarsat Programme*". Decades after its entry into force, the Agreement remains the cornerstone of the Programme. In hindsight, this foundation showed remarkable flexibility, allowing the Council of the Programme to effectively manage major System evolutions and adapt its operation to a fast-changing environment.

The ICSPA contains 20 Articles. This section summarises the principles that guided its development and explores their impact on the management of the cooperative Programme.

4.3.1 Basic Principles of the International Cospas-Sarsat Programme Agreement [13]

Having noted the success of the implementation of the Cospas-Sarsat System accomplished under the cooperative framework of the 1984 Memorandum of Understanding (MOU), the preamble of the ICSPA 'recognises' that "*it is therefore desirable to operate the Cospas-Sarsat System […] so as to endeavour to provide long term alert and location services in support of search and rescue and provide access to the System to all States, on a non-discriminatory basis and free of charge for the end-user in distress.*"

These basic objectives of the Agreement are further detailed in Article 2 'Purpose of the Agreement', which specifically states the intent of the Parties to the Agreement to "*support the objectives of IMO and ICAO concerning SAR*".

System Definition

Article 3 is a description of the 'initial System': the polar orbiting satellite system comprising four LEO satellites with 121.5 MHz and 406 MHz SAR payloads, ground receiving stations (LUTs), Mission Control Centres (MCCs) and distress beacons, including 121.5 MHz and 406 MHz beacon types. By defining the Cospas-Sarsat system (the 'System') as a space segment, a ground segment and the distress beacons operating in this System, Article 3 also establishes the boundaries of the System and the scope of the services provided. The System definition effectively delineates the extent of the domain where the Parties to the ICSPA accept responsibility: from the characteristics of distress beacon radio-emissions, the relay of beacon transmissions via LEO satellites and the processing of these radio signals on the ground, up to the transmission of distress alert messages by Cospas-Sarsat MCCs to the appropriate Rescue Coordination Centre (RCC).

13/ The complete text of the ICSPA in three language versions (English, French and Russian) is available from the Cospas-Sarsat official website (http://www.cospas-sarsat.int/en/documents-pro/system-documents) under the reference C/S P.001.

RCC operations and the processing of Cospas-Sarsat distress alerts by SAR authorities remain outside the Cospas-Sarsat mandate. For distress beacons, the System boundary is more difficult to delineate. Although Cospas-Sarsat has sole competency, in coordination with international organisations such as ITU, IMO and ICAO, to define the radio signal characteristics at 406 MHz that will ensure successful operation with the System, it does not control the deployment of beacons nor the environmental requirements that these beacons should meet. Furthermore, Cospas-Sarsat is actually dependent on national Administrations to enforce its own requirements regarding the 406 MHz radio signal emitted by the beacons.

With regard to 121.5 MHz beacons, Cospas-Sarsat has no control at all. The ICSPA can only recommend that States ensure accepted beacon models are conforming to existing ITU transmission requirements.

Having set the contour of the System that the Parties are committed to maintain, Article 3 provides that the System can be enhanced as decided by the Council of the Programme. This short provision actually gave the Council full flexibility when the need to modify the System was recognised. This was the case when geostationary satellite capabilities were formally added to complement the LEO system in 1998. No changes to the ICSPA were required. The Secretariat notified the Depositaries of the Agreement, on behalf of the Cospas-Sarsat Council, that GEO capabilities had been added to the System.

Parties' Responsibilities

The implementation of the Cospas-Sarsat Programme (*the Programme*) is the responsibility of Cooperating Agencies designated by the Parties (Article 4). The ICSPA then details the responsibilities of the Parties (Article 5) and specifically each Party's contribution to the Space Segment. These contributions are described as 'basic units' of the System, a basic unit consisting of a satellite platform, or a 121.5 MHz repeater, or a 406 MHz receiver-processor and memory unit.

The space segment of the initial System "*under normal operating conditions*" (except for satellite platform and SAR payload failures) is composed of a minimum of four polar-orbiting satellites, comprising 12 'basic units'. According to Article 5, the USSR commits to provide the six 'units' of the nominal Cospas system comprising two polar-orbiting satellite platforms, two 121.5 MHz repeaters and two 406 MHz receiver-processor-memory units. The United States provides two polar-orbiting satellite platforms, Canada provides two 121.5 MHz repeaters and France two 406 MHz receiver-processor-memory units, all integrated to form the Sarsat system. The contribution of each Party may change, but a Party must contribute at least one basic unit, or cease to be a Party to the Agreement. This rule is also applicable when considering the possible accession of other States to the ICSPA (Article 16). Other States wishing to accede to the Agreement as a Party would have to make contributions which could be either replacements for existing basic units of the initial System, or additional units. Any new contribution, whether a replacement or an additional unit, would remain subject to the approval of the Parties to the ICSPA who collectively assume responsibility for the management of the System and decide on required or desirable enhancements.

Per Article 5 a Party providing a satellite platform is responsible for its operation in accordance with agreed technical and operational requirements. All Parties also agree to "*endeavour to deliver relevant Cospas-Sarsat alert and location data to appropriate search and rescue authorities [...]*".

No details are given as to how this should be done, the matter being left to the Council established under Article 7. The Parties only commit to "*coordinate System activities with [search and rescue] authorities.*"

Common Costs and Financial Matters

The following Articles of the ICSPA address basic management issues: financial matters (Article 6) and the administrative structure of the Programme (Articles 7 to 10).

As the Parties to the Agreement are the sole providers of System 'units' and retain full responsibility for the operation and management of their contribution to the Space Segment, Article 6 does not have to address financial contributions for the space segment. Similarly, ground segment equipment contributions remain the responsibility of Parties or Ground Segment Providers under the provisions of Article 11. After recalling that each Party is responsible for funding its own contribution and that the use of the System (the transmission and reception of distress alert data through the System) is provided free of charge to all States, Article 6 addresses the only item open for direct financial contributions: the "*common costs*"[14] incurred for the organisation, administration and coordination of the Programme. Article 6 states that common costs shall be shared equally among the Parties, but the Article also opens the possibility for other States to contribute financially towards these common costs, if they choose to actively participate in the management of the System.

Programme Administration and Management

The administrative structure of the Programme (Article 7) consists of a Council composed of one representative of each Party who take all decisions unanimously and a Secretariat designated as "*the permanent administrative organ of the Programme*", which "*assists the Council in the management of its functions*". The Council has broad authority on all aspects of the Programme, including the definition of policies, relations with other States and international organisations, the establishment of subsidiary organs as required to implement the Agreement and address technical, operational or administrative matters, and the direction of the Secretariat.

The Secretariat, managed by a 'Head of Secretariat' appointed by the Council, is placed entirely under the authority of the Council. No guidance is given in the Agreement on how the Secretariat should be established. Although the ICSPA is clearly inter-governmental in nature and enjoys the force of an international agreement, it does not ascribe an independent legal personality to the new Programme or its Secretariat. As a consequence, the Secretariat must either operate under the legal personality of an existing entity, or receive the required legal status from another instrument. This arrangement clearly reflects the low-profile policy of the negotiators of the ICSPA in 1988 and the stated desire of the Parties to avoid the set-up costs of a new permanent international structure. The implied assumption is that the secretariat function will be fulfilled through an existing international organisation.

As reported in section 4.2, a Cospas-Sarsat Secretariat was established by Inmarsat in August 1987, prior to the signing of the ICSPA, under a contractual arrangement with the four Cospas-Sarsat partners, signatories to the 1984 MOU. After the ICSPA entered into force in August 1988,

14/ The Programme 'common costs' are essentially administrative costs, including the Secretariat operation and official Cospas-Sarsat meetings. They exclude all System procurement, installation and operation costs.

only minor changes to the Understanding with Inmarsat were required to continue with the existing Secretariat. The same partners, now designated as the Cooperating Agencies of the Parties to the ICSPA, continued as signatories of the new Understanding. When the Parties decided in 2005 to establish the Secretariat as an independent legal entity, a new and separate inter-governmental agreement was required to provide a legal status to the Programme and its Secretariat (see section 4.4).

Ground Segment Providers and User States

The Cospas-Sarsat System described in Article 3 of the ICSPA is not closed to space segment contributions by other States. Article 16 clearly envisages the possibility of other States acceding to the status of a Party by providing additional 'basic units' of the space segment, subject to approval of existing Parties. This restriction is meant to ensure that the integrity and coherence of the System is maintained.

Regarding ground segment equipment and distress beacons, the System is far more open by design. Both the preamble to the ICSPA and its Article 2 declare that Cospas-Sarsat alerting services are provided "*to all States on a non-discriminatory basis*", which implies that anyone can use a distress beacon that operates through the System and that all States can receive the relevant distress alerts produced by the System; that is, the alerts located in their area of SAR responsibility.

Article 11 addresses the issue of relations between Cospas-Sarsat Parties and States that are not a Party to the ICSPA, but choose to operate a LUT and an MCC. These States are designated 'Ground Segment Providers'. The System design allows unrestricted access to the satellite SAR channels that are broadcast on a continuous basis at 1544.5 MHz, and any LUT operator can produce location data from beacon signals relayed by the satellite instruments. However, in practical terms, the reliability of alert data can be ensured only by developing the appropriate expertise and maintaining technical information exchanges with the satellite providers, for example to receive satellite ephemeris [15] data.

The great originality of the mechanism of association with the Programme is that it is unilateral. Non-Party States wishing to be associated with the Programme as a Ground Segment Provider only have to sign a standard 'Letter of Notification of Association'[16], at the proper government level, by which they commit to certain rules and procedures for commissioning, maintaining and operating their equipment. The specific terms of the standard Letter of Notification of Association have been approved by the Cospas-Sarsat Council. Therefore, if the approved standard text is used for the notification letter sent to one of the Depositaries of the ICSPA, no further agreement is required from the Cospas-Sarsat Council and the association becomes automatically effective after a 30-day advance notice. Ground Segment Providers are invited to relevant Cospas-Sarsat Council meetings and to meetings of the Council's subsidiary organs. The association excludes all exchange of

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15/ A satellite ephemeris is a set of time and orbit parameters that allow ground receiving station operators to determine precise satellite positions on orbit. Updates to the ephemeris data are required from time to time for the computation of accurate beacon locations using the Doppler technique.

16/ The complete texts of the Letter of Notification of Association as a Ground Segment Provider and the Letter of Notification of Association as a User State, as approved by the Cospas-Sarsat Council, are available for downloading from the official Cospas-Sarsat website at: http://www.cospas-sarsat.int/en/documents-pro/system-documents under the reference: C/S P.002 - Procedure for the Notification of Association with the International Cospas-Sarsat Programme by States Non-Party to the Cospas-Sarsat Agreement (available in English, French and Russian languages).

funds, except for the administrative costs described as the 'Programme Common Costs'. Ground Segment Providers must fund their own contribution to the System through the procurement, installation and operation of the required ground segment equipment (LUT and MCC).

A similar unilateral procedure is used to formalise relations between the Cospas-Sarsat Parties and States that want to avail themselves of the System and participate in its management, without procuring and operating a LUT or an MCC. Pursuant to Article 12 of the ICSPA, these States need to notify their association through the appropriate standard 'Letter of Notification of Association as a User State' sent to one of the Depositaries of the ICSPA. User States enjoy the same privileges as Ground Segment Providers with regard to their participation in meetings. Both Ground Segment Providers and User States agree to contribute financially towards the 'common costs' of the Programme as decided with the Council.

It is important to note that a formal association with the Programme via the voluntary notification procedure described above is not a requirement for using the System and receiving distress alert messages from Cospas-Sarsat. Although SAR authorities may incur some costs for receiving and responding to Cospas-Sarsat distress alert messages, these alerts are provided free of charge by all Cospas-Sarsat Programme participants.

Liability

The liability attached to the provision of distress alerting services, in case of system failure or in case Cospas-Sarsat alert data could be proven to be in error, was a constant preoccupation of the Cospas-Sarsat Parties. Specifically, the international acceptance of the Cospas-Sarsat System as part of the GMDSS and its recognition as an international safety device mandated in maritime and aeronautical regulations entailed clear responsibilities in term of service reliability. In the particular circumstances of a distress situation, many factors could affect the distress beacon operation or the success of the distress signal processing by Cospas-Sarsat. Therefore, success could not be guaranteed at all times. The absence of expected alert messages, or errors in computed locations, might be interpreted as system failures, possibly leading to legal actions.

Article 14 of the ICSPA states that Parties will not make claims or bring actions against each other and that they collectively accept no liability towards users for any losses arising out of activities, or lack of activities, pursuant to the Agreement. Parties will also cooperate with a view to protecting themselves from such potential claims. Similar provisions are included in the Letters of Notification of Association signed by Ground Segment Providers and User States.

Entry into Force and Duration

The ICSPA was signed at Paris on 1 July 1988 and entered into force sixty days later. Article 20 declares that it shall remain in force for fifteen years and shall be automatically extended for successive periods of five years. As of 2016, the International Cospas-Sarsat Programme Agreement has been extended three times.

4.3.2 The Maritime Response: Cospas-Sarsat in the FGMDSS

By signing the ICSPA and choosing IMO as one of the Depositaries, the Cospas-Sarsat Parties demonstrated that they were resolute in ensuring the long-term continuation of the System. In addition, free access to the System and open competition for the production of EPIRBs were now assured. The ICSPA also clearly acknowledged the responsibility of IMO regarding maritime SAR regulations and stated the intention of the Cospas-Sarsat Parties to fully cooperate with IMO and ICAO (Article 2).

The response at IMO was immediate, even preceding the actual signing of the ICSPA. At its 54th session in May 1988, the MSC "*expressed the opinion that the ICSPA, when concluded, would adequately guaranty the availability and continuity of the Cospas-Sarsat System for the GMDSS*". The Cospas-Sarsat System was accepted as part of the FGMDSS with the inclusion of 406 MHz EPIRBs in ship carriage requirements for the ship-to-shore alerting function, on all ships above the 300 gross tons limit, on par with L-band satellite EPIRBs operating through the Inmarsat geostationary satellite system.

In 1988, Cospas-Sarsat was still the only operational satellite EPIRB system available as no L-band EPIRB model was yet on the market. A number of States, starting with the UK and Norway, made satellite EPIRBs mandatory safety equipment for certain classes of fishing vessels not covered by GMDSS requirements. This initiative was soon followed by France, Canada, the USSR and the United States. These decisions boosted the production of 406 MHz satellite EPIRBs, encouraged growing competition among manufacturers and led to decreasing retail prices. IMO finally decided to speed up the introduction of satellite EPIRBs making them mandatory on SOLAS vessels from 1 August 1993, six years ahead of the full implementation of the GMDSS.

4.3.3 ICAO: Status-Quo at 121.5 MHz

The views and expectations of civil aviation authorities on Cospas-Sarsat were somewhat different from the expectations of maritime administrations. The carriage of 121.5 MHz ELTs on all aircraft had been made mandatory in a number of States and ICAO SARPs[17] had made 121.5 MHz ELTs mandatory safety equipment for international commercial flights since 1967. The signing of the ICSPA was a welcome development but did not fundamentally change the global regulatory picture. ICAO encouraged States to authorise the use of 406 MHz ELTs as a replacement for 121.5 MHz units, provided they include a low-power 121.5 MHz transmitter for homing purposes, but there was no call for a complete switch to the new frequency.

ICAO and national civil aviation authorities were aware of the strong opposition by private aircraft owners, as well as airlines, to any new regulation that would have enforced a replacement, which they considered costly and with no real benefit. The matter would not be resolved until 1999, after a long and difficult debate, when ICAO decided to mandate the replacement of 121.5 MHz ELTs with 406 MHz units by 2005 (see section 5.4).

4.3.4 The Russian Federation Takes Over the Responsibilities of the Former USSR

On 21 December 1991, a protocol was signed by 11 former USSR republics in Alma-Ata, Kazakhstan, establishing a Commonwealth of Independent States (CIS). The USSR was officially dissolved on 26 December 1991. This date actually marked the conclusion of momentous changes which started in the USSR in 1987 under President Gorbachev and effectively opened a new 'Post Cold War' era.

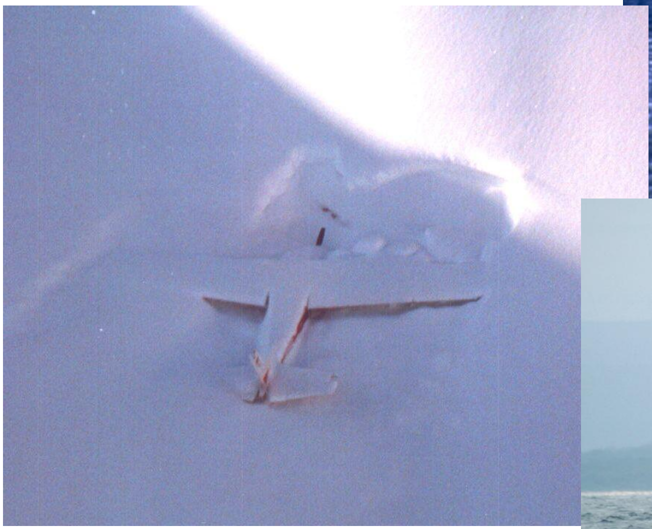
17/ SARPs: ICAO Standards and Recommended Practices.

For the partners in the International Cospas-Sarsat Programme, less than three years after the ICSPA entered into force, the changes in the former USSR could be seen as a potential threat to the continuation of the adventure. However, it rapidly became clear to the international community that the previous international prerogatives and responsibilities of the former USSR, such as its permanent seat at the UN Security Council, were effectively assumed by the new Russian Federation. The same evolution was acknowledged at ICAO and IMO where the Russian Federation took over the seat of the former USSR and newly independent States of the CIS were accepted as member States of these organisations.

In Cospas-Sarsat, the change was officialised by a 'Note Verbale' dated 6 January 1992, sent by the Ministry of Foreign Affairs of the Russian Federation to the Secretary-General of the IMO, informing the IMO in its capacity of Depositary of the International Cospas-Sarsat Programme Agreement that the membership of the Union of Soviet Socialist Republics in the International Cospas-Sarsat Programme was continued by the Russian Federation. Specifically, the document stated that "*the Russian Federation maintains full responsibility over all rights and obligations of the USSR in the International Cospas-Sarsat Programme, including financial obligations*".

On 20 January 1992, a copy of the of the Russian Federation's Note Verbale was sent by the Depositary to the Cospas-Sarsat Secretariat, formally completing the transfer of responsibility.

Sea, lakes or mountains,
a variety of incidents,
but always the same urgent
need for assistance.



Photos courtesy of the International Cospas-Sarsat Programme

4.4 A New International Organisation

The signing of the ICSPA marked a new phase in the Cospas-Sarsat adventure. Nevertheless, however impressive the achievements, much was left to do to build a new international organisation capable of addressing the challenges of a global, operational satellite system. The first challenge was to accommodate the diversity of contributions to the System by participating countries and organisations.

4.4.1 A Short History of Participation by Other Countries

1981-1984: Investigators in the Cospas-Sarsat Demonstration and Evaluation Phase

From the early days of their cooperation, the Cospas-Sarsat partners welcomed other countries' interest in the Cospas-Sarsat System. Daniel Ludwig, Sarsat Project Manager at CNES Toulouse Space Centre (France) organised the first 'Sarsat regional meeting' on 21 to 22 September 1981. It was attended by representatives of Norwegian agencies and the UK Department of Trade[18]. The Norwegian representatives announced Norway's intent to implement their own LUT. The second 'regional meeting' was held on 2 to 3 March 1982 in Oslo, Norway with attendance by representatives of the UK, Norway, Finland and Sweden.

In April 1982, representatives of Norway, UK and Japan were invited to join the Sarsat Steering Group meeting (SSG-6) held in Paris, France, on the last day of that meeting (9 April 1982). Further, the representatives were invited to attend an Investigators' Meeting held in Moscow, USSR on 17 April 1982, in conjunction with the third Cospas-Sarsat Coordinating Group meeting (CSCG-3, 13 to 17 April 1982). The role and status of these countries in the Cospas-Sarsat experiment was officially addressed in Moscow. They would later be referred to as 'Investigators'. The East-West divide of the Cold War being still in place, and the satellite system still under development, the partners agreed that the Sarsat side would coordinate the involvement of Western countries, while the USSR would coordinate Eastern countries' participation in the experiment. In the following years, 'Understandings' for participation in the demonstration and evaluation phase as Investigators were signed by the three Sarsat partners and agencies in Norway, the UK, Japan, Finland, Brazil, and by Morsviazsputnik and Voden Transport in Bulgaria, allowing these countries to run trials with Cospas and Sarsat satellites and report on their results.

> The term "family" is not unnatural when speaking of those that met regularly in Cospas-Sarsat, a family with very few internal feuds. This was our clear experience of the cooperation throughout all these years: *"A sense of good spirit to reach common goals, sharing common values; to achieve a good result in coordinated efforts to save lives in distress situations – anywhere. Done by people who do not claim, but provide."*
>
> Norway is a small country, but we were taken seriously and we were heard in Cospas-Sarsat. There were no hidden motives to our participation, other than achieving good results for search and rescue services all over the world.
>
> **Olav Sonderland**
> **Head of RCC northern Norway/NMCC (1985-1993)**

Further European regional meetings were held in 1983 in Toulouse, France (26 January 1983), Tromsoe, Norway (13 to 17 June 1983), London, UK (19 to 20 September 1983), to coordinate European trials during the D&E Phase, which involved exchanging data from LUTs in Toulouse (France), Tromsoe (Norway) and Lasham (UK). By the end of 1984, in addition to Norway, the UK, Bulgaria, Japan, Brazil, Finland and

18/ The Norwegian delegation was led by Bjorn Landmark from the Norwegian Space Centre and David Pope led the UK DOT delegation.

Sweden already mentioned above, agencies in Australia, Denmark, India, Venezuela, Singapore, Spain and Switzerland had also expressed their desire to establish links with the Cospas-Sarsat endeavour.

1985-1990: Participation as LUT Operators or User-Countries before the ICSPA

Under the 1984 MOU, a new body was established for the management of the System; the Cospas-Sarsat Steering Committee (CSSC). The LEOSAR system was declared operational at the first CSSC meeting held in Seattle, WA, USA in 1985. Interest in participating was being expressed by a growing number of countries; however, no clear status was defined in the new quadripartite MOU for other countries' agencies. The countries wishing to operate LUTs or join the partners in the management of the operational system were invited to sign a separate arrangement defining their obligations, this time between the country's lead agency and the four Cospas-Sarsat partners jointly, to establish their role in the System on a formal basis. As for their participation in Cospas-Sarsat meetings, the 1984 MOU only declared that "*participation of other countries or international organisations in Cospas-Sarsat meetings will be at the discretion of the CSSC*", and that "*normally, agencies responsible for LUTs or other ground segment facilities would be invited to attend*".

Actually, the number of 'observers' from other countries at Cospas-Sarsat meetings continued to grow, irrespective of the countries' official status. By the CSSC-4 meeting in November 1987, Understandings had been signed with four LUT operator agencies/administrations in Brazil (INPE), India (ISRO), Norway (Ministry of Justice), and the UK (Department of Transport). Four additional Understandings had been signed with user-countries' agencies/administrations in Bulgaria (Voden Transport Shipping Corp.), Denmark (Civil Aviation Administration), Sweden (National Rescue Service Board) and Switzerland (Federal Office of Civil Aviation). Japan's Ministry of Transport signed a separate agreement for its own investigation of the System and additional LUT operator Understandings were under discussion with agencies in Chile, Italy and Venezuela.

Ground Segment Providers and User States under the ICSPA

After the ICSPA entered into force in 1988, formal association by States with the International Cospas-Sarsat Programme was opened, although detailed procedures to achieve this, in particular the texts of the standard 'Letters of Notification of Association as a Ground Segment Provider' or as a 'User State', were yet to be agreed. The definition of the procedure for association would be one of the first tasks of the newly established Cospas-Sarsat Council and the Secretariat. This was accomplished in coordination with the Depositaries of the ICSPA (the legal offices of ICAO and IMO acting on behalf of the Secretary General of ICAO and the Secretary-General of IMO), who were expected to receive and formally accept the States' notification of association after vetting the document for conformity with the agreed procedure.

In the past, because of the diversity of authorities or agencies in charge of aeronautical, maritime or in-land SAR matters, the determination of which organisation in a particular country should be leader at Cospas-Sarsat meetings or in the discussion of Understandings with the Cospas-Sarsat partners, had sometimes been an issue. The partners still had memories of meetings where identifying a head of delegation for a particular country had been problematic, due to conflicting views among representatives in that country's delegation. Similar circumstances could not be tolerated in a mature international organisation where States, not agencies nor administrations, were represented. Furthermore, because of the unilateral nature of the procedure of association by States, no ambiguity could be allowed in the notification process regarding the representation of the State in the meetings of the Programme.

Therefore, a strict rule was established requiring that the Letters of Notification of Association be signed by the Head of State, or the Head of Government, or the Minister of Foreign Affairs. Alternatively, if the letter was signed by a lower rank official, this signature must have been authorised in writing by one of the three higher State officials. This strict requirement was occasionally seen as excessive and burdensome. Together with the unusual notification procedure, it probably resulted in delays of some States' formal association with the Programme [19]. However, thanks to the diligence of the Legal Bureaus of IMO and ICAO, the enforcement of the strict procedure certainly avoided annoying diplomatic complications in a number of cases where over-enthusiastic officials would rush into notifying their personal desire to join the Programme and lead their country's representation at Cospas-Sarsat meetings.

The first 'Conference of User States' held in London from 17 to 18 November 1988, followed the first Cospas-Sarsat Council meeting (CSC-1). Fourteen countries [20] were represented in addition to the four Parties to the ICSPA. After a formal presentation of the contents and principles of the ICSPA, the draft texts of the standard letters of notification of association were reviewed with prospective participants. The proposed texts were drawn using the formal language of the ICSPA to serve two major purposes, namely to:

- avoid unnecessary discussions by using terminology already approved through the signing of the ICSPA; and
- acknowledge the status of other States' association in a formal document that would be signed by the highest authorities of the State.

Another major change to the relations between the four 'space segment providers', now Parties to the ICSPA, and other participants was the prospect of sharing the financial burden of the Programme common costs. Although modest when compared to the cost of providing the space segment or procuring and operating a LUT and an MCC, the financial contribution towards the costs of meetings and the Programme administration was important as a sign of membership in the Cospas-Sarsat community. Being a member entitled participants to express views at Cospas-Sarsat meetings, both the 'open' Council meetings and the Council subsidiary bodies where all participants enjoyed equal status. The common cost contribution by non-Party States was established in the form of an annual flat fee agreed with the Council. Its amount was increased over the years as the Programme developed, eventually offsetting more than 50% of the total common costs expenditure. Under this approach, the Parties to the ICSPA still retained the full control of the Secretariat management and the ultimate liability for the common costs incurred by the Programme. The rule established by the Council after discussion with the other participating States was that both Ground Segment Providers and User-States would contribute the same annual amount, irrespective of their own expenditure, obviously different for the two types of association.

19/ For instance, because of the required level of signature, the association of Japan had to be authorised by the national parliament, which was the cause of a one-year delay in the completion of the notification procedure. The association of Japan became effective on 10 July 1993.

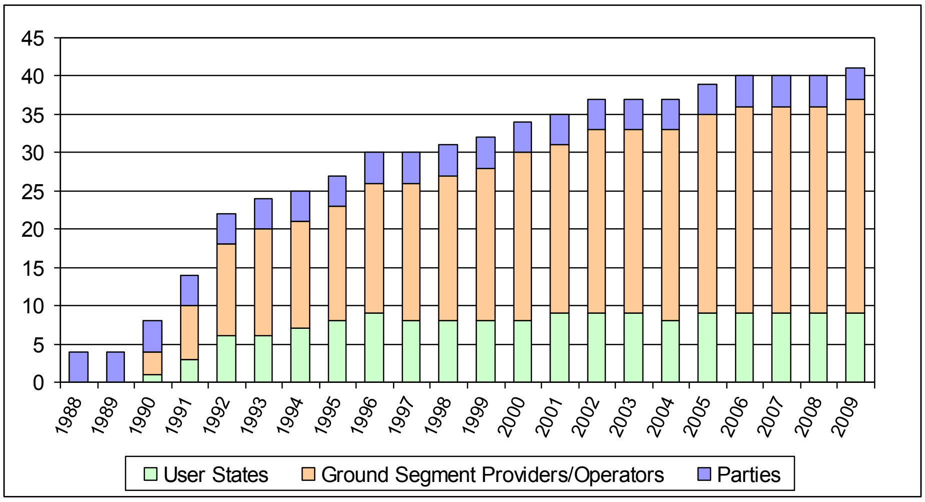
20/ Australia, Brazil, Bulgaria, Chile, Denmark, India, Italy, Japan, Norway, Poland, Sweden, Switzerland, the UK and Venezuela.

'Closed' and 'Open' Council meetings

The clarification of associated States' status in the Programme and their role in the management of the System did not change the basic responsibilities of the Parties regarding the provision of the space segment. Only Parties' Representatives were full Council members and only they could make formal decisions on all aspects of the Programme.

However, it was obvious to all participants that any decision that might impact the ground segment operation or the beacons and could entail significant costs to users and Ground Segment Providers had to be accepted by all, including associated States and organisations. In a fully interoperable satellite system, this concerned almost all technical and operational issues to be addressed by the Council. Therefore, any subsidiary organ tasked with addressing such questions to prepare Council decisions would have to be open to all, Parties and associated States. Similarly, Council meetings where decisions on these technical and operational matters would be made should be 'open' to the participation of associated States.

Two types of Council meetings were organised. During the Closed Meetings of the Council, administrative, policy and management issues would be addressed by the four Parties, along with specific space segment matters that required close coordination. At least once a year, an Open Meeting would also be held, where all associated States would be invited to participate and questions of general interest, including technical and operational issues, would be debated before a formal decision was made.



Number of Participants: Parties, Ground Segment Providers and Operators, User States, 1988 to 2009

Source: Cospas-Sarsat Secretariat

A growing number of Participants

As of 2009, in addition to the four Parties to the ICSPA (Canada, France, the Russian Federation and the United States), 26 States were associated as Ground Segment Providers and nine as User-States. The figure above which shows the evolution of the number of Participants over the years, including Parties, Ground Segment Providers, Ground Segment Operators, and User States, is a clear illustration of the rapid success of the Programme and the particular impact of the ICSPA on other States' decision to join Cospas-Sarsat. The list of associated States and organisations as at the end of 2009 is provided at Annex 3. The official, up-to-date list is provided in Cospas-Sarsat document C/S P.010, which can be downloaded from the Cospas-Sarsat website[21].

21/ http://www.cospas-sarsat.int/en/documents-pro/system-documents

4.4.2 The Special Case of Associated Organisations

As explained in section 4.3.1, only States could implement the formal association procedure defined in the ICSPA or accede to the Agreement through the provision of at least one space segment basic unit. The same rule was applicable regarding the formal association with the Programme as 'Ground Segment Provider' or 'User State'. The restriction to States was overcome in the case of agencies in Hong Kong, China and Taipei, China, which were granted a status of 'associated organisation', specially defined by the Council to deal with their particular circumstances.

The Hong Kong Marine Department

In 1989, under British rule, the Hong Kong Marine Department decided to upgrade its Maritime Rescue Coordination Centre (MRCC) equipment to GMDSS standards. By 1990, in an effort led by the Head of the HK MRCC, Mr. Philip Weaver, two Cospas-Sarsat LEOLUTs and a Mission Control Centre (MCC) were in operation in Hong Kong. However, Hong Kong could not become associated with the Programme through the formal procedure, which was applicable to States only. Through diplomatic channels, the Peoples' Republic of China indicated that they would not object to the participation of Chinese regional entities in the Cospas-Sarsat System. The P.R. of China was at the time considering their own association with the Programme as a User State, which became effective on 18 November 1992.

International Telecommunications Development Corporation (ITDC)

In parallel with the developments concerning Hong Kong, the Secretariat was approached in 1991 by the International Telecommunications Development Corporation (ITDC) of Taipei, China which was considering the installation of a LUT on the island of Taiwan.

At the CSC-7 session in 1991, the Cospas-Sarsat Council decided that participation by Hong Kong, China and Taipei, China in the Cospas-Sarsat System would be beneficial to the Programme and that Article 9 of the ICSPA gave the Council sufficient authority to decide on these System enhancements. Therefore, the Council adopted a special procedure through which an organisation such as ITDC or the Hong Kong Marine Department could become associated with the Programme as a 'Ground Segment Operator' with obligations and entitlements similar to those of Ground Segment Providers. The only difference with the procedure applicable to States, besides the replacement of the 'State' designation by 'associated organisation', was that a proposal for association would have to be submitted to the Council and approved by the Council prior to forwarding a notification letter to the Secretariat, rather than the Depositaries of the ICSPA. The notification letter for an association as a Ground Segment Operator was otherwise quite similar to the standard notification letters to be sent by States. The same financial contribution towards the common costs of the Programme was expected from associated organisations.

Two Chinese Associated Organisations

The association of ITDC according to the procedure for associated organisations adopted by the Council was completed in 1992, through a letter of notification received by the Cospas-Sarsat Secretariat. ITDC's association as a Ground Segment Operator became effective on 4 June 1992.

The actual implementation of the procedure in the case of Hong Kong was delayed by the ongoing negotiations taking place at that time between the UK and the People's Republic of China regarding the return of Hong Kong under Chinese rule. Although China had no objections in principle to the association of the Hong Kong Marine Department with the Cospas-Sarsat Programme, the Hong Kong Department of Justice recommended that the Marine Department should not sign the letter of association because of the ensuing international obligations. With the usual pragmatism of the Cospas-Sarsat approach to this type of circumstance, Hong Kong continued to operate its LUTs with the support of Cospas-Sarsat, and to pay on a voluntary basis the standard annual contribution toward the common costs of the Programme, while attending meetings in the status of 'observer'.

The matter came to a conclusion at the 19th Session of the Cospas-Sarsat Council in 1997, after Hong Kong was effectively returned to Chinese sovereignty. The People's Republic of China which was already associated as a User State decided to raise their association to the level of Ground Segment Provider with its own LUT and MCC in Beijing. The change became effective in March 1997. However, at CSC-19, the Chinese delegation also expressed that they wished to maintain the activities of Hong Kong in the Cospas-Sarsat Programme, thereby clearing the way for a separate association by the Hong Kong Marine Department as a Ground Segment Operator. The association of Hong Kong in the special category of 'Ground Segment Operator' became effective on 28 June 1998.

4.4.3 India as Ground Segment Provider and Space Segment Provider

India's association as a Ground Segment Provider became effective on 23 May 1991, after its letter of association was deposited with ICAO in accordance with the provisions of the ICSPA. India had developed its own LUT, initially installed in Lucknow and later moved to Bangalore, the main technical centre of ISRO, the Indian Space Research Organisation.

However, as leader of India's ambitious space programme, ISRO had expressed an interest in contributing to the Cospas-Sarsat System as early as 1986, during the CSSC-2 meeting held in Villefranche, France. ISRO's representative, Mr. Jay Singh, indicated that ISRO would be prepared to examine the feasibility of installing a SAR payload on a future Indian polar orbiting satellite, if the partners confirmed their interest in India's proposal to complement the Cospas-Sarsat polar system. Another option was the provision of a 406 MHz repeater on a future geostationary communication satellite of the INSAT series. As the polar system had already been declared operational, the geostationary satellite option was of greater interest to the Cospas-Sarsat partners. The challenge for Cospas-Sarsat was now to provide a GEOSAR complement to the LEOSAR system, with complete coverage. INSAT satellites would constitute an essential complement to the partial GEOSAR coverage that was to be provided by 406 MHz payloads installed on U.S. geostationary meteorological satellites of the GOES series. INSAT at a longitude of about 82^{o} East would be ideally located to fill the gap.

Unfortunately for ISRO's representative in Villefranche, that particular meeting was not the best time for coordinating new plans with the Cospas-Sarsat partners. The hectic debate on the planned establishment of the Secretariat at Inmarsat, now in jeopardy, and the lack of progress on the institutional issue had raised the tension among the partners (see section 4.2.4). The future seemed rather cloudy and plans for system expansion were not a priority. Nevertheless, the prospect of a complete GEO coverage at 406 MHz was highly attractive and ISRO was encouraged to further explore and develop the INSAT option.

The INSAT 2-A geostationary satellite with a 406 MHz repeater was launched in 1992 and trials of the INSAT system with a receiving station in Lucknow, India, were included in the GEOSAR Demonstration and Evaluation (D&E) phase (1996 and 1997). Following extensive testing of all technical and operational aspects the Council agreed that GEOSAR satellites provided significant advantages in terms of distress alerting and, therefore, the available GEOSAR components should be declared 'operational' and an enhancement to the Cospas-Sarsat System.

INSAT Geostationary Satellite
Photo courtesy of ISRO

The 'system enhancement' approach was consistent with the authority bestowed on the Council under the provisions of the ICSPA. Therefore, at the CSC-21 session in 1998, the U.S. GOES satellites could be declared part of an enhanced Cospas-Sarsat space segment and the GEOSAR system operational, although formally still incomplete.

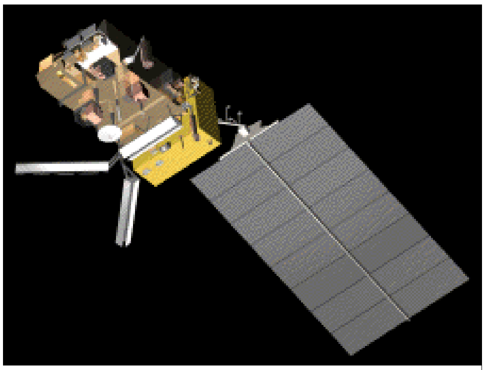
INSAT 2-A was available and a new GEOLUT had been installed at ISRO's main technical centre in Bangalore, together with the Indian MCC. However, the formal integration of INSAT satellites into the Cospas-Sarsat System raised delicate policy issues. India was not a Party to the ICSPA and had not clearly stated their intention on this matter. Becoming a Party to the ICSPA would require some negotiations with the existing Parties, as well as policy adjustments. In particular, Cospas-Sarsat would have to decide formally that a geostationary satellite platform and a payload could be considered a "basic unit" of the system under the terms of Article 3 of the ICSPA. For India, this would also mean higher commitments, such as attending all Council meetings and assuming a higher portion of the Programme common costs, on par with other Parties. ISRO was under some pressure to manage an expanding national space programme with far more pressing commitments than its current involvement in the management of the global Cospas-Sarsat System. Finally, after lengthy preparation, a less demanding approach was preferred and a separate Understanding was negotiated between the four Cospas-Sarsat Parties and the Republic of India for the provision of GEOSAR system components, including a geostationary satellite platform with a 406 MHz GEOSAR payload and the required ground processing equipment. The Understanding[22] was still to be signed at government level, with clear commitments by the State signatory to maintain the GEOSAR capability and abide by Cospas-Sarsat System performance requirements. It was signed in 2007 and India formally became a "Space Segment Provider" as well as a "Ground Segment Provider" in the Cospas-Sarsat satellite system, without having to assume the responsibilities of a Party to the ICSPA.

4.4.4 EUMETSAT and the International Cooperation on Meteorological Satellites

Under the terms of the ICSPA, the two LEO satellite platforms of the Sarsat system were provided by NOAA in the United States. When the European meteorological satellite organisation, EUMETSAT, began developing its own LEO satellite capabilities, the advantages of a cooperation

22/ Document C/S P.009 "Understanding Between the States Parties to the International Cospas-Sarsat Programme Agreement and the Republic of India Concerning the Association of the Republic of India with the Cospas-Sarsat Programme as a Provider of Geostationary Satellite Services for Search and Rescue (GEOSAR)" is available from the Cospas-Sarsat official website.

with NOAA for a co-ordinated dual LEO satellite system for meteorology became clear. In 1998, EUMETSAT and NOAA signed the 'Initial Joint Polar System Agreement' (the IJPS Agreement). Under this new Agreement, each organisation would develop and operate their own spacecraft, sharing the burden of providing data for weather prediction. Each organisation exchanged instruments for hosting on the other's spacecraft, avoiding the duplication of some development costs and ensuring the commonality of data collected by those instruments on both operational satellites. Under the NOAA/EUMETSAT IJPS Agreement, the first spacecraft of the EUMETSAT Polar system (EPS), Metop-A launched on 19 October 2006, carried the Canadian SARR and French SARP payloads and became one of the operational satellites of the Sarsat system. EUMETSAT contributed two LEO satellites carrying SAR payloads for the LEOSAR system: Metop-A (Sarsat-11) and Metop-B (Sarsat-13).



EUMETSAT's Metop satellite
Picture courtesv of EUMETSAT

In addition to, and independently from its contribution through the IJPS Agreement, EUMETSAT agreed to provide a 406 MHz repeater capability on its Meteosat Second Generation (MSG) series of geostationary satellites. MSG-1 and MSG-2 were launched in 2002 and 2005 respectively, eliminating a potential GEOSAR coverage gap at the longitude 0°. The EUMETSAT contribution of four MSG satellites to the 406 MHz GEOSAR system was formally acknowledged in 2010 via a specific Arrangement [23].

Cospas-Sarsat LEOLUT Antenna
Photo courtesy of CNES

EPIRB Installation

Photo courtesy of the International Cospas-Sarsat Programme

23/ Document C/S P.008 "Arrangement on Cooperation between the Cooperating Agencies of the Parties to the International Cospas-Sarsat Programme Agreement and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) on the EUMETSAT Contribution to the Cospas-Sarsat GEOSAR System" is available from the Cospas-Sarsat official website.

4.5 From Informal Beginnings to a Mature International Organisation

The second challenge for the new international organisation was to implement efficient working methods and fulfil the expectations of a growing number of participants.

4.5.1 Learning to Walk at Inmarsat

Looking back at the early days of the Cospas-Sarsat partners' cooperation

Cospas-Sarsat started in 1979 as a cooperative endeavour between space agencies and communication research centres. Although the international cooperation between Western and Eastern countries, rather unusual at the time, required the involvement of senior management and imposed formal work procedures such as the signing of a report at the end of each meeting, the proceedings of the Cospas-Sarsat partners' meetings were rather informal. The healthy principle of chairmanship and meeting venue rotation among partners helped create mutual trust and ultimately mutual understanding, despite Cold War prejudice, language barriers and obvious cultural gaps. Moments of tension were noticeable when difficult choices were required. However, the usually small size of the delegations, at least in the early days, and the stability of the teams allowed a gradual overcoming of differences in working methods and technical cultures.

As there was no email and Internet to communicate between meetings, the exchange of information took place only during the week long meetings and much emphasis was placed on socializing before and after the sessions, through welcome parties and the celebration of the work accomplished, including toasts with beer, wine or vodka. A special mention should be made of the dedication of interpreters, then members of national delegations, who agreed to mix with other delegates in after-work sessions and contributed an extensive glossary of technical terms, acronyms and colloquial expressions in three languages: English, mostly the American and Canadian varieties, French and Russian. Their participation was instrumental in bridging some of the cultural gaps that sometimes looked like insurmountable obstacles.

After eight years of meetings held alternatively in Canada, France, the United States and the USSR, plus some meetings in Norway and the United Kingdom for the Sarsat teams, the time for travelling the world ceased, at least temporarily, when the Secretariat was established at Inmarsat, then headquartered near Euston Station in London, UK. Taking advantage of fixed conference facilities at Inmarsat that greatly facilitated the planning and the management of meetings, the Cospas-Sarsat partners decided to settle and concentrate on the considerable task ahead of them, including completing the details left open in the final text of the ICSPA. The urgent issues concerned the procedure for non-Party States' association with the Programme, the rules of procedure of the newly established Council and the organisation of subsidiary organs.

First steps at Inmarsat

The last meetings of the Cospas-Sarsat Steering Committee held in London in 1987 and in the spring of 1988, before the CSSC was replaced by the Council, had recreated the mild chaos of previous sessions. Too many meetings were run in parallel with varying terms of reference, or in sequence, but with different lists of participants. Management sessions would be held successively, some open to all participants, some restricted to the core partners. Reporting procedures were loosely defined and working methods would change depending on the current Chair of the meeting. The newly hatched Secretariat was benefiting from the support and experience of Inmarsat's conference services. However, in the absence of established work procedures, the management of documents and the preparation of the final meeting report still represented a challenge. As in the old days of Cospas-Sarsat Coordinating Group meetings, the final report had to be signed by the heads of delegations of the four partners, and copies of all documents, including the CSSC report and its annexes, provided to all participants at the end of the meeting. Even with Inmarsat's substantial means in terms of conference facilities which featured high speed copying devices, this was still an awesome task for the small team of the Secretariat limited to two officers plus Inmarsat's support.

The breakthrough came with the adoption of a number of decisions at the first Council Session, including Council rules of procedures, rules for the preparation of the 'Summary Record', and abandoning the requirement to produce a clean document for signature before the end of the meeting. Per Council decision, the draft Summary Record, marked up by delegates during the final review, would be the last document produced during the meeting. The final 'clean' text of the Summary Record with all corrections approved by the Council would be prepared by the Secretariat after the meeting and distributed by post to all delegations, as was practised in other established international organisations. Following a suggestion by Yuri Zurabov from Morsviazsputnik, now the Representative of the USSR Party, the Council also decided to streamline the preparation of the Summary Record, following guidelines already used by Inmarsat. The Summary Record of the Council would be structured according to a formal three-step presentation. For each agenda item, the issue being addressed would first be stated with appropriate references to the working papers submitted for review, using the introductory words: "*The Council noted…*". The major points of the discussion would then be summarised to introduce and explain the final decision. Finally a carefully worded decision would be produced for conclusion of the item under discussion and introduced with the words: "*The Council decided…*".

This formal approach could seem rather artificial to unfamiliar observers. Its considerable advantage was firstly to facilitate the work of the Secretariat as it eliminated any temptation to report discussions verbatim. By creating a stable and familiar reporting pattern, it also provided members of delegations whose mother tongue was not English with a better grasp of the reported issue, its discussion and the conclusion actually reached, as stated in the final decision. As the number of associated countries and attendance at meetings was rapidly growing, this last aspect was noteworthy. After highly technical issues, a new series of difficult operational matters were now to be addressed by delegations with a great diversity of backgrounds and generally unfamiliar with large international meetings. This was unexplored territory for the partners.

In an international cooperative Programme where all decisions were supposed to be made unanimously by the Council members, the Summary Record format had another advantage. It played down differences of opinion expressed during the actual discussion, while highlighting the basis of the final consensus reflected in the decision. Divergence of opinion was frequent and could still be recorded if requested by delegations to illustrate the complexity of an issue, but past experience had abundantly shown the drawbacks of recording on paper the words actually spoken in the heat of a debate. The joint preparation of meeting reports by a small team composed of one delegate from each delegation had been the rule at Cospas-Sarsat Coordinating Group meetings before 1985. It was dropped for Cospas-Sarsat Steering Committee meetings, partly because of the inflation of the number of delegations and partly because of the time pressure imposed by lengthy agendas. The consequences had not been good, with report reviews expanding into many nightly hours and their conclusion delayed to the early hours of the next morning.

The formal methodology of the Summary Record preparation served the Programme well, allowing a clear tracking of decisions, which would later be recorded in separate documents [24] approved and controlled by the Council. Together with clear rules of procedure adopted by the Council, it greatly improved the efficiency of meetings.

Subsidiary organs of the Council: the Joint Committee

The establishment of subsidiary organs that would meet separately from the Council to prepare decisions on all technical and operational issues also had a significant impact. Although small ad-hoc technical or operational meetings had been held in the past with specific terms of reference, generally limited to a single issue [25], the partners never allowed large technical or operational sessions with specific agendas to be held separate from the main Cospas-Sarsat Coordinating Group (CSCG) meetings, or from the Cospas-Sarsat Steering Committee (CSSC) meetings which replaced the CSCG in 1985. All discussions in working groups meeting outside the main session had to be reported at plenary CSCG or CSSC meetings and included in a single final report, even if this meant attaching to the report an astonishing number of annexes [26] .

The establishment in 1988 of subsidiary organs of the Council in the form of two working groups, the Operations Working Group (OWG) and the Technical Working Group (TWG) [27], allowed more efficient working methods. Each working group had its own agenda approved by the Council and both groups met in parallel. To maintain the coherence of recommendations proposed by the working groups, both reported to a plenary forum labelled the 'Joint Committee' to produce a single integrated report.

The two-step approach to Council decisions, whereby the Joint Committee would prepare recommendations to the Council and the Council would pronounce on their final adoption or rejection in its formal decisions, also contributed to a more effective and structured work methodology. Joint Committee recommendations could be freely debated by all participants, including delegations from non-Party States, while final decisions remained the prerogative of the Council formally composed of the four Parties' Representatives. The drawbacks of possible delays to the implementation of technical or operational recommendations were balanced by the opportunity to review carefully the pros and cons of changes imposed in a fully integrated satellite system. Such changes, which could result in very significant costs to manufacturers, beacon owners or LUT and MCC operators, actually deserved careful scrutiny at Programme management level.

24/ Programme documents C/S P.011, "Cospas-Sarsat Programme Management Policy" and C/S P.012, "Cospas-Sarsat Secretariat Management Guide".

25/ For example, the protocols to be used in computer-generated message formats for exchanging System data and distress alert data internationally via telex were first defined at a special meeting in Odessa, USSR in 1982. This would become the SIT message format still in use for the exchange of Cospas-Sarsat alert data.

26/ 55 attachments to the CSSC-1 meeting report (1985, Seattle). A Technical Working group (TWG) and an Operations Working Group (OWG) met for the first time at the CSSC-2 meeting (1986, Villefranche), essentially as an had-hoc arrangement to prepare CSSC decisions. At the CSSC-3 session (Feb. 1987, Quebec City) there were up to 106 attachments to the CSSC-3 meeting report, including 56 for the Technical Working Group, 26 for the Operations Working Group and 24 for the plenary CSSC session.

27/ A third working group, the Exercise Working Group (EWG) also met as part of the Joint Committee until 1992 under the chairmanship of Mr. Lloyd Green from NASA to produce the "Exercise of 1990 Report", which provided a comprehensive assessment of the performance of the System at that time.

Contrary to the expectations of some participants who thought the adoption of the ICSPA would result in more relaxed proceedings, the years following the establishment of the Council and the Joint Committee saw a constant flow of changes to the Cospas-Sarsat System. These changes were brought about by the effective development of a global, operational satellite system, with new Ground Segment equipment operators in numerous countries eager to join the Programme. Fine tuning of technical specifications was also required to respond to questions from a growing number of 406 MHz distress beacon manufacturers who faced difficult technical challenges in producing reliable radio-beacons at prices acceptable to the consumer.

Therefore, the swift development of the System resulted in an annual flow of changes, both operational and technical, recommended by the Joint Committee and adopted by the Council. For the partners and the Secretariat this meant a steady workload of existing document updates or new documentation developments. Maintaining the coherence of System changes was a constant preoccupation, but repeated calls by the Council to 'freeze' the system documentation simply could not be put into practice by the Joint Committee, which was under pressure from manufacturers, operators and System users to constantly enhance System operation.

Task Groups and Experts Groups

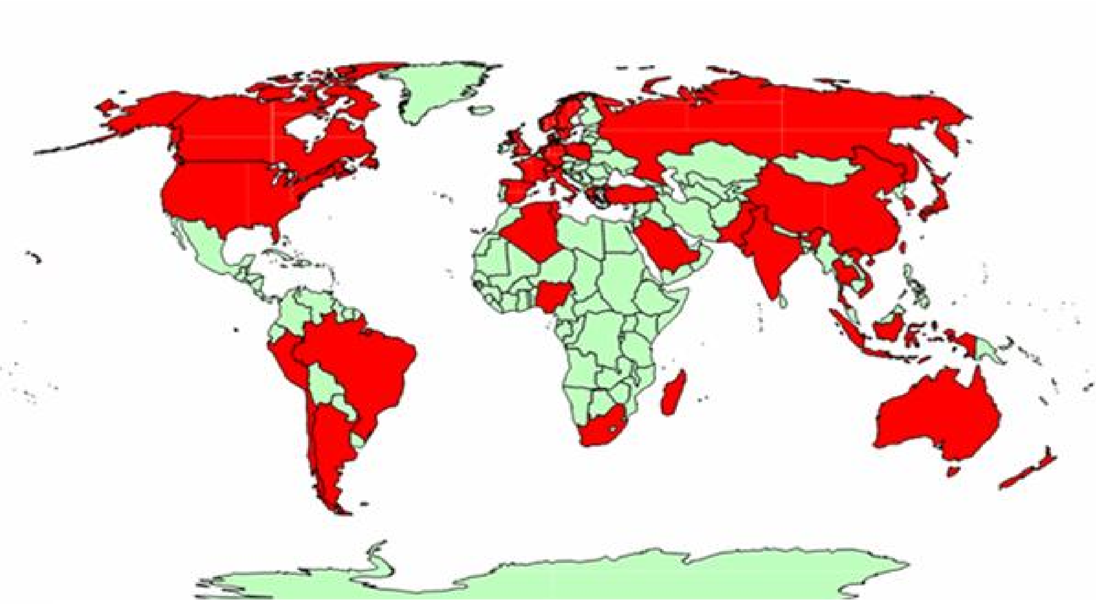
The first Joint Committee meeting (JC-1) was held from 1 to 8 February 1989 in London and the second meeting (JC-2) from 18 to 22 September 1989, also in London. The bi-annual rhythm was maintained in 1990 and two meetings were also scheduled in 1991. However, this pace, combined with two Council sessions per year, each with 'Closed' and 'Open' meetings, was not sustainable for the growing number of countries wishing to participate. Furthermore, frequent meetings with long agendas were not efficient. Little preparation could be done between meetings. During meetings discussion time was limited due to the large number of topics to be addressed. From 1990, only one Open Meeting of the Council would be held during the autumn session, while the spring Council Session would be restricted to a short Closed Meeting with attendance by the four Parties only, focusing primarily on Programme policy, management issues and space segment matters.

In 1991, the JC-5 meeting had been scheduled to be held in Bangalore, India from 27 February to 6 March 1991. However, an external event, the first Gulf War, prevented some delegations from Europe and North America from travelling to India. The meeting was postponed to the scheduled dates of the following JC meeting (11 to 18 September 1991), but the venue in India was maintained. The outcome convinced participants that better preparation and fewer JC meetings was the way forward and, from 1992, only one JC meeting would be scheduled each year, together with an appropriate number of Task Group or Experts Group meetings, as required to address urgent technical or operational matters. The agendas of these ad-hoc groups, approved by the Council at its autumn session, would be restricted to specific issues and, in the case of Experts Groups, attendance would be limited to experts in the particular topic to be addressed. Task Group and Experts Group reports would be reviewed at the following Joint Committee meeting and their recommendations supported or amended for transmission to Council. The structured approach of these working arrangements imposed a one-year cycle for System changes. This annual cycle provided the desired regulation of the pace of System changes, which ultimately facilitated implementation planning.

Associated States' new role and status

Prior to 1988 and the entry into force of the ICSPA, the Cospas-Sarsat partners had maintained informal relations with agencies or administrations in 'investigator countries'. Norway and the UK had joined the Cospas-Sarsat Demonstration and Evaluation phase, from 1982 to 1984, with their own LUTs. The rather informal relationship was strengthened when the System was declared operational in 1985 and new Understandings were signed. However, the status of LUT operators under these new Understandings did not entail any responsibility in the management of the System and decisions were essentially made by the partners with little consultations of other countries' representatives.

Matters changed when the ICSPA and the association procedure for Ground Segment Providers and User States became effective. The first change was purely of status and visibility. The four Parties, still the sole providers of the space segment, maintained full control of the decision process. However, the letters of notification of association approved by the Council and signed by the highest authorities of the participating countries, as well as the rules of procedure of the Council, formally acknowledged the participation of other States in 'Open Meetings' and in the appropriate meetings of the subsidiary organs. Associated States now had a right to submit papers, present views and have these views recorded in the Summary Record of the Council session or the reports of the meetings. In the Joint Committee, all States' delegations had the same status. They could participate in the discussion of recommendations to the Council and have their objections to a particular recommendation recorded in the meeting report. In the mechanics of international meetings, these are significant privileges that separate 'participants' from 'observers'.



Cospas-Sarsat Participating Countries in 2009
(shaded area, see the list of Participants at Annex 3)
Source: Cospas-Sarsat Secretariat

A second development changed the actual role of associated States, in particular Ground Segment Providers. A growing portion of the ground segment was now provided by non-Party States. The global development of the ground segment imposed the establishment of strict rules for the exchange of operational data, including distress alerts, through a network of MCCs structured around communication 'nodes'. Nodal MCCs were first provided by Parties (France, the United States and Russia). However, additional nodes would soon be required in other countries:

Australia, Japan, and Spain, to streamline the flow of data from new MCCs in the various regions of the world.

These developments clearly enhanced the role of associated States, raising their status to that of full partners in the operation of the System. They also introduced a new culture among Programme participants. Although the introduction of the GEOSAR system did raise new technical challenges to be addressed by satellite communications specialists between 1990 and 1995, the new priority of the Programme was now clearly on operational matters. MCC operators and SAR experts had their own forum in the Operations Working Group, on par with space and telecommunication specialists in the Technical Working Group. In 1989, a special Exercise Working Group (EWG) was established under the Joint Committee to address System trials and the assessment of the System performance. The EWG did not continue after the completion of the 1990 exercise report, but its mere existence for a few years was proof of a new emphasis placed on System operational performance and its effectiveness in assisting SAR authorities in the planning of the SAR response to a distress alert.

4.5.2 The Cospas-Sarsat Secretariat and the Shock of Inmarsat Privatisation

In 1995, Cospas-Sarsat was busy addressing the challenges of integrating 406 MHz GEOSAR components into its operational System when the basis of its working arrangement with Inmarsat regarding the provision of secretariat services was shaken by repeated calls for privatisation of the international organisation. The rationale for the privatisation is explained in Chapter 1, section 1.2.2. In April 1998, after several years of debates and preparation, the Inmarsat Assembly made a final decision to privatise the operation of the Inmarsat system. Inmarsat Ltd, a new company under British law, was created on 15 April 1999.

In 1999, a revised Convention came into effect and, to avoid confusion of names with the new Inmarsat Limited Company, the international body was renamed the "*International Mobile Satellite Organisation*" or IMSO. The sole responsibility of IMSO was now to oversee Inmarsat Ltd., assessing whether the Company discharged its public service obligations with regard to maritime safety in the GMDSS as required by its own charter, and to report to IMSO's Council. At its peak, in its Old Street Headquarters in London, the Inmarsat organisation had a staff of well over 300 persons, including the small Cospas-Sarsat Secretariat composed of seven staff members. The new IMSO would initially be composed of only three staff members, including its Director, plus the staff of the Cospas-Sarsat Secretariat.

Until 1998, the Cospas-Sarsat Secretariat had relied on Inmarsat's finance and administration departments to address budget and accounting matters, as well as personnel recruitment and management. The Secretariat personnel were part of the Inmarsat staff complement and all policies applicable to Inmarsat personnel, whether staff contracts, remuneration policies, performance assessment, pension fund, holidays, etc., were applicable to the Cospas-Sarsat Secretariat staff. The Cospas-Sarsat Parties approved the annual work plan and the annual spending plan of the Secretariat, but personnel management matters were essentially the responsibility of Inmarsat's Human Resources Department, while Inmarsat's Finance Department was responsible for payments and accounting matters.

A new IMSO Headquarters' Agreement was signed on 15 April 1999 with the UK as the host country. The legal framework of the international organisation was maintained with the same privileges and immunities. However, the practical administrative environment of the new, smaller organisation had to be entirely recreated, including a new accounting system, staff contracts, pension plan, staff management rules and a new staff handbook. Furthermore, this had to be done between April 1998, the date when the Inmarsat Assembly decided to proceed with the privatisation, and the 15 April 1999 deadline when the new structure would become effective. The Director of the future IMSO had not been selected. Except for existing Cospas-Sarsat Secretariat staff members, the future IMSO had no staff and the existing Inmarsat organisation was primarily concerned with its own transformation into a private company. Consequently, much of the preparatory work to be done was actually accomplished by the Head of the Cospas-Sarsat Secretariat assisted by an external consultant and, from February 1999, the newly recruited Accountant-Administrator of the Cospas-Sarsat Secretariat, Anthony Boateng. Essential advice and guidance was provided by Inmarsat's Director of Human Resources, Bob Dahlgren, whose support must be acknowledged. However, Mr. Dahlgren's own priorities were understandably with the rest of the organisation and the creation of the appropriate staff environment for the new Inmarsat Ltd.

IMSO came into existence on 15 April 1999, under the direction of its recently appointed Director General, Mr. Jerzy Vonau, with a staff complement of two consisting of his assistant Ms. Jenny Ray and a Technical Officer, Mr. Andy Fuller, plus the eight members of the Cospas-Sarsat Secretariat. On 19 April 1999, on the first day of the CSC-22 Council session, an amended Understanding was signed between IMSO and the Cooperating Agencies of the Cospas-Sarsat Parties. IMSO thus officially became the new home of the Cospas-Sarsat Secretariat. For the Secretariat, except for moving to new offices in the same building, changes were minimal. IMSO and the Cospas-Sarsat Secretariat were hosted at Inmarsat Ltd. Headquarters and conference facilities were rented from the new Company under similar arrangements as before.

The Cospas-Sarsat Secretariat team (CSC-28 Council Meeting, April 2002)

Celebrating 20 years of Cospas-Sarsat operations in the 'Salon de l'horloge' at the Quai d'Orsay in Paris, France - From left to right: Bill Ruark, Vladislav Studenov, Bernadette Elfick, Daniel Levesque, Anthony Boateng, Diane Hacker, Wayne Carney, Sergey Mikhailov.

The Head of the Cospas-Sarsat Secretariat was now expected to report to the Director General of IMSO for all legal matters concerning the employment of the Cospas-Sarsat Secretariat staff and the Secretariat operation. However, for all Cospas-Sarsat Programme matters, the Head of Secretariat would exclusively report to, and take directions from the Cospas-Sarsat Council. Between Council Sessions, the reporting line was to all Parties' Representatives and when required, after appropriate coordination with all Parties, directions would ultimately be given to the Head of Secretariat by the Chair of the Council. These arrangements worked reasonably well with no real conflict between the Cospas-Sarsat Parties and the Director of IMSO or the Parties to IMSO, as there was no overlap of responsibilities between the two organisations.

However, by 1999, the Cospas-Sarsat System had grown to encompass operational SAR payloads on seven polar orbiting satellites (the LEOSAR system), three geostationary satellites with appropriate in-orbit spares (the GEOSAR system), 35 LEOLUTs tracking the LEOSAR satellites, a growing number of GEOLUTs processing GEOSAR satellite channels and 20 MCCs responsible for the distribution of distress alerts to SAR authorities, worldwide. About 200,000 406 MHz distress beacons were deployed and the estimated number of 121.5 MHz beacons users was around 600,000. During 1998, over 1,300 persons had been rescued in 385 documented SAR events where Cospas-Sarsat alert data had been of assistance in the rescue operation. The global operational System was continuing to evolve and required thorough and efficient management. Its effectiveness was dependent upon the close coordination of activities of agencies and SAR authorities in 29 participating States plus two organisations. The Open Meeting of the CSC-23 session was attended by delegations of 23 of these States, two associated organisations and representatives of the two UN organisations with responsibilities on SAR matters, ICAO and IMO. The whole organisation had grown far beyond the ad-hoc arrangements of the past and its continuing success was dependent on the smooth operation of the small Secretariat, the only permanent administrative body of the Programme.

The privatisation of Inmarsat had revealed one obvious weakness of existing arrangements, whereby the mere existence of the Secretariat was dependent upon an organisation with no direct responsibility in the operation of the Cospas-Sarsat System or the management of the Programme. Furthermore, the Secretariat was now hosted by IMSO, an organisation with a smaller staff complement than the Secretariat itself, and the Cospas-Sarsat Council had no control or any insight into the management of IMSO. The Inmarsat experience had shown that the Cospas-Sarsat Council could be faced, at very short advance notice, with a decision by the IMSO Parties incompatible with a continuation of the Secretariat operation. A more stable environment was required for the Programme and the Cospas-Sarsat Secretariat, which should provide the Council with full control of its management in a long term perspective. At the CSC-23 session in October 1999, the Council decided that "*all Parties should further research the feasibility of providing the Cospas-Sarsat organisation with an independent legal status*".

4.5.3 Providing the Cospas-Sarsat Organisation with an Independent Legal Status and Moving to Montreal, Quebec, Canada

Eleven years after signing the ICSPA, the Parties had recognised that the lack of an independent legal status was a potential threat to the Programme. The question was now how to make the desirable change happen. There was no easy solution.

Possible options

The first proposal was to prepare an amendment to the ICSPA. Aside from the Programme legal status issue, an amended ICSPA could also have facilitated other pending questions. The status of

India's contribution to the GEOSAR space segment was still unresolved at the time and additional flexibility for such contributions could be built into an amended Agreement. A new puzzle was forthcoming concerning the status of future contributions by EUMETSAT[28], whether to the LEOSAR system with its Metop polar platform, which would soon replace one of NOAA's polar orbiting satellites, or to the GEOSAR system with 406 MHz repeaters on the MSG geostationary meteorological satellite series, which would complement the GEOSAR system coverage. As an international organisation, EUMETSAT did not have the standing and legal power of a State and an international organisation could not become a Party per Article 16 of the ICSPA.

So far, the Parties had resisted proposals to amend the ICSPA and these questions remained highly sensitive. In particular, the fact that any review of the Agreement could also lead to unwanted attention by politicians and government authorities and bring all sorts of undesirable changes on a successful space programme explains why the Parties were extremely reluctant to re-open the ICSPA, unless such exercise was absolutely inevitable.

The second option was to negotiate a new, separate agreement that would be strictly limited to granting an independent legal status to the Programme, with appropriate privileges and immunities, such as the exemption of taxes for Secretariat staff and Programme activities, as well as immunities for Secretariat officials and representatives of the Parties and participating countries. This second option, being limited in scope, appeared to be less fraught with potential dangers and easier to negotiate. Therefore, the Parties choose this path as their preferred approach to resolve the problem.

A new agreement for a new home

The next step was to select possible host countries for the new independent legal entity. The first choice was the UK. As the Secretariat was already based in London, this choice would clearly facilitate the necessary transition to a new organisational framework. Unfortunately, under British law, the required privileges and immunities could be granted by the UK government only to organisations in which the UK was a full Party. This was the case at IMSO, but not in Cospas-Sarsat where the UK was associated with the Programme, not a signatory of the ICSPA. A 'legally independent' Cospas-Sarsat Secretariat would have to move abroad.

The search started for venues that would provide a suitable international environment: a small organisation like Cospas-Sarsat could not afford dedicated conference facilities of its own and would need to rely on other larger international organisations to host meetings, as was done at Inmarsat. Several options were explored:

- Geneva, Switzerland, home of the ITU, WMO, WTO[29] and other UN agencies;
- Vienna, Austria, home of UNOV, the United Nations Office at Vienna, UNOOSA, the UN Office for Outer Space Affairs, and numerous other UN agencies, all hosted in the Vienna International Centre, a large international compound close to the city centre; and

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28/ EUMETSAT: the European Organization for the Exploitation of Meteorological Satellites. EUMETSAT had agreed to cooperate with NOAA, to provide one polar platform for the dual polar orbiting meteorological system and exchange meteorological and data collection instruments to be carried on both platforms, including the 121.5 and 406 MHz SAR instruments.

29/ ITU: International Telecommunications Union, WMO: World Meteorological Organisation, WTO: World Trade Organisation.

- Montreal, Quebec, Canada, host of ICAO, the UN organisation dealing with international civil aviation safety matters, and of a large number of smaller international organisations such as the UNESCO Institute for Statistics (UIS) and the Secretariat of the Convention on Biological Diversity (SCBD).

The financial aspect of a move out of London was the second more important parameter of the choice. The city of Montreal and the Province of Quebec, eager to attract new international organisations, made a very significant offer for one-time financial support, partially offsetting the installation costs of the Secretariat, plus an allowance for each Secretariat staff position over five years. Despite the reputation of Montreal as a cold place with sub-freezing temperatures and long winters, and despite the administrative complication of having to deal simultaneously with Federal and Provincial authorities to secure some aspects of the required privileges and immunities, Montreal won the race. A new quadripartite Arrangement[30] was negotiated in 2004 between the four Parties. The choice of Canada to host the organisation had the additional benefit of eliminating a possible fifth Party to the new legal instrument. The new Arrangement granted the Programme, including its Council and its Secretariat under the terms of the ICSPA, the status of an international organisation under Canadian law, with appropriate privileges and immunities in Canada. This Arrangement would be complemented by an Understanding[31] to be signed by the Head of Secretariat, as representative of the newly created Canadian corporate entity, and the Minister of international relations of the government of the Province of Quebec.

The negotiations of the Arrangement and the Understanding were diligently completed in 2004, but the review at government level among the Parties took somewhat longer. The Arrangement was finally signed on 5 April 2005 in Montreal, during the CSC-34 Session of the Cospas-Sarsat Council held in ICAO's conference facilities. The next step was the publication by the Canadian government of the "Order in Council" which would effectively create the new legal entity. Prior to this publication the organisation did not exist legally and no contract could be signed. The publication was made on 13 April 2005, less than four months before the expected date of the Secretariat installation in Montreal. The Understanding with the Quebec government was signed on 17 May 2005.

Moving to Montreal, Quebec, Canada

In the short period from April to July, the Secretariat had, among other things, to open bank accounts, find office accommodations, purchase equipment, organise the move of its archives, install a new IT system, prepare new contracts for its staff and organise the move of staff families from London to Montreal. The move also stressed the small Secretariat staff who, in addition to normal duties, would have to find accommodations in an unknown city while officially residing on the other side of the Atlantic Ocean, register children at school, organise the transfer of their belongings, obtain appropriate residency documents allowing dependents to work in Quebec, organise health services, etc.

30/ The "*Arrangement Between Canada, the Republic of France, the Russian Federation and the United States of America regarding the Headquarters of the International Cospas-Sarsat Programme*" is available from the Cospas-Sarsat website as document C/S P.005.

31/ The "*Understanding Between the Cospas-Sarsat Programme and the Gouvernement du Québec Concerning Exemptions, Fiscal Advantages and Courtesies Accorded to the Programme Representatives of Member States and Officials of the Secretariat*" is available from the Cospas-Sarsat website as document C/S P.006.

Showing extraordinary dedication, all eight staff members from five different nations, some of them recently recruited in London, agreed to sign new employment contracts and move to Montreal with their families. The move was organised in two shifts, between 1 July and 31 August 2005, allowing the Secretariat to continue to operate without interruption. The Cospas-Sarsat Secretariat officially closed at IMSO in London on 31 July 2005 and formally began operation in Montreal on 1 August 2005. The effective assistance of Canadian Federal authorities and of Quebec Provincial authorities must be acknowledged, together with the efficient support of Montreal International, an organisation dedicated to assisting with the installation of international organisations and companies in Montreal. A special note should also be made of ICAO's support of the whole process, particularly regarding the practical installation of Secretariat facilities in the vicinity of their Headquarters building in Montreal. In addition to logistical support for the initial provision of IT and communication services, ICAO offered easy access to their international conference facilities by the Secretariat staff and Cospas-Sarsat meeting delegates. In London, Cospas-Sarsat had enjoyed the support of IMO's conference interpreters; in Montreal, the same effective and friendly support would be provided by ICAO's professional team of conference interpreters.

With the inevitable administrative complications of moving to a new country, settling into a new organisation and adjusting to a different cultural environment, the move was certainly stressful for all. It was nevertheless swiftly and smoothly completed. In Montreal, there was the additional concern to prepare for the Canadian winter, definitely a new experience for former residents of the city of London in the UK.

Inmarsat Headquarters in Old Street, London, UK former home of the Cospas-Sarsat Secretariat

Photo b By Tarquin Binary - Own work, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=544719

Cospas-Sarsat Secretariat

When moving to Montreal, Quebec - Canada in 2005, the Cospas-Sarsat Secretariat offices were located near ICAO's Headquarters at 700 de la Gauchetière West, in the 'Bell Tower' illustrated here at left. ICAO Headquarters are seen on the right side of the picture.

In 2016, the Secretariat relocated to:

1250 boulevard René-Lévesque Ouest,
Suite 4215;
Montréal, Québec
H3B 4W8 Canada

Photo courtesy of the International Cospas-Sarsat Programme

Chapter 5

Cospas-Sarsat System Operations and Follow-on Developments

5.1 Building an Operational System

The Meaning of 'Operational'

The word 'operational' as used to qualify the state of a system can have different meanings for different people. To professionals in the transport industry, at sea or in the air, an operational system or service would have to be proven by years of reliable, practical use, with clear, unchanging operating procedures allowing thorough training of qualified personnel as well as long term investment in costly equipment. In both domains, when used to qualify a maritime or an aeronautical system, 'operational' is an antonym to rapid changes and swift evolutions.

Photos courtesy of the International Cospas-Sarsat Programme

In the early years of the space adventure, to the space agencies tasked with the development of new technologies, an operational system had a rather different meaning and a much shorter time scale. Space scientists and engineers would declare a satellite for science research in space 'operational' as soon as it could return useful data. Its 'operational life' would usually be counted in a few short years. Emerging space applications brought about a change of perspective.

After the completion of the Demonstration and Evaluation (D&E) phase, the agencies that had developed and tested the Cospas-Sarsat System were eager to declare the System operational and to transfer the responsibility of its management, together with the responsibility for funding its continuation, to 'operational agencies'. The management of the space and research agencies, whether NASA in the United States, DOC in Canada, or CNES in France, had difficulty with the concept that teams of engineers and experts would have to be maintained for many years to ensure the continuation of the System and its adaptation to the evolving requirements of users. The Cospas-Sarsat organisation had no dedicated resources and always relied on the contributions of the space or research agencies of the major players: the Space Segment Providers. As a result, maintaining the appropriate expertise and technical memory to ensure System integrity and reliability in the long term would be a recurring concern for the Cospas-Sarsat Council after the formal declaration that the System was fully operational.

The Challenge of Alert Data Distribution

For SAR authorities, the 'user agencies', the D&E had shown that useful data could be produced by Cospas-Sarsat and used in SAR operations, but the System as a whole was far from being truly operational. No internationally agreed procedures existed for the distribution of distress alerts, whether from existing 121.5 MHz beacons or from the new 406 MHz beacons. Traditionally, a Rescue Coordination Centre (RCC) receiving a distress alert had the responsibility of processing the SAR case until its full resolution, or until the responsibility was accepted by and duly transferred to another RCC.

This approach was retained by Inmarsat for all maritime alerts generated through its GEO satellite system. Inmarsat-E EPIRB alerts received by a Coast-Earth Station were forwarded to the nearest maritime RCC (see Chapter 2, section 2.5). This procedure could work for a limited number of alerts, but was clearly impractical for the flow of all Cospas-Sarsat alerts, whether at 121.5 MHz or at 406 MHz.

When the System was declared operational in 1985, Cospas-Sarsat still had no established policy regarding the distribution of the continuous flow of alert data generated by successive passes of LEO satellites in visibility of transmitting beacons. Should such data be treated as redundant and eliminated after the first alert had been passed to SAR authorities? How should Cospas-Sarsat Mission Control Centres (MCCs) deal with the 'image' locations produced by the unresolved ambiguity of Doppler solutions? These matters could be addressed on a national basis with minimal constraints, but the issues were far more complex internationally. Specifically, since the global coverage of the 406 MHz system would produce, in each LUT, the same distress alerts from all parts of the world, how should distress alerts located in the responsibility areas of foreign RCCs be handled? Declaring the Cospas-Sarsat System operational entailed defining new responsibilities in the handling of alerts produced by the System.

5.1.1 A Short History of the Cospas-Sarsat Data Distribution Plan

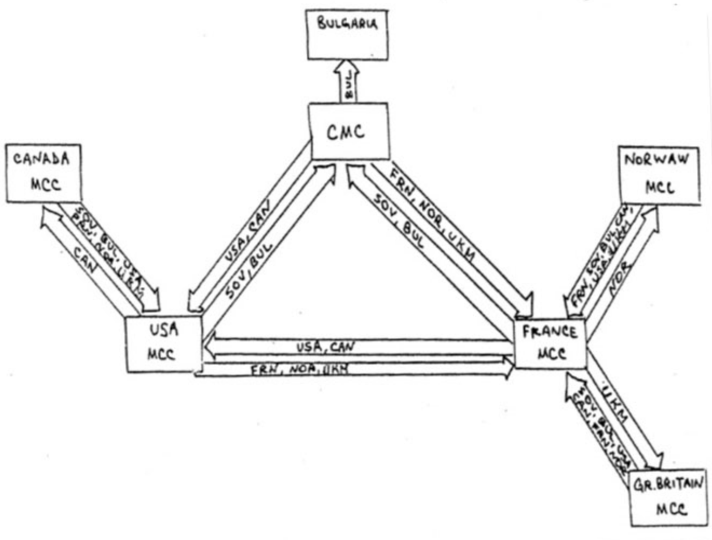
The need for a mechanism to rapidly transmit global distress alert messages received by Cospas-Sarsat LUTs to SAR services became clear even before the LEOSAR system demonstration and evaluation was completed. Therefore, in parallel with discussions on the technical aspects of satellite, beacon, and LUT development, a core group of people with knowledge of SAR structure, communications and network operations began efforts to create a new international framework for the distribution of Cospas-Sarsat distress alerts.

In April 1981, at the first Cospas-Sarsat Coordination Group meeting (CSCG-1) held in Toulouse, France, message formats to be used for communications between Mission Control Centres (MCCs) were considered together with methods to reduce the volume of data exchanged, a theme to be carried forward for many more meetings. The means to be used for international data exchange at that time were essentially based on slow and unreliable telex technology. The Internet was still a pure futuristic fantasy.

In October of that year in Ottawa, Canada, at the CSCG-2 meeting, the United States presented a proposal to mitigate the redundancy of 406 MHz LEOSAR alert data exchanged among MCCs. The underlying principle was that a unique 406 MHz transmission was defined by the 406 MHz beacon identification (ID), the satellite, and the time of closest approach (TCA) of the satellite to the beacon. Therefore, when an MCC received a 406 MHz alert message from a LUT or another MCC, it could be 'matched' against other alerts already received, using these three data elements, and 'filtered out' if redundant. This principle was subsequently refined over the course of operational experience, but remained as the basis of 406 MHz LEOSAR alert data distribution.

A different kind of processing problem existed with 121.5 MHz alert data messages. Even though 121.5 MHz data was not stored on the spacecraft and would not be seen by all LUTs around the globe, transmissions from the same beacon and satellite combination could be seen by multiple LUTs, possibly associated with different MCCs in the same region. Because 121.5 MHz was an analogue transmission with no associated identification, it was very difficult to match alert messages coming from different sources and filter out redundant messages. Various techniques based on close frequency matching and nearby location matching were put into place by participants, but in the end it was left to the design of each MCC to implement the 'best' solution for its region.

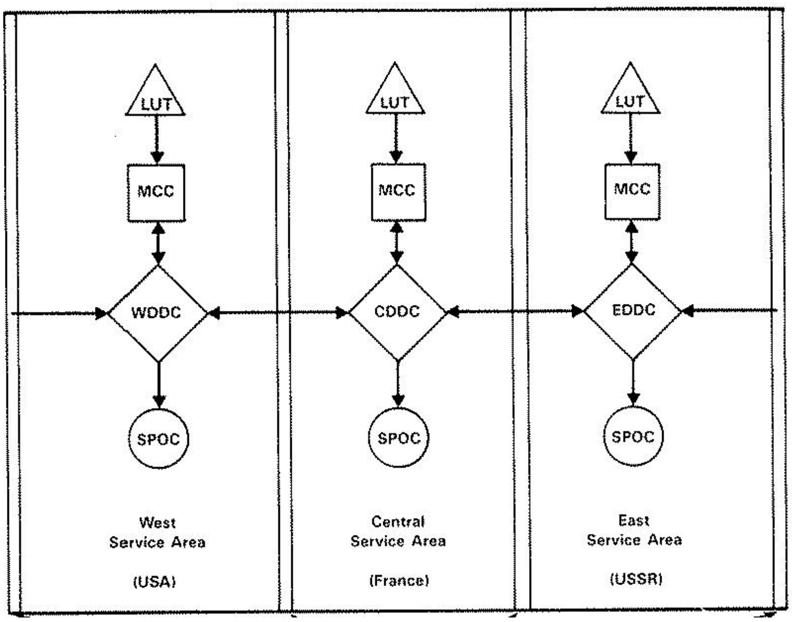
Hand-in-hand with the problem of data reduction in the ground network was the salient issue of how to deliver distress alert messages to the appropriate SAR entity for action. The first concept developed at the CSCG-5 meeting in 1983 proposed to distribute 406 MHz alerts according to the assigned country code in the beacon identification. Acceptable for the D&E experiment and only applicable to 406 MHz alerts, the concept was still far from a workable operational proposal.



Early Proposed Data Distribution Arrangement
(CSCG-5 Meeting Report, Toulouse, France 1983)

The declaration in 1985 that the system was ‘operational’ resulted in a flurry of meetings to design and put in place a truly operational ground network. Intertwined with the exchange of alert data between MCCs was the transmission of alert messages (121.5 MHz and 406 MHz) to any Search and Rescue point of contact (SPOC) worldwide.

By early 1986 the participants had developed a rudimentary plan entitled the Regional Data Distribution and Implementation Plan (affectionately known as the RIP) that introduced the concept of 'data distribution centres' (DDCs) and service areas. The concept stated that a DDC was to serve as a focal point for acquiring, archiving, retrieving and distributing alert data and system information to other DDCs and to SAR points of contact (SPOCs) in its service area. The geographic areas envisioned in the RIP consisted of three regions roughly encompassing 120° of longitude from pole to pole, with the USMCC (Suitland, MD, USA), the FMCC (Toulouse, France), and the CMC (Moscow, USSR) as regional DDCs.



Basic Regional DDC Concept

The RIP was also the genesis of data processing algorithms that would guide future development of the ground segment. The RIP stated that alerts would be distributed according to the computed distress beacon location:

- A DDC that acquired alert data for a beacon position in its service area would distribute this data to the appropriate RCC/SPOC.
- A DDC that acquired alert data for a beacon position outside its service area would forward the alert to the DDC in whose service area the alert was located.

At the April 1986 CSSC-2 [1] meeting in Villefranche, France, the RIP concept of DDCs was merged with a more detailed Operations Plan. According to the Operations Plan, each Cospas-Sarsat Mission Control Centre (MCC) would assume the data distribution centre function within a service area defined as the maritime and land regions where the MCC's national authorities accepted to provide the Cospas-Sarsat alert data distribution service [2]. In the initial years of Cospas-Sarsat operations, the MCC service areas of the Cospas-Sarsat partners would include vast and remote areas, such as the Antarctic, in an effort to provide complete global data distribution.

The issue generated conflicts within countries' delegations. At CSSC-2 in Villefranche, the Head of the French delegation, who was also chairing the 'plenary' meeting, insisted that France should approve the preliminary Operations Plan, even as the representatives of the French administrations responsible for SAR strongly disagreed. They opposed the proposed concept of regional data distribution centres, which they feared would generate an unacceptable burden on French RCCs for reasons explained above regarding the traditional role and responsibilities of RCCs. If the French MCC was in charge of a vast service area with scarce or non-existent SAR services, ultimately a considerable load could be placed on French RCCs for processing Cospas-Sarsat alerts.

> It soon became clear that the emergency signals that were downloaded by a LUT were not limited to the LUT's "own" Search and Rescue Region (SRR). Cospas-Sarsat needed to establish an effective and reliable system for secure delivery of distress alerts to the country that had the SAR-responsibility. [...]
>
> Norway was actively involved from the start in Cospas-Sarsat's effort to address the challenge of Data Distribution through RRC Bodø and its function as Norwegian Mission Control Centre (NMCC). This work became quite extensive over time and a Nordic (later expanded to Northern European) collaboration was established, with constructive meetings headed up by the NMCC. Kaare Øyre from RCC Bodø/NMCC was central to this collaboration, which was carried through the Cospas-Sarsat Operations Working Group (OWG) meetings and then reflected in the Cospas-Sasrsat Data Distribution Plan.
>
> Einar Ellingsen (2013)
> Norway's Cospas-Sarsat Council Representative

Because of the urgent need for a common approach to alert data distribution and the lack of any workable alternative, a compromise was necessary. Inevitably the issue resurfaced at the following meeting in Quebec City, Quebec, Canada (CSSC-3 in February 1987) and, even after the concept had been generally accepted, the definition of common data distribution procedures and the delimitation of MCC service areas would remain very hot topics for many more meetings.

The Operations Plan was ultimately re-titled the Cospas-Sarsat Data Distribution Plan (the DDP, document C/S A.001), becoming the first in a series of important operational documents that allowed Cospas-Sarsat to effectively meet its objective to provide a truly operational alerting service for SAR. Ted King (Canada), Claude Augoyard (France), Bill Ruark (United States) and Konstantin Ivanov (USSR) were instrumental in the development of the operational concepts and the corresponding documents.

1/ In 1985, the former 'Coordinating Group' had become a 'Steering Committee' with new operational responsibilities.

2/ The tentative agreement on the first draft of the Operations Plan was one of the few positive outcomes of the Villefranche meeting (CSSC-2), which was otherwise the scene of a major spat between the Cospas-Sarsat Partners on the plan to create a permanent Secretariat (see Chapter 4, section 4.2.4). Mr. Pierre Bescond from CNES had the difficult task of chairing the operations' group meeting that achieved this first compromise on Cospas-Sarsat alert data distribution.

5.1.2 The MCC Network and 'SIT' Messages

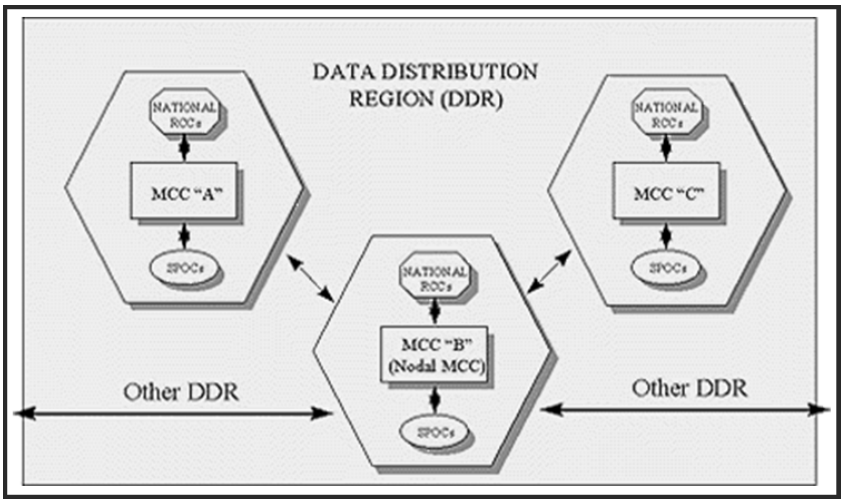
According to the Cospas-Sarsat DDP each Ground Segment Provider (country operating one or more LUTs) was required to establish a Mission Control Centre (MCC) that assumed three basic functions:

a) receive System information from the Space Segment Providers, as required to operate their own LUT, and inform other MCCs of the status of their ground segment equipment;

b) receive alert data from their own LUTs, sort the alert information as necessary, distribute the relevant alert data to RCCs in the service area, or forward the information to other MCCs if the alert was located outside the MCC service area; and

c) receive alert data from other MCCs, sort and eliminate redundant information already passed to RCCs, or forward new, updated information to RCCs as necessary.

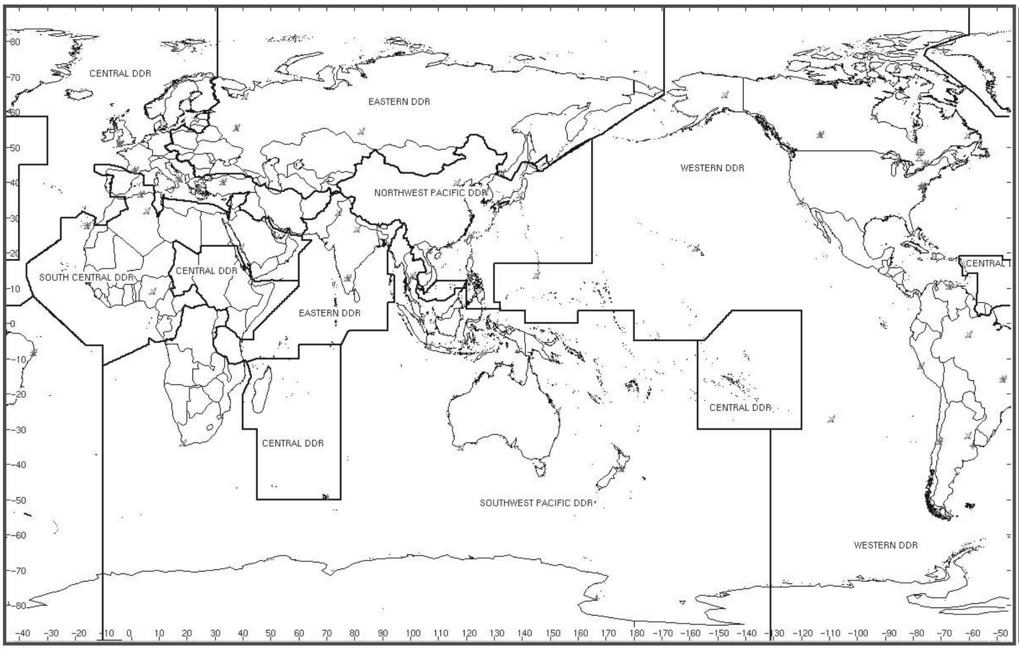
Nodal MCCs



Simplified Flow Diagram of Cospas-Sarsat Alert Data
Diagram courtesy of the International Cospas-Sarsat Programme

The network was organised on a regional basis with one 'Nodal MCC' in each Data Distribution Region (see network structure in the picture at left). Each MCC would communicate with the regional node and distribute data to its own national RCCs and to the SAR points of contact of countries in its service area.

Although simple in design, this network structure had to be adapted in various regions of the world to take into account actual communication capabilities and particular operational or political constraints.



Data Distribution Regions

Western DDR
Node USMCC (USA)

Central DDR
Node FMCC (France)

Eastern DDR
Node CMC (Russia)

South West Pacific DDR
Node AUMCC (Australia)

North West Pacific DDR
Node JAMCC (Japan)

South Central DDR
Node SPMCC (Spain)

Source: Cospas-Sarsat Secretariat

For example, MCCs with adjacent service areas on each side of the Northern Atlantic Ocean could exchange alert data directly without going through the regional nodes (the USMCC and the FMCC) to speed up communications, particularly for 121.5 MHz alerts located in the Atlantic Ocean. In other parts of the world, political considerations had to be accommodated, some countries refusing to be part of a particular MCC service area due to acute neighbourhood conflicts. After additional nodes were established to enhance the data distribution service, the Data Distribution Regions geography looked somewhat more complex than the simple original design. The production of computer-generated maps for the GEOSORT document became one of the on-going tasks of Vladislav Studenov at the Cospas-Sarsat Secretariat (see the map of DDRs on the previous page).

SIT Messages

To overcome the limitations of 1980s data communication networks in a pre-Internet era, typically telex or the Aeronautical Fixed Telecommunications Network [3] (AFTN), and to allow automatic processing of alert data by computers, Cospas-Sarsat alert messages were coded according to a specific format for each possible eventuality (the Subject Identification Type or SIT). For example, a 406 MHz initial alert with Doppler location, exchanged between two MCCs, a 'SIT 125' message type, is shown in the top text box to the left:

The decoded plain text format of the same alert message, a 'SIT 185', is shown below in the second text box. Even after decoding, the interpretation of this type of alert message obviously required some basic training of RCC personnel.

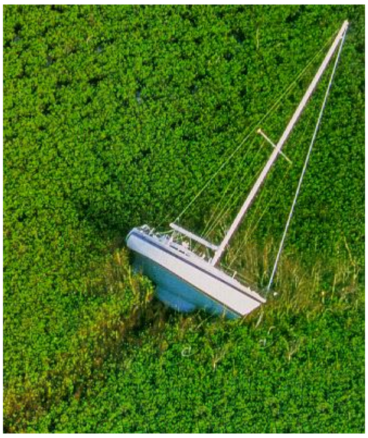
Example of a SIT 125 Message

/12590 00000/5030/08 008 0401 /125/5030/010/01 /5121/-9/+02983.9
002.3 +00.00/08 008 0354 56.60/0 /9/13.803/0000/09
/6007A14ABC00160E90824000000000 /+503/-41.234/+172.516/337
000.7 000.6/79/08 008 0409/3/002.5 000.6 /+503/-48.334/+135.857/325
002.8 001.4/21/08 008 0547/1/008.1 004.6 /LASSIT /ENDMSG

Decoded SIT 185 of a 406 MHz Alert

080401Z JAN 08
FROM AUMCC
TO RCC WELLINGTON
BT
1. DISTRESS COSPAS-SARSAT INITIAL ALERT
2. MSG NO: 12590 AUMCC REF: C00F429578002C1
3. DETECTED AT: 08 JAN 08 0354 UTC BY SARSAT S10
4. DETECTION FREQUENCY: 406.0280 MHZ
5. COUNTRY OF BEACON REGISTRATION: 512/ NEWZEALAND
6. USER CLASS:
SERIAL USER
PLB - SERIAL NO: 0042334
7. EMERGENCY CODE: NIL
8. POSITIONS:
RESOLVED - NIL
DOPPLER A - 41 14 S 172 31 E PROBABILITY 79 PERCENT
DOPPLER B - 48 20 S 135 51 E PROBABILITY 21 PERCENT
ENCODED - NIL
9. ENCODED POSITION PROVIDED BY: NIL
10. NEXT PASS TIMES:
RESOLVED - NIL
DOPPLER A - 08 JAN 08 0409 UTC WELLINGTON LUT NEW ZEALAND
DOPPLER B - 08 JAN 08 0547 UTC ALBANY LUT AUSTRALIA
ENCODED - NIL
11. HEX ID: C00F429578002C1 HOMING SIGNAL: 121.5 MHZ
12. ACTIVATION TYPE: MANUAL
13. BEACON NUMBER ON AIRCRAFT OR VESSEL NO: NIL
14. OTHER ENCODED INFORMATION:
CSTA CERTIFICATE NO: 0176
BEACON MODEL - STANDARD COMMS, AUSTRALIA: MT410, MT410G
15. OPERATIONAL INFORMATION: LUT ID: WELLINGTON, NEW ZEALAND
16. REMARKS: NIL
END OF MESSAGE

Cospas-Sarsat document C/S G.007



Photos courtesy of the International Cospas-Sarsat Programme

3/ International Telex was slow, expensive and not very reliable. AFTN, a closed network for civil aviation safety needs, was not available at some SPOCs, particularly Maritime RCCs. These communication systems were later replaced by a data network using the X.25 protocol, when available, and ultimately by the Internet, but the SIT message format is still the basis of automatic data exchange in the Cospas-Sarsat MCC network.

5.1.3 The Politics of Boundaries

Very few issues to be debated in international meetings can be more sensitive than the concept of boundaries, not only when applied to the territorial borders of States, but also for services provided over international waters, such as the Flight Information Regions (FIRs) for air traffic management and the Search and Rescue Regions (SRRs) for maritime SAR services.

An SRR is a sea area in which a State volunteers to exercise responsibility for the provision of SAR services. SRRs established by agreement among the parties concerned should be contiguous, but not overlapping. The 1979 maritime SAR convention[4] explicitly stipulates that "*the delimitation of search and rescue regions is not related to and shall not prejudice the delimitation of any boundaries between States*". However, this cautious and diplomatic wording was not enough to prevent actual disputes between States on the delineation of SRRs. In many parts of the world, disagreements between neighbouring States were experienced in the development of SRRs and many remain unresolved to this day. Therefore, it was not entirely a surprise that the definition of service areas for the distribution of distress alerts by Cospas-Sarsat MCCs would create similar difficulties, particularly when Cospas-Sarsat initiated the production of maps to describe these MCC service areas.

As the Cospas-Sarsat Council had no authority to impose a solution on disagreeing parties, the Council adopted a pragmatic approach whereby:

- where possible, MCC service areas should be based on existing SRRs and, like SRRs, MCC service areas should be contiguous, not overlapping and agreed among interested parties;
- if agreement on a common boundary could not be reached, both MCCs would distribute to the appropriate RCC Cospas-Sarsat alert data for distress situations located in the overlapping portion of their respective service area;
- Cospas-Sarsat would define in an internal document (the GEOSORT document), not to be publicly released, the MCCs' individual service areas as a series of geographical coordinates (latitude-longitudes), without showing on maps the existing overlaps.

For all practical purposes, the Cospas-Sarsat approach ensured that responsible RCCs would in any case receive the appropriate alert data, although sometimes twice. What the Council did not foresee was that, on rare occasions, participating States would refuse to accept the compromise solution and insist that the opposing party could not be allowed to operate their newly established LUT and MCC. The matter was particularly hot in the Western portion of the Pacific Ocean and the China seas.

During a Cospas-Sarsat Joint Committee Meeting held in Fremantle, Western Australia in 1993 (JC-7), the Head of Secretariat invited two East-Asian countries' delegations to join in a splinter meeting to clearly state and acknowledge the disagreement on their respective MCC service area boundaries, which would allow the Joint Committee to recommend implementing an overlap and bring the new MCC into operation in accordance with the stated Council policy. Before the end of the JC meeting, a junior diplomat from one of the opposing parties had flown all the way from Canberra to Fremantle to convey to the Head of Secretariat the diplomatic but firm disapproval of his Embassy on the initiative that forced a bilateral meeting of both delegations and would lead to the unwanted compromise solution to the existing conflict. Similar situations happened several times, although not always where expected. There was no difficulty bringing the Chinese Taipei

4/ See in Annex 2, section 1 on Maritime SAR.

MCC (TAMCC) in Taiwan, China into operation with a service area that was completely overlapped by the Hong Kong, China MCC (HKMCC) service area.

5.1.4 Official Policies and Pragmatic Alternatives for Effective Alert Distribution

IMO and ICAO, the two international organisations with responsibilities for international SAR regulations, acknowledged the efforts undertaken by Cospas-Sarsat to organise the distribution of the satellite-generated alerts and the positive contribution of the system to search and rescue operations. However, formal policy considerations did at times lead to diverging approaches to operational issues. IMO and ICAO were both engaged in a continuous effort aiming to develop RCCs in parts of the world where such facilities did not exist. In accordance with this policy, both organisations insisted that all alert data be transferred automatically to the relevant RCC according to the computed location of the distress situation. The IMO and ICAO SAR Plans effectively recorded the States' declarations of existing and planned facilities for SAR, but the Plans sometimes gave an optimistic picture of the operational status of the listed facilities.

Faced with the considerable diversity of national SAR organisations and the complexity of having to deal with aeronautical and maritime distress alerts, as well as alerts from Personal Locator Beacons (PLBs), Cospas-Sarsat requested that each State designate a single SAR Point of Contact (SPOC). This strategy was accepted by both ICAO and IMO, but many States failed to designate a single SPOC. Cospas-Sarsat MCCs soon experienced serious difficulties concerning the responsiveness of the designated SPOCs or RCCs in some parts of the world. RCCs that were supposed to receive and act upon Cospas-Sarsat distress alerts were sometimes unreachable or did not act upon the alert messages they were receiving. Even where RCCs had been effectively established and a single SPOC designated by the State, several factors were identified as the source of the problems experienced by Cospas-Sarsat MCCs:

- unreliable telecommunication networks for automatic data transmissions;
- 'operational' facilities not available 24 hours a day, and sometimes not available at all;
- misinterpretation of the alert messages sent by Cospas-Sarsat due to a lack of knowledge about the satellite system; and
- lack of SAR resources to adequately respond to a distress alert.

For diplomatic reasons, openly naming the failing SAR authorities in international meetings was almost impossible and would have been ineffective in bringing actual changes in those countries. Therefore, Cospas-Sarsat MCCs had to develop stop-gap measures, sometimes in opposition with the officially stated policies for alert data distribution, which included:

- forwarding the alert in parallel to the national SAR authority of the ship/aircraft in a distress situation [5], which soon became a standard Cospas-Sarsat policy;
- forwarding the alert in parallel to their own national SAR authorities; or
- forwarding the alert to the SAR authorities of neighbouring countries known to be responsive.

After years of fruitless efforts to improve the operational response of some of their SPOCs, Cospas-Sarsat MCCs also started regular communication tests. Although the test results did not

5/ In the Cospas-Sarsat operational jargon, this procedure is referred to as the 'notification of country of beacon registration (NOCR)' change the actual situation on the ground, they allowed Cospas-Sarsat to publish evidence of the improper status of facilities supposed to be 'operational' and organise alternative distribution channels where necessary.

5.1.5 406 MHz Combined LEO/GEO Operations

The Cospas-Sarsat satellite system for SAR was initially designed for operation with low-altitude Earth orbiting (LEO) satellites. This choice ensured its successful demonstration with spectacular contributions to real world SAR operations through the 121.5 MHz capability. However, even after 406 MHz EPIRBs had been adopted by IMO in 1988 for use in the GMDSS, it was clear that a quasi real-time alerting capability would soon be required, which LEO systems could not provide at an acceptable cost.

The challenges for Cospas-Sarsat were to:

a) demonstrate that 406 MHz beacon transmissions, tailored for LEO on-board processing, could be relayed by geostationary satellites orbiting 36,000 km above the Earth and adequately processed on the ground to reliably produce beacon identification data and, when available, the encoded beacon position [6];

b) ensure that at least three GEO satellites adequately spaced in longitude would be available at all times to provide global and continuous alert monitoring; and

c) devise appropriate procedures to automatically process, sort and forward LEO and GEO generated alert messages to the appropriate SPOC/RCC on a worldwide basis.

The design issues of the 406 MHz GEOSAR system and its implementation using geostationary satellites provided by the United States, India, the EUMETSAT organisation and Russia are described in Chapter 3, section 3.3. The third aspect, alert data distribution in a combined LEO/GEO system, is briefly addressed in this section.

Merged LEO/GEO Operations

In the 406 MHz LEOSAR system, despite the complexities of the Doppler ambiguity resolution, the alert validation and sorting process was rather straightforward. If the same or similar information provided by another LUT had already been forwarded to the relevant SPOC/RCC and Doppler ambiguity had already been resolved, the new data could be considered redundant and not processed further. The introduction of a continuous flow of 406 MHz GEOSAR alert data after 1996, some with encoded position data, added a new level of complexity.

All GEOLUTs in a given GEO satellite coverage area would essentially produce the same alert data. The benefit of a very high level of redundancy was a high probability of actually detecting all beacon transmissions in quasi real-time. The drawback was that a continuous flow of alerts could flood RCCs with repetitive, irrelevant information, unduly consuming the valuable time of RCC personnel.

6/ 406 MHz location protocol beacons, which allowed the transmission of encoded position data provided by a Global Navigation Satellite System receiver integrated in the beacon, were first introduced in 1996. This evolution required major adaptations of the Cospas-Sarsat Ground Segment (LUTs and MCCs) and the development of a comprehensive set of new message processing procedures at the MCC level.

Therefore, a GEOLUT that received 406 MHz beacon bursts on a continuous basis had to 'decide' whether 'new' information was available in the data being processed. Objective criteria were required to define what constituted new or updated information, for instance a different, more recent encoded position, and decide whether this data was worth processing and forwarding further.

At the MCC level, new LEOSAR data with two Doppler positions (the A and B solutions of the Doppler location computation) had to be compared to previously received LEOSAR data and to GEOSAR data for the same beacon if an encoded GNSS position was available in the previous transmissions of the beacon. An automatic 'decision' was then required to either forward the new data or block further transmissions. Similarly, new GEOSAR alert data had to be compared with 'older' LEO and GEO data and processed according to strict filtering criteria. The same MCC sorting rules would apply to alert data produced by other LEO or GEO LUTs and received from other MCCs.

Without a thorough and efficient automatic sorting algorithm, the added flows of LEO and GEO alerts to be distributed worldwide could have become a major stumbling block for the combined LEO/GEO 406 MHz system. The matter was addressed in a Task Group meeting in Canberra, Australia, in March 1996 (TG-1/1996). The Task Group produced the desired filtering algorithms, leading to a new, augmented issue of the Data Distribution Plan. Major upgrades to the MCC network were implemented by 1998 and the Council at its CSC-21 Session in October 1998 could make the formal decision to "*accept the 406 MHz GEOSAR components of the US Geostationary Operational Environmental Satellites (GOES-East and GOES-West) as an enhancement to the existing Cospas-Sarsat satellite system*"[7].

Although the 406 MHz GEOSAR component of the INSAT-2 system was also available at the time, providing an almost complete GEO coverage, the status of India as a 'Space Segment Provider' had not been finalised. The matter would be resolved in 2007, after a nine-year delay, with the signing of a separate agreement between India and the Cospas-Sarsat Parties[8]. However, INSAT 406 MHz GEOSAR alerts were made available to Cospas-Sarsat and distributed to RCCs from 1998, though formally on a 'trial' basis.

The USMCC in Suitland, Maryland, USA
Photo courtesy of NOAA

Ship Security Alerts

With a quasi real-time alerting capability, the Cospas-Sarsat System could also support an IMO anti-piracy effort with a class of beacons called Ship Security Alerting System (SSAS). These beacons are processed in the same way as EPIRBs, but ship security alerts are distributed only to the national authorities responsible for ship security, according to the country code embedded in the SSAS beacon alert message.

7/ Quoted from CSC-21/OPN Summary Record, section 4.2.4 - October 1998.

8/ See Chapter 4, section 4.4.3.

5.2 System Reliability, Equipment Commissioning and Type Approval Procedures

Ground Segment Equipment Commissioning

Cospas-Sarsat is an open satellite communication system. To ensure the reliability of a safety system based on a variety of equipment operated in a large number of countries, strict 'commissioning' procedures were required. The procedure aimed to ensure that ground segment equipment met agreed performance criteria prior to being declared operational and accepted for operation into the Cospas-Sarsat System.

This policy was gradually introduced after 1985 with the development of appropriate functional and performance specifications and commissioning tests, firstly for LUTs which could be freely manufactured and sold to operating agencies, and then for MCCs with a view to standardizing the distribution and processing of alert messages and guaranteeing a minimum level of reliability. Through the formal association procedure of participating countries, the Cospas-Sarsat Council could impose on 'Ground Segment Providers' commissioning tests and formal reporting procedures on the performance of their equipment.

Distress Beacon Type Approval

The situation was different for distress beacons deployed in the field. As 121.5 MHz ELTs existed before the satellite system was implemented, no control could be exercised by Cospas-Sarsat on their specifications or the actual performance of beacons sold to the public. At 406 MHz, Cospas-Sarsat had full control of the transmission characteristics of the beacons, as specified in document C/S T.001 approved by the Council, but no means of directly controlling national Administrations who authorised the sale of particular beacon models to users, especially in countries not formally associated with the Programme. The prerogative of formal certification and type approval remained solely with national Administrations.

The alternative approach was to:

- develop a specific Cospas-Sarsat type approval procedure addressing the transmission characteristics of 406 MHz beacons, including a series of tests thoroughly defined in document C/S T.007, 'Cospas-Sarsat 406 MHz Distress Beacon Type Approval Standard';
- encourage manufacturers to submit new beacon models for testing according to the Cospas-Sarsat procedure and publicize the list of models that had received a Cospas-Sarsat type approval certificate; and
- encourage participating countries to require the Cospas-Sarsat type approval certificate, as part of their own national procedure, before authorising placement on the market of new beacon models.

The Cospas-Sarsat type approval procedure was used as a sub-set of the national certification procedures imposed by major countries. A similar approach was adopted by national Administrations for other beacon characteristics (environmental specifications, resistance of ELTs to crash or fire, floatability of EPIRBs, etc.). After functional and performance requirements had been adopted by international organisations such as IMO and ICAO, detailed specifications and testing standards were set by industry organisations[9] and formally adopted by national Administrations as part of their national regulations.

9/ RTCA (Radio Technical Commission for Aeronautics) and RTCM (Radio Technical Commission for Maritime Services) in the United States; ETSI (European Telecommunications Standards Institute), EUROCAE (European Organization for Civil Aviation Equipment) in Europe and IEC (International Electrotechnical Commission).

5.3 Highlights of Operational Results to 2009 [10].

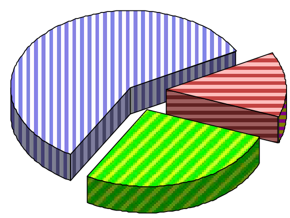
At the end of 2009, 43 States and Organisations were active participants in the Cospas-Sarsat Programme. Six LEOSAR satellites and five GEOSAR satellites were operating in orbit. The ground segment included 57 LEOLUTs and 20 GEOLUTs. The 406 MHz beacon population was estimated at over 945,000.

From September 1982 to December 2009, the Cospas-Sarsat System provided assistance in rescuing at least 28,375 persons in 7,746 SAR events

Cospas-Sarsat Alert Data Used in SAR Events in 2009

From January 2009 to December 2009, the Cospas-Sarsat System provided assistance in rescuing **1,596 persons in 478 SAR events.**	**Type of distress**	**Number of Persons rescued**	**Number of events**
	Aviation	271	66
	Maritime	1,101	281
	Land/Persons	224	131
	TOTAL	**1,596**	**478**

Categories of SAR Events (Jan. - Dec. 2009)



5.3.1 Examples of SAR Events with Cospas-Sarsat 121.5 MHz Distress Alerts

The processing of 121.5 MHz signals by the Cospas-Sarsat System was terminated on 1 February 2009, more than 26 years after the beginning of Cospas-Sarsat operations (1 September 1982). During this time period, the 121.5 MHz system was used in more than **3,500 distress events** (all types: maritime, aviation and personal beacons on land) in which over **8,900 people were rescued**. The following sections illustrate some SAR cases in which Cospas-Sarsat data assisted SAR authorities in rescuing people and cases in which Cospas-Sarsat data was not of assistance to SAR.

The following cases in the Pacific Ocean region provide examples of both the benefits of the Cospas-Sarsat 121.5 MHz system and its limitations, particularly in terms of coverage. They were presented by Lt. S. Burlingame of the Joint Rescue Coordination Centre (JRCC) Honolulu during the Cospas-Sarsat Pacific Region Conference (17 May 1990).

The MARGARET G. SAR Case

At 04:45 local time, **2 May 1989**, a merged Cospas-Sarsat (121.5 MHz) solution was received in the Joint Rescue Coordination Centre (JRCC) Honolulu for a position approximately 300 NM south of Honolulu. A U.S. Coast Guard C-130 aircraft was launched to investigate.

Approximately 4 hours later the drifting fishing vessel Margaret G. and an orange life raft were sighted. The raft contained the sole survivor from the original crew of three from Margaret G. The vessel had lost all power and the fish in its holds became rotten. While trying to throw the rotten fish overboard, two crewmen died when they were overcome by toxic fumes. The survivor deployed the vessel life raft and activated the 121.5 MHz EPIRB. U.S. Navy and Coast Guard vessels were dispatched and the survivor was delivered safely ashore.

Lt. Scott Burlingame, JRCC Honolulu

10/ Statistical data are published annually by the Cospas-Sarsat Secretariat in the document titled "Cospas-Sarsat System Data" which can be downloaded from the Cospas-Sarsat Website at www.cospas-sarsat.int. Up-to-date statistics are available from the Cospas-Sarsat Secretariat for the years after 2009.

The SIBONEY SAR Case

The sailing vessel Siboney departed the Panama Canal on an intended voyage to Honolulu with two people aboard, a 121.5 MHz EPIRB, and a variety of other electronic communications and navigational equipment.

On **15 June 1989**, approximately 1,200 NM west-south-west of the canal the vessel was sunk by a whale and the two passengers forced into a small life raft. The Siboney was not within the area covered by our present or future Cospas-Sarsat LUTs and its 121.5 MHz EPIRB signal was not received. The raft remained **adrift for 66 days** before being sighted by a Costa Rican Coast Guard vessel on routine patrol approximately 30 NM off the Costa Rican coast. Despite losing 50 pounds each the two people survived and have fully recovered from their ordeal at sea. Had Siboney been carrying a 406 MHz EPIRB, they almost certainly would have been rescued much sooner.

Lt. Scott Burlingame, Joint RCC Honolulu

Aeronautical SAR cases, such as the Ziegleheim SAR case, where Cospas-Sarsat alert data was instrumental for the rescue of survivors, have been presented in Chapter 2 and Chapter 3, section 3.2. The following case illustrates the need for SAR authorities to build their experience of using the satellite alerting service. The effectiveness and the limitations of the 121.5 MHz system, in particular the absence of an identification in the alert signal, are also highlighted.

The Lost Varig Flight from Marabá to Belém, Brazil

On 3 September 1989, 20:35 UTC, the Varig flight RG-254, a Boeing 737-200 aircraft, took off from Marab**á**, in northern Brazil, on the last leg of its flight to Belém. The flight crew had inadvertently entered the wrong heading (*270° instead of 27°*) into the flight computer (*i.e., a West heading instead of the required North/North-East heading*). After the expected flight time to reach Belém, unable to locate the destination airport, the crew finally discovered the error. However, the aircraft was far from a suitable airfield and the crew had lost considerable time, having tuned its navigation receiver on the wrong radio-aids (same Non-Directional Beacon frequencies as expected for Belém, but incorrect NDB identifications), the aircraft ran out of fuel. The pilots had to make an emergency landing in full darkness. Forty three of the fifty four aircraft occupants survived the forced landing. A twelfth passenger died before being rescued.

All communications with Air-traffic Control Centre, ACC Belém, had been via HF. At 21:35 UTC, ACC Belém declared an 'Incerfa' (uncertainty phase), followed by a 'distress phase' at 00:35 UTC, four hours after the aircraft had taken-off from Marabá. This started a full scale SAR operation and RCC Belém asked INPE (Instituto Nacional de Pesquisas Espaciais; the Brazilian space agency that was operating a LEOLUT) for possible satellite alerts.

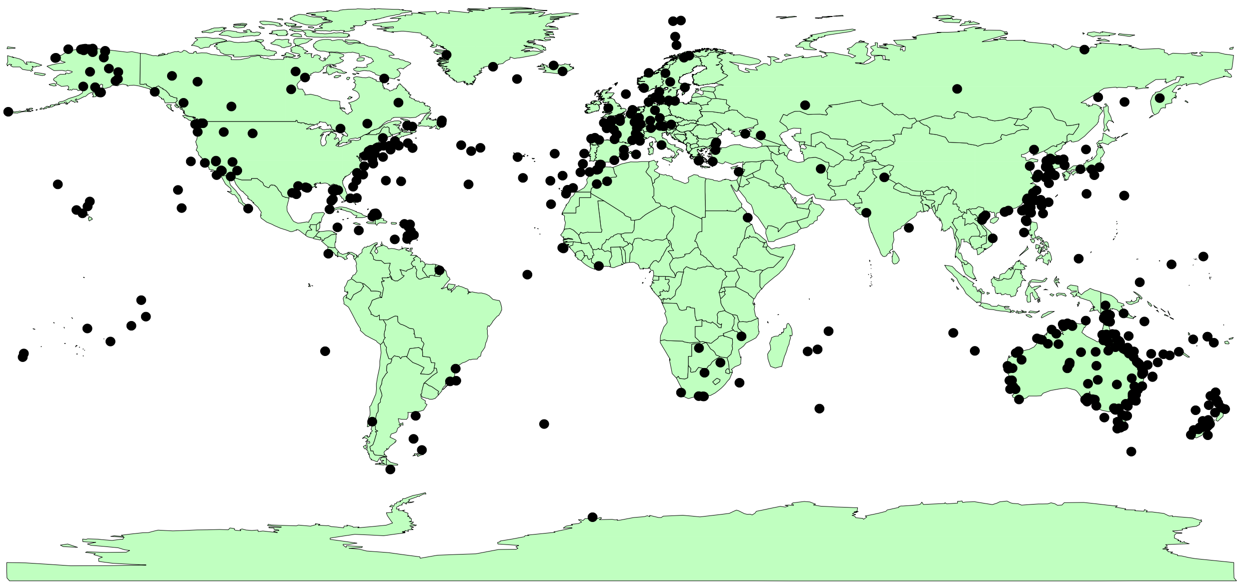
The aircraft did not have a 'fixed' ELT which could have been automatically triggered by the crash landing. However, it carried a water activated ELT, a type that would transmit in case of immersion after a landing on water. The pilot had recovered the ELT and used ice cubes from the aircraft galleys, and urine, to trigger ELT transmissions. On the second day, a passenger, an experienced gold miner, went out to find water and discovered a creek, which helped maintain the ELT operation.

At 12:50 UTC on 04 September, RCC Belém received via telephone a Cospas-Sarsat location (the A and B position coordinates: 09°50' S/052°04' W and 10°57' S/051°55' W) for a possible 121.5 MHz ELT, far from the expected aircraft flight path. A search in this area was programmed on the next day.

On the next morning, 05 September, SAR resources were concentrated in the indicated Mato Grosso region. 121.5 MHz signals were received intermittently by the search aircraft, but they were unable to home on the signals using the aircraft direction finder. More Cospas-Sarsat locations were forwarded to RCC Belém. The same morning, two survivors of the crash went for help and reached the Curumaré farm at 17:15 UTC, where they could make phone calls to aviation authorities. Approximately 44 hours after the accident, the downed aircraft was finally located at the position 10°46' S/052°21' W - 1,100 km from the intended destination. One injured passenger was evacuated by helicopter on the same evening. All remaining survivors were evacuated on the following day.

Maj. Av. Fábio L.C. Barbosa
DECEA (Air Space Control Department) - SAR Planning Section, Brazil

The disappearance of an airliner is a rare event and the survival of the ELT in a severe crash is rather unlikely. However, the above example where an ELT did operate in a distress situation is not unique. When a bomb exploded on the Air India 182, a Boeing 747 flying from Montreal, Canada to London, UK, on 23 June 1985, the aircraft crashed into the Atlantic Ocean 120 NM off the south-west coast of Ireland, causing 329 casualties. 121.5 MHz transmissions were reported by overflying aircraft. The ELT location was provided by the French MCC one hour after the loss of radar contact (Sarsat-1 spacecraft - ELT position 51-01.9N, 123-46.8W). The ELT from the Air India, a floating type stowed with life rafts, was recovered by a Sea King rescue helicopter of the UK Coastguards about 4 hours after the crash. In the case of lighter aircraft, the likelihood of passengers and ELT survival is much greater and between September 1982 and February 2009, Cospas-Sarsat ELT alerts at 121.5 MHz have helped in the rescue of 3,020 persons in 1,489 SAR events involving crashed aircraft.



Cospas-Sarsat System Use during 2008

The figure shows the geographical distribution of 2008 SAR events assisted by Cospas-Sarsat alert data (406 MHz and 121.5 MHz). During 2008, Cospas-Sarsat alert data provided assistance in 502 SAR event in which 1,981 persons were rescued.

Cospas-Sarsat Information Bulletin No. 22 - February 2010

5.3.2 Examples of SAR Events with Cospas-Sarsat 406 MHz Distress Alerts

Cospas-Sarsat alerts are not necessarily the 'only alert' received by an RCC in a distress situation. However, Cospas-Sarsat alert data is often instrumental to the success of the rescue.

The following stories illustrate the diversity of SAR cases and the effectiveness of the Cospas-Sarsat 406 MHz system in providing assistance to SAR forces at sea or on land.

Photos courtesy of the International Cospas-Sarsat Programme

406 MHz Beacon Registration Can Save Your Life

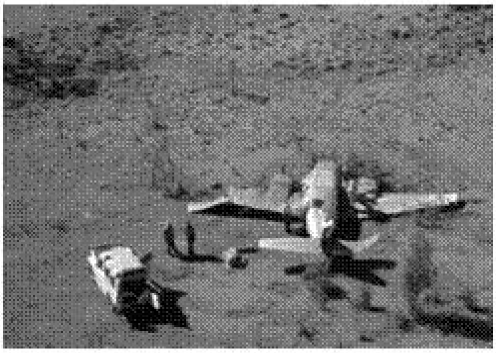
GPS position data encoded in 406 MHz beacon distress messages is a tremendous help for SAR operations, as demonstrated in numerous alerts. However, the value of a reliable Doppler position and accurate registration information was again demonstrated by the following incident.

At 20:33, 30 January 2003 the operations duty watch at MRCC Falmouth received, via the UK Mission Control Centre (UKMCC) at Kinloss, an alert from a 406 MHz beacon equipped with a GPS receiver. However, no position data was available, either encoded or derived from Doppler processing. The UK 406 EPIRB database was checked and the emergency contact provided the last known position of the vessel, confirming that there was only one person onboard. MRCC Falmouth was able to ascertain a possible search area.

At 20:45, the first LEO satellite data provided good position information, although at this stage there still wasn't any GPS data. A helicopter and lifeboat were tasked and vessels in the vicinity were alerted. At 21:01 a second Doppler location was received confirming the previous data. As the incident progressed and more satellite passes were received, the position was further pinpointed. The SAR resources used directional finding equipment to pick up the beacon's 121.5 MHz homing device and were able to identify the casualty.

The helicopter was able to isolate strong 121.5 MHz signals, 15 NM from the target, flying at 1,800 feet. The yacht had been dismasted and was floating just beneath the water. The lifeboat rescued the single occupant. The beacon continued to transmit, but it was not until 22:41 hours that the first GPS data was received. The importance of beacon registration, especially in the early stages of SAR action, is well highlighted in this incident. Although GPS data was not immediately available, given the LEO position data, information from the registered shore contact and the ability to home in on 121.5 MHz, the rescue was successfully completed. The weather conditions that evening were not favourable for a single-handed yachtsman, with rough seas and a northerly force 7/8 wind speed. The casualty had attempted to alert SAR authorities using his mobile phone but had been thwarted by flat batteries. In the end, a correctly registered beacon, good LEO data, and 121.5 MHz homing saved the day and his life.

Information Bulletin No.16 - August 2003



Australian Mayday Call Located

At 09:17 on 17 July 2008, a Piper Navajo (PA31) declared a mayday while on a flight to Mount Isa, a mining town in central Queensland, Australia. RCC Australia responded by diverting aircraft of opportunity to the scene but the position given was inaccurate and a search ensued. The pilot was badly injured in the crash landing and was unconscious for about 30 minutes. However, on regaining consciousness, he was able to return a call left on his mobile phone by the RCC. Unsure of his position and in considerable pain from a broken leg and back injuries, the pilot was unable to reach his 406 MHz PLB or first aid kit. He had been dislodged from the pilot's seat and partially wedged in the seat one row back. He also reported he could hear fuel leaking and that the aircraft master switch was still on.

With tension high and the crashed aircraft covered in fine red dust, which made it difficult to see, search aircraft were unable to locate the crash site. After encouragement from the RCC, the injured pilot was finally able to reach and activate his 406 MHz PLB. A light helicopter heard the signal and, with deft use of aural homing and terrain shielding, commenced a search in the vicinity. The injured pilot heard the helicopter nearby but said it was heading away, whereupon the RCC guided it back to the scene. Simultaneously, a Cospas-Sarsat satellite detected the 406 MHz PLB (non-GPS type) at the crash position and the aircraft was subsequently located (20° 28' S 139° 26' E).

A paramedic was rushed to the scene and the injured pilot was taken by ground ambulance to Mount Isa Hospital where he was treated.

Cospas-Sarsat Information Bulletin No. 21 - February 2009

Fishing Vessel 'Villa de Aquete'

1 July 2009 - The Spanish fishing vessel *Villa de Aguete* sank at a position approximately 28 nautical miles south of Cabo Blanco, Mauritania. The case began when at 13:46 UTC, the MRCC Madrid received an EPIRB alert within the Mauritanian SAR responsibility area from the Spanish MCC (SPMCC) in Gran Canaria.

Immediate communications were established with the SAR Authorities of Mauritania as well as with the ship owner. The ship owner provided the information that two other fishing vessels from the same company were located in the same area. These vessels were contacted to report the state of the vessel *Villa de Aguete*.

At 14:05 UTC a 'mayday' relay transmission from the fishing vessel *Manuel Nores* was received at the Regional Rescue Coordination Centre in Las Palmas indicating the same graphical position of the sinking fishing vessel *Villa de Aguete*.

Communication with the fishing vessels answering the alert call established that the vessel *Portomayor* was participating in rescue operations. The *Portomayor* informed that it had rescued 22 crew members (one dead) and that the *Villa de Aguete* had sunk at the position 20°26' N, 17°24' W. The Spanish fishing vessels *Curbeiro* and *Santomar* participated in the rescue operations along with an unidentified Mauritanian vessel. The rescued crew members were transferred to the *Estela* fishing vessel and taken to the port of Nouadhibou (Mauritania) where the 13 Mauritanian crew members disembarked.

In this case, the Cospas-Sarsat System provided the **first alert**.

Cospas-Sarsat Information Bulletin No. 22 - February 2010

Brothers Survive Fall Through Ice

Brothers Sølve and Bård Pettersen, aged 18 and 21, had been spending the winter hunting in the most northerly reaches of Norway's Arctic archipelago of Svalbard. On **27 March 2008** they set off on a ski trip, following the coast, when their ordeal began. Their dogs, fastened to the brothers' belts, caught the scent of a polar bear and went after it, dragging the brothers out onto the ice, according to Petter Braaten of the Svalbard sheriff's office.

The ice farther out in the fjord was too thin to support the weight of the boys and the dogs. It cracked, and all the dogs and the two brothers landed in the icy seawater.

"Sølve and Bård got themselves up on the ice again," Braaten said, "but Bård jumped back in the water to retrieve his backpack, which held an emergency transmitter." Unfortunately, they couldn't reach the dogs, and all five drowned in the Arctic waters.

The brothers activated their PLB, which provided the **first and only distress alert** for this incident (79°35' N - 14°00' E). The brothers made it back to the hut, which was still warm. Both suffered serious frostbite, however, with the outdoor temperature at minus 20°C. Rescue crews arrived about 90 minutes after their PLB was activated and the boys were taken first to hospital in Longyearbyen and then to Bodø on the mainland for treatment. "That they survived the drama at all is due to the excellent operation of the Cospas-Sarsat System," said Tore Wangsfjord of the Norwegian JRCC at Bodø.

Cospas-Sarsat Information Bulletin No. 21 - February 2009

Bird Strike in Botswana: 406 MHz ELT Alert Received Within Minutes

On Thursday, **14 September 2006**, a pilot with the Flying Mission Services of Gaborne, Botswana, took off from Nxabega with four passengers on what should have been a routine flight to Tsigaro. The Cessna 206 aircraft took off at 12:07 UTC, anticipating a short flight with an estimated time of arrival at Tsigaro at 13:25 UTC. […]

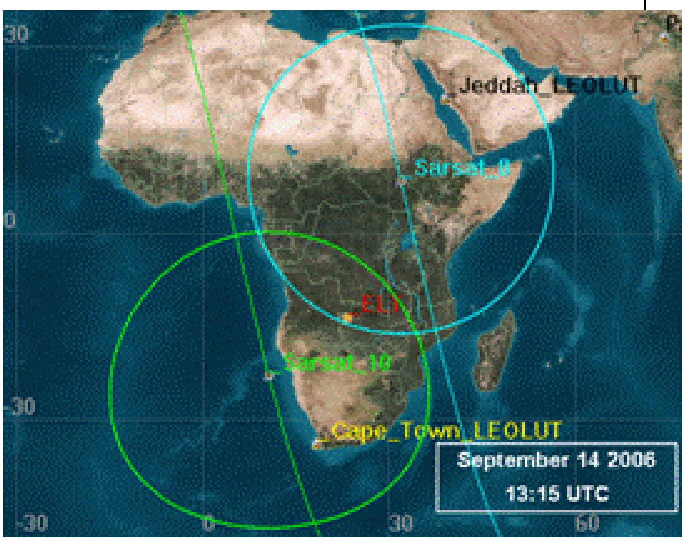
About 15 minutes into the flight, the pilot looked up to see a large bird, less than 20 meters away. He said, "I immediately turned left, trying to avoid the vulture, but the bird hit directly into the windscreen on the pilot side. There was a huge blast and I felt a strong hit into my face and my upper body." […] Two miles from Stanley's it was apparent that we wouldn't make it to the field. I saw a flat clear opening with shallow water just past a little lagoon. As soon as the airplane touched the water, the plane looped and water gushed into the cabin. When we stopped moving, we were hanging upside down in our seat belts. My head was in the water."

The pilot helped all evacuate the plane through the co-pilot side window. He states, "I climbed back into the airplane to see if I would be able to make a distress call. I could not get the radios to work but the Emergency Locator Transmitter (ELT) was beeping." The Cape Town Cospas-Sarsat Mission Control Centre (ASMCC) received an un-located alert from the UK's Geostationary satellite station (GEOLUT) at 12:32:21 UTC on 14 September. The beacon's identification was decoded and the registration data indicated that the aircraft was registered to the Botswana Flying Mission Services. The RCC operators were able to use this information to begin telephone liaison with the listed emergency contact, approximately 18 minutes after beacon activation.

The GEO detection was followed by LEOSAR detection at 13:15 UTC by Sarsat-10, tracked by the South African LUT. This detection provided an alert message that was sent to the RCC at 13:20:05 UTC indicating a Doppler A position of 19°38' S / 023°17' E with a 91 % probability. A second LEOSAR overpass of the distress site by Sarsat-8 at 13:15 UTC on 14 September was tracked by the Saudi Arabian LEOLUT at Jeddah, and a resolved position of 19°38' S / 023°17' E was provided to South Africa at 13:28:44 UTC. A helicopter was sent to the coordinates and was able to reach the site at 14:45 UTC. Within two hours of the emergency landing, all passengers and the pilot were safely evacuated.

Mr. Derek Cooper of the South African Cospas-Sarsat MCC said, "The 406 MHz ELT carried by the Flying Mission Services aircraft provided the first and only alert in this distress incident. The fact that the beacon was properly registered allowed search and rescue to proceed quickly, with the first responders arriving on scene only one and a half hours after the emergency landing."

Cospas-Sarsat Information Bulletin No. 19
February 2007



5.4 Phasing-out 121.5 MHz Satellite Alerting Services

Year by year, from the time of its inception, the Cospas-Sarsat 121.5 MHz alerting system assisted in the rescue of hundreds of persons in distress. In 1999, the Cospas-Sarsat 121.5 MHz System provided alerts in 160 actual distress situations, whereas the 406 MHz system provided alerts in 180 SAR incidents. At the end of 1999 there were more than 640,000 beacons operating on 121.5 MHz worldwide and, by comparison, 220,000 beacons operating on 406 MHz. In the light of these statistics it is reasonable to ask why the Cospas-Sarsat Council, in 2000, should decide to plan for the termination of the 121.5 MHz satellite alerting system. The answer lies in the negative impact that the 121.5 MHz service had on the SAR organizations that received and acted upon the alerts provided by the Cospas-Sarsat System.

5.4.1 False Alerts: a Severe Hindrance to RCC Operations

> The extent of the 'false alerts' problem can be appreciated by incidents of alerts being generated by transmissions from such irrelevant equipment as defective garage door openers, satellite TV receivers, pizza ovens and radios.

Cospas-Sarsat, IMO and ICAO have worked in close cooperation to optimize mutual understanding of system needs, capabilities and prospects for improvement. These relationships are so important to the Cospas-Sarsat Programme that it is official Cospas-Sarsat policy, documented in the International Cospas-Sarsat Programme Agreement, to "*support the objectives of IMO and ICAO concerning search and rescue*" (Article 2 of the ICSPA). As described in section 5.2, distress alerts produced by the System are distributed to the Rescue Coordination Centre (RCC) in whose area of jurisdiction the distress event occurs. RCCs are provided and managed by national administrations. They operate according to provisions established by IMO and ICAO. It is through IMO and ICAO working groups that senior RCC personnel and representatives of national SAR authorities meet to coordinate activities, share experiences and make recommendations to address deficiencies and improve the quality of services. It is also through ICAO and IMO that concerns with the alert data provided by the Cospas-Sarsat 121.5 MHz system were expressed.

In comparison to the 406 MHz alerting and locating system, the 121.5 MHz system had clear limitations, specifically in terms of coverage, responsiveness and location accuracy. However, for all these disadvantages:

- the satellite system was still the quickest way of locating 121.5 MHz beacons;
- there were hundreds of thousands of such beacons in use; and
- 121.5 MHz beacon carriage had been encouraged by many national Administrations and mandated by ICAO for international commercial flights.

The critical problem that eventually made the 121.5 MHz alerting system unacceptable to SAR service providers was the harmful impact that 121.5 MHz false alerts had on RCC operations.

Impact of 121.5 MHz False Alerts

Both the 121.5 MHz and the 406 MHz systems generated false alerts. However, their respective impact on the effective functioning of RCCs was significantly different.

First introduced on military aircraft in the early 1950s, 121.5 MHz beacons were never designed with a global satellite alerting service in mind. Rather, they were intended for use on aircraft and for detection after a crash by over-flying aircraft using standard VHF voice communication equipment. The location of activated beacons would then be determined by aircraft homing-in on the source of the 121.5 MHz signal. In this concept of operations, 121.5 MHz beacons did not need, nor did they include, features for providing their specific identification. Furthermore, beacons' transmit power levels were optimized for detection only within air/ground ranges measured in the tens of kilometres.

The consequence of these characteristics was that the 121.5 MHz signals, when relayed by satellites at distances of about one thousand kilometres, were near the noise threshold of LEOLUT receivers. When operating with such weak signals, it was technically very difficult to distinguish real beacon transmissions from background noise, or to differentiate them from other emitters operating near the 121.5 MHz frequency. As a consequence, many Cospas-Sarsat System alerts to RCCs were found to be false and SAR resources were expended to chase phantoms. The extent of the problem can be appreciated by incidents of alerts being generated by transmissions from such irrelevant equipment as defective garage door openers, satellite TV receivers, pizza ovens and radios. Statistics on 121.5 MHz false alerts varied from location to location depending upon the level of interfering activity in the frequency band. In some parts of Europe the false alerts accounted for 99% of all 121.5 MHz alerts received at RCCs.

These numbers were troublesome in their own right, but the fact that the analogue 121.5 MHz signals did not include a specific beacon identification made these false alerts particularly troublesome. In contrast, 406 MHz false alerts were far fewer and almost exclusively caused by the inadvertent activation of an actual 406 MHz beacon. Further, since Cospas-Sarsat provided RCCs with the 406 MHz beacon unique identification, RCCs were able to rapidly obtain additional information from beacon registration databases, such as the telephone number of the beacon owner, and so quickly verify the veracity of the alert before dispatching costly SAR units (aircraft, ships or land vehicles) to the detected location. Without any specific identification attached to 121.5 MHz alerts provided by Cospas-Sarsat, the only way to determine whether the alert was genuine was to go and see. Besides being disruptive, this procedure took time, was frequently expensive and could be dangerous to search crews. In reality, RCCs had to develop strategies to validate 121.5 MHz alerts, looking for additional information (calls for overdue aircraft, etc.) or waiting for a confirmation of the alert on a second satellite path in visibility of the site.

Clearly RCCs faced a dilemma. On the one hand there were over 600,000 beacons in use operating at 121.5 MHz and the Cospas-Sarsat System was the quickest way of locating these beacons in an actual distress situation. On the other hand the opinion shared by most RCCs was that:

- 121.5 MHz alerts were unreliable;
- 121.5 MHz false alerts were costly to resolve;
- 121.5 MHz false alerts robbed the SAR system of resources required to assist others in distress and were a burden to the civilian assets often solicited to respond.

5.4.2 IMO Requests the Termination of the 121.5 MHz Satellite Alerting Service

Although 121.5 MHz beacons were used on some watercraft (mainly small pleasure craft), they were not accepted by IMO as satellite-EPIRBs for the ship-to-shore alerting function of the Global Maritime Distress and Safety System (GMDSS). Nevertheless, the workload on RCCs caused by the high number of 121.5 MHz false alerts directly affected the efficiency of maritime SAR service providers. In particular, the unresolved ambiguity of 121.5 MHz Doppler locations provided by Cospas-Sarsat often resulted in two alerts sent to adjacent RCCs, each one requiring an investigation which could be particularly costly at sea. Furthermore, because of the low cost of 121.5 MHz beacons, their number had multiplied since the inception of Cospas-Sarsat and kept growing, which made the problem worse year after year.

For this reason, after considering the issue at length, the IMO Maritime Safety Committee (MSC), at its 70th Session in December 1998, concluded that the satellite processing of 121.5 MHz distress alerts should be phased out and a plan for doing so should be developed by Cospas-Sarsat.

121.5 MHz ELT model (1980s)
stowed in safety rafts, presented by Wayne Carney, Cospas-Sarsat Secretariat (2005)

5.4.3 ICAO's Dilemma and Policy on 406 MHz ELTs

The situation at ICAO was somewhat different. The ICAO Convention provided for the carriage of 121.5 MHz ELTs on aircraft operating internationally within its mandate. This notwithstanding, ICAO was well aware of the shortcomings of the 121.5 MHz system and the superiority of 406 MHz ELTs, which had been allowed in lieu of 121.5 MHz ELTs since 1993 under ICAO regulation. However, ICAO could not call for the termination of the 121.5 MHz satellite alerting service on grounds of performance while its provisions, at contracting States' insistence, continued to allow for carriage of 121.5 MHz beacons.

Severe pressure was brought to bear on ICAO by national administrations and representatives of industry associations for the retention of the 121.5 MHz system. Thousands of aircraft had been equipped with 121.5 MHz beacons. Thousands of general aviation aircraft would be affected by a termination of 121.5 MHz satellite processing and the cost to owners and operators of re-equipping with 406 MHz units was deemed by many to be excessive. Operators of commercial passenger-carrying aircraft were well represented by industry advocates making a case for the penalizing cost of retrofit to existing aircraft. Switching to 406 MHz beacons meant that new installation requirements had to be met by commercial aircraft operators, such as allowing for the remote control of the beacon operation by the crew. This was intended to enhance reliability, but the new requirement substantially increased installation costs.

After intense debate, the conflict was resolved in March 1999 when the ICAO Council adopted amendments to the ICAO Convention that mandated the carriage of 406 MHz ELTs on new aircraft from 1 January 2002 and by all aircraft from 1 January 2005. For all practical purposes, from 1 January 2005 the ICAO position conformed to that of IMO. Specifically, at its March 1999 session, the ICAO Council agreed that the large number of 121.5 MHz false alerts seriously hindered RCC efficiency and that the satellite processing of 121.5 MHz emissions should be terminated from 2008.

ICAO requirements, however, were not implemented as planned by some air carriers in the United States. In November 2004, less than two months prior to the 1 January 2005 deadline for applicability of the installation requirements to aircraft built before 1 January 2002, the International Air Transport Association (IATA) wrote to ICAO proposing to postpone the applicability date to 1 January 2007 "*to give aircraft operators the opportunity to equip their fleets in an orderly and economical manner*". The request to ICAO was also supported by the International Business Aviation Council (IBAC). After a debate in the Air Navigation Commission of ICAO, member States were consulted and a task force convened in the summer of 2005 in Washington, DC, USA to address again all aspects of the issue. A new amendment to Annex 6 to the ICAO Convention, after further review by the ANC, was adopted by the ICAO Council in March 2007. Rather than requiring carriage over 'designated land areas' and for 'long range over water flights' per the former Annex 6 amendment, the new ICAO requirements were applicable to all new aircraft and from 1 January 2008 to older aircraft "*authorised to carry more than 19 passengers*".

5.4.4 National Administrations' Considerations

By 1999 it had become stated policy that both IMO and ICAO wanted Cospas-Sarsat to discontinue the satellite processing of 121.5 MHz signals at some point in the not too distant future; however, the impact on SAR operations at a national level raised complicated regulatory issues. In particular, States had responsibility for:

- civil aircraft not under the jurisdiction of the ICAO Convention (typically small privately owned airplanes operating domestically) and many State regulations continued to mandate carriage of 121.5 MHz ELTs;
- water pleasure-craft that did not come under the auspices of the GMDSS (such as recreational boating) and many State regulations allowed the use 121.5 MHz beacons for distress alerting at sea; and
- adventurers, such as hikers, climbers and canoeists, who would carry 121.5 MHz personal locator beacons (PLBs) for use when in distress.

Notwithstanding the revised policies of ICAO and IMO, the Cospas-Sarsat 121.5 MHz alerting service continued to play an important role for the hundreds of thousands who continued to use these beacons and for national administrations responsible for SAR services. For many user groups, the cost of purchasing and installing a 406 MHz distress beacon continued to be an issue. Therefore, to Administrations, the call for termination of the 121.5 MHz alerting service was a difficult decision to make, let alone mandating the exclusive carriage of 406 MHz beacons.

Within the Cospas-Sarsat community many national delegations were pulled in opposite directions. On the one hand, their RCCs echoed the reality expressed by IMO and ICAO – they simply could not handle the workload caused by 121.5 MHz false alerts; on the other hand, they were heavily influenced by user groups in their countries whose members had purchased 121.5 MHz beacons, sometimes in response to national regulations, and were opposed to financing alternative, more expensive 406 MHz beacons.

5.4.5 The Cospas-Sarsat 121.5 MHz Phase-Out Plan

The decision to continue or terminate the satellite processing of 121.5 MHz signals was the source of extensive and intense discussion within Cospas-Sarsat. Noting the requests made by IMO and ICAO, Representatives to the Programme concluded that it was impractical to continue the 121.5 MHz service. Equally, some countries could not support the termination of the service unless the concerns of the 121.5 MHz beacon user base were adequately addressed.

It was in this perspective that Cospas-Sarsat convened a Task Group of Experts in March 1999 (TG-1/99) to study all aspects of the issue and develop a plan of action for consideration by the Council. The key findings of the Task Group that met in Hampton, Virginia, USA were that:

- from a technical perspective, the 121.5 MHz service could be terminated without adversely impacting the Cospas-Sarsat 406 MHz system;

- should Cospas-Sarsat decide to terminate the service, Cospas-Sarsat and national administrations should implement information campaigns to ensure that all organizations, administrations and user groups were informed well in advance, and that adequate education was provided to user groups on the benefits brought by the 406 MHz system;
- to encourage 121.5 MHz beacon users to switch to 406 MHz beacons, Cospas-Sarsat and Administrations should investigate means of lowering the cost of 406 MHz beacons; and
- there were several strategies available for shutting down the service, ranging from fixing a future date for turning off all 121.5 MHz instruments, all the way to allowing for a slow degradation and ultimate termination of the service by not replacing 121.5 MHz satellite instruments when they reached their end of life in orbit.

First Council Decision

The first real attempt to make a decision on the future of the Cospas-Sarsat 121.5 MHz service took place during the 23rd Session of the Cospas-Sarsat Council in the fall of 1999. During this meeting there was almost unanimous agreement that Cospas-Sarsat should terminate the satellite processing of 121.5 MHz alerts and announce a fixed date for doing so. Having received clear guidance from IMO and ICAO, Cospas-Sarsat credibility would be affected if the decision was not taken soon. In addition, without a fixed termination date, Administrations, beacon manufacturers and users would not take the necessary actions to prepare for a transition to 406 MHz beacons.

The single dissenting opinion came from Canada, which could support an eventual phasing out of the 121.5 MHz service, but could not agree to turn off 121.5 MHz payloads until affordable replacements to existing 121.5 MHz beacons were available. Although not endorsing a fixed termination date, Canada agreed to Cospas-Sarsat not providing 121.5 MHz instruments for future satellites, beyond those instruments that were already under procurement contract. This laid the ground work for the following compromise:

- 121.5 MHz alerts would be phased-out from the Cospas-Sarsat System, although no firm termination date would be set at that time;
- except for the 121.5 MHz payloads already in service, in-storage awaiting launch, or under current procurement, future Cospas-Sarsat payloads would not include 121.5 MHz instruments; and
- another task group of experts would be convened in March 2000 to revise the phase-out plan to reflect CSC-23 deliberations.

Final Council Decision

Within the constraints agreed by the Cospas-Sarsat Council, the Task Group of Experts convened in March 2000 in Canberra, Australia (TG-3/2000) considered the following two strategies for phasing out the 121.5 MHz service, to:

- continue to provide the service as available, but with no guarantee, until the last satellite with 121.5 MHz capabilities was decommissioned; or
- decide on a minimum level of service and, when that minimum level of service could no longer be maintained, switch off the remaining 121.5 MHz satellite instruments in orbit.

With respect to the first option, experience had demonstrated that payload lifespan was nearly always different from its designed life expectancy. In most cases the payloads remained operational many years (sometimes decades) beyond their design life; conversely, on rare occasions payloads failed at launch or upon initial activation. As a consequence, the 'operate until the last payload died' option was ruled out because it was impossible to reliably estimate a final termination date, without which administrations and affected organizations could not plan for a transition.

With respect to the 'minimum level of service strategy', the challenge was to determine the minimum level of service that all would find acceptable, and then agree upon a mechanism for calculating the associated termination date. The recommendation was made to base the service level upon commitments documented in the ICSPA, namely, to operate four LEO satellites with 121.5 and 406 MHz instruments. Using the design life of the payloads as a guide, experts then determined that the four-satellite level of service could not be guaranteed beyond February 2009. Importantly, allowing for the expected differences between payload design and service life, the task group recommended that Cospas-Sarsat should review the status of phase-out activities in 2005 with a view to making adjustments as needed.

At the Open Meeting of the CSC-25 Cospas-Sarsat Council session in October 2000, all delegates supported the proposed strategy and the 1 February 2009 termination date, but there was uncertainty regarding the rationale and scope of the planned 2005 review. The concern was that the planned review would lead to difficulties convincing regulatory agencies and beacon users that Cospas-Sarsat was committed to the planned termination date. In a typical Cospas-Sarsat compromise it was agreed to remove reference to a 2005 review, but to commit to reviewing the status of phase-out preparations at each session of the Cospas-Sarsat Council. This change was intended to convey the sentiment that the phase-out of the service would be managed closely, with a view to ensuring that the February 2009 target date would be achieved, rather than using the planned 2005 review as a vehicle for updating the termination date.

At CSC-25, the Council publicly announced the intention to terminate the 121.5 MHz satellite alerting service on 1 February 2009 and approved the phase-out plan.

5.4.6 Implementing the 121.5 MHz Phase-Out Plan

The first approved version of the Cospas-Sarsat Phase-Out Plan for 121.5/243 MHz Satellite Alerting Services (C/S R.010) was a 70-page document whose actions and recommendations fell under two categories. The first category concerned issues that were under the direct control of Cospas-Sarsat. Most importantly this included the actions necessary to ensure that:

- the Cospas-Sarsat System would be able to handle the increased 406 MHz traffic as users switched from 121.5 MHz to 406 MHz beacons;
- from a technical perspective turning off 121.5 MHz instruments would not adversely impact satellite and ground based 406 MHz instruments; and
- there would continue to be sufficient 121.5 MHz space and ground segment instruments to maintain the committed level of service to the termination date.

These matters were within the complete control of Cospas-Sarsat and, despite their complexity, there was great confidence that they could be effectively managed. The second category of actions was aimed at assisting the user community and National Administrations to transition from 121.5 MHz to 406 MHz satellite alerting services.

These actions included:

- ensuring that user groups were well informed of the impending termination of the 121.5 MHz service;
- providing assistance, as appropriate, for updating national legislation for 121.5 MHz beacon carriage;
- promoting the benefits of the 406 MHz system; and
- efforts to lower the cost of 406 MHz beacons[11].

Cospas-Sarsat launched information campaigns promoting the benefits provided by 406 MHz beacons and advising 121.5 MHz users, Administrations and affected international organisations that the Cospas-Sarsat 121.5 MHz service would be terminated. However, it fell upon regulators at the national level to amend beacon carriage legislation. These were complicated and often politically charged issues, outside of the Cospas-Sarsat sphere of responsibility.

To lower the cost of 406 MHz beacons, Cospas-Sarsat worked with manufacturers to understand beacon cost drivers and took action where possible. This included changes to the Cospas-Sarsat 406 MHz beacon specification and streamlining the Cospas-Sarsat beacon type approval process. However, there again some of the cost drivers (national beacon specification, installation and environmental requirements, etc.) had an important national administration component and could not be directly addressed by Cospas-Sarsat. Regarding the 406 MHz beacon technical specifications, the requirement for high stability of the 406 MHz carrier frequency, a driver of the accuracy of beacon location computations, was deemed unnecessarily severe by some stakeholders and consequently impacting the cost of beacon oscillators. Australia proposed to create a new 'class' of 406 MHz beacons with reduced frequency stability requirements, hence reduced performance in terms of Doppler location accuracy. The advantage would be that the new class of 406 MHz beacons at reduced price would still be much better than the phased-out 121.5 MHz beacons.

Long and sometimes acrimonious debates ensued over several years, until the Council accepted a minor relaxation of the specification applicable to all beacons. Within a few years, a breakthrough in oscillator technology allowed manufacturers to meet the specification and lower the price of the component for all Cospas-Sarsat 406 MHz beacons.

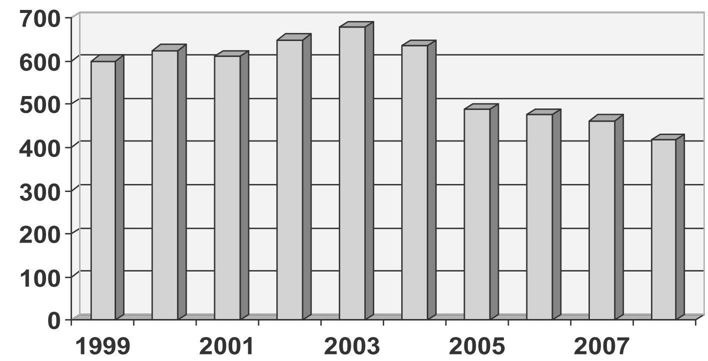
Effectiveness of the Plan

It is difficult to objectively assess how effectively the termination of the Service was handled by Cospas-Sarsat, national Administrations and international organizations. However, the following facts can be highlighted:

- the Cospas-Sarsat 121.5 MHz Service was terminated on 1 February 2009 without any adverse impact on the 406 MHz system;
- when the decision to terminate the service was announced there were approximately 250,000 406 MHz beacons in use; by the end of 2008 this figure had tripled to more than 750,000 and was growing at a rate of almost 200,000 per year;
- IMO and ICAO regulations pertaining to 406 MHz beacon carriage were fully implemented;

11/ Detailed information on beacon costs is provided in Chapter 6, section 6.2. In the case of ELTs, the driving cost factor was retrofitting older aircraft. Efforts to lower the cost of 406 MHz beacons had a limited impact.

- in the year 2000 the cost of a 406 MHz EPIRB with an integral GPS was about US $2,000; it was less than half that price by 2009; and
- an international 406 MHz beacon registration database was developed and managed by Cospas-Sarsat to provide registration services for those users living in jurisdictions that did not operate national beacon registries.



Evolution of the Number of Cospas-Sarsat 121.5 MHz Alerts
(1999 - 2008)
(includes false alerts from beacons but excludes false alerts from interferers)

Source: Cospas-Sarsat Secretariat

Despite numerous efforts to convince private aircraft owners / operators to replace their 121.5 MHz ELTs with 406 MHz beacons, this objective was not achieved in all countries by 2009. In some countries home to large private aircraft populations, national regulations still allowed the carriage of 121.5 MHz ELTs. Plans to update legislation to require 406 MHz ELTs were contested by user groups that considered the change an unjustifiable expense. The number of 121.5 MHz ELTs in service after the termination of the satellite processing capability was not tracked by Cospas-Sarsat; however, conclusions can be drawn from the evolution of the number of 121.5 MHz beacon activations detected by the System up to service termination.

Assuming that the 121.5 MHz beacon population can be correlated to the number of beacon activations, one can conclude that there were a significant number of 121.5 MHz beacons still in use at the date the Cospas-Sarsat Service was terminated. On a positive note, in 2008, the last full year of 121.5 MHz satellite service, the total number of SAR events and number of persons rescued using the 406 MHz system was significantly more than the figures recorded at 121.5 MHz.

5.4.7 The Legacy of the Cospas-Sarsat 121.5 MHz System

The effort to terminate the Cospas-Sarsat 121.5 MHz satellite alerting service consumed considerable resources within Cospas-Sarsat, IMO, ICAO, and national administrations.

The false alerts produced by the System were a major problem for SAR providers and for the operators of civilian ships and aircraft that were diverted in response. Notwithstanding, the System was used in more than 3,500 distress events, in which almost 9,000 people were rescued. Furthermore, it was the 121.5 MHz alerting service with its pre-existing user base, with over 250,000 first generation 121.5 MHz ELTs installed on aircraft that made Cospas-Sarsat relevant even before it was officially declared operational in 1985.

During the early years of the Programme the 121.5 MHz service played an important, arguably critical, role proving the potential of space-based SAR alert detection and location services. It is fair to ask whether the Cospas-Sarsat System would have survived its infancy as an experimental space project, had it not included a service for 121.5 MHz beacons.

5.5 Distress Beacon Users' Responses: From Scepticism to Casual Acceptance

Distress alerting via orbiting satellites was a successful development and is now commonplace. It is barely mentioned in media reports of major incidents, except perhaps in case of failure, which is probably the true measure of its success. However, users' responses to new technology can be rather unpredictable and some users were not enthusiastic about switching to the new 406 MHz digital technology. Among those who adopted the new system, a variety of responses could be observed and the casual acceptance of satellite distress alerting also led to some abuses of the service provided free of charge to the individual users, but at a cost to SAR authorities and rescuers.

5.5.1 ELT Users' Perspective on 'Old' Analogue Beacon Technology versus 'New' 406 MHz Digital Beacons

All systems on an aircraft are designed and built with one clear goal in mind: to ensure maximum safety and avoid life threatening incidents. However, this rule is restricted by two specific constraints: the system must be affordable and cost-effective. Therefore acceptance of a particular system will vary depending on the type of aircraft, the operational environment and the costs incurred.

Emergency Locator Transmitters (ELTs) were introduced in civilian aircraft in response to a major concern, the too-frequent disappearance of light aircraft and the impossibility of searching efficiently for missing aircraft when no distress call was received and no position information was available. The demand for action first came from the relatives of missing aviators who could not accept the loss without any evidence of their fate. A crash is always perceived as a failure of safety measures which should not be allowed, if avoidable. However, anticipating and preparing for an 'after-the-crash' situation was not always seen by aviators as an imperative necessity.

121.5 MHz ELTs were rather inexpensive and initially installed without the attention that would be required to ensure adequate operation in a crash situation. The consequence was a high failure rate which led pilots to question their relevance. Second generation ELTs had significantly improved performance, particularly with respect to the inadvertent triggering of the G-switch, the accelerometer that allows automatic activation in a crash situation. However, the improvement failed to convince some pilots of their worth as ELT failure in crash events could not be eliminated, due to problems such as detached transmission cables, broken antennas or depleted batteries.

The 121.5 MHz ELT system was not as effective as desired, but is was affordable and therefore 'good enough' in the opinion of most private plane owners in the United States and Canada. This opinion was reinforced when Cospas-Sarsat started providing 121.5 MHz alert and location data at no additional cost to users. The Cospas-Sarsat Project Report published after the completion of the Demonstration and Evaluation Phase showed that, between September 1982 and August 1984, 121.5 MHz Cospas-Sarsat alert and location data had been used in 112 SAR events, including 72 aviation and 40 maritime distress events, with 333 people involved and 289 rescued.

The consequence of this judgment on the cost-effectiveness of 121.5 MHz ELTs was strong resistance in the private aircraft owners' community to switching to the new, enhanced, but more expensive 406 MHz ELT system. The problem was less about the cost of the 406 MHz device itself, as sales prices had decreased with time to acceptable levels (less than 1,000 US$ for some 'fixed' 406 MHz ELT models in 2009), than about high installation costs for the new ELT system when retrofitting the equipment on aircraft previously equipped with the 121.5 MHz type. New installation requirements, such as an additional cabling to add a switch on the aircraft control panel for more reliable ELT operation, were also viewed as costly and excessive by some private aircraft owners.

As a result, in a number of countries, after the termination of 121.5 MHz satellite monitoring in 2009, the installation of fixed 406 MHz ELTs was not imposed by national regulations on reluctant small aircraft owners. Instead, carriage of portable 406 MHz ELTs (not installed on the aircraft as fixed equipment, actually a PLB type), was authorised as a complement to the fixed 121.5 MHz ELT still installed on board. If survivors could secure and operate the 406 MHz portable ELT/PLB, they would benefit from the Cospas-Sarsat 406 MHz satellite alerting and positioning service. If after the crash no conscious person could activate the device, the automatically triggered fixed 121.5 MHz ELT might be transmitting an alert, but no satellite alerting system would monitor its transmissions.

The paradox of this development is clearly that those users who could have benefited most from the new technology were actually refusing the proposed enhancement, which was deemed unaffordable, and accepted the risks of a pre-Cospas-Sarsat environment, where no global monitoring service was available for 121.5 MHz distress beacons.

Carriage of 406 MHz ELTs is mandatory on commercial air transport as a result of new ICAO regulations. However, in severe crash circumstances, if the aircraft is totally destroyed, the fixed ELT carried on board is also likely not to survive the crash. This type of system failure and the high costs of retrofitting older aircraft raised questions regarding the effectiveness of the concept for large commercial aircraft. Recent losses of airliners at sea in 2009 and 2014 (AF 447 in the Atlantic Ocean and MH 370 in the Indian ocean - see Annex 2, section 2 on Aeronautical SAR), for which no distress calls were received and no ELT signals could be transmitted after the airplanes had sunk, have reopened the debate in the aviation community on in-flight triggering of ELTs and automatic transmission of flight data to the ground, as well as the feasibility of in-flight releasable ELTs and flight data recorder devices.

5.5.2 Changing Expectations among Sailors and Adventurers

In the 1980s, 121.5 MHz beacons started being used at sea pursuant to safety regulations in the USA, but also as 'Personal Locator Beacons' (PLBs) carried by recreational sailors on a voluntary basis, as at the time national regulation did not preclude or recommend their use. The first SAR operation at sea assisted by Cospas-Sarsat alert data derived from 121.5 MHz beacon transmissions was on 10 October 1982, just one month after the first rescue of airmen in Canada [12]. The three crewmembers of the capsized trimaran Gonzo were rescued by the U.S. Coast Guard 300 NM off the coast of New England. At the time, there were no 'operational' 406 MHz beacons. The first rescue assisted by 406 MHz alert data occurred only on 31 December 1984, involving an injured solo driver during a car race in Somalia. The first 406 MHz EPIRB models were approved for operational use in 1987 and the first case of 406 MHz alert data assisting in a rescue event at sea was on 1 August 1987 when the French sailboat 'Tifa Jolivet' sank in the Bay of Biscay.

National regulations for mandatory carriage of 406 MHz EPIRBs on fishing vessels began to be effective in 1988. Fishermen were undoubtedly the most frequent casualties in distress incidents at sea. Norway and the U.K. were the first to issue regulations, followed by France, Canada, the USSR,

12/ See the report on the Ziegleheim SAR case in Chapter 2, section 2.4.3, and the Gonzo SAR case in Chapter 3, section 3.2.3

the United States and many other countries. The fishing industry, initially rather cautious about this new imposed safety measure, adopted the new system as soon as its effectiveness in helping SAR forces save lives was demonstrated during well publicised incidents.

For commercial fleets, the carriage of a satellite EPIRB was made mandatory under IMO SOLAS regulation in 1993. As a result of decreasing costs (see Chapter 6, section 6.2), 406 MHz satellite EPIRBs spread rapidly to pleasure crafts and sailing boats, with owners installing EPIRBs or carrying a Personal Locator Beacon (PLB) on a voluntary basis when regulations did not require it. The technical constraints of installation on board vessels and the costs involved were far less than those affecting small aircraft owners.

A fringe section of the user community started considering that, since EPIRBs were made mandatory, or recommended safety equipment even for pleasure boats, being rescued free of charge by SAR forces in any difficult situation was a kind of new obligation on State authorities.

There was, however, an unexpected consequence to the new system availability: the changing expectations of users. A fringe section of the user community started considering that, since EPIRBs were made mandatory, or recommended safety equipment even for pleasure boats, being rescued free of charge by SAR forces in any difficult situation was a kind of new obligation on State authorities. This behaviour can be illustrated with a number of real life incidents.

In the French Caribbean Islands, France subsidised the purchase of 406 MHz EPIRBs by local fishermen and made it mandatory equipment with a view to improving safety records. The success of the initiative was excellent, perhaps somewhat beyond SAR authorities expectations. A local fisherman was rescued three times between February 2006 and November 2007 [13], using his 406 MHz EPIRB when his boat 'Elephant Man' became disabled in varying circumstances, all reported as 'engine failure'. The satellite EPIRB had become an alternative to proper engine maintenance and a substitute to the radiotelephone, which ensured a swift response from SAR authorities. Some users also started suing States' authorities when, in their opinion, their rescue had been unduly delayed. If the distress situation resulted in casualties, relatives would start proceedings to obtain compensations on the ground that State authorities had failed their obligations. In most cases, these legal proceedings were fruitless, but nevertheless a concern for SAR service providers.

Another aspect of the change of expectations was illustrated by adventurers taking any sort of risk, such as launching into an Atlantic Ocean crossing unprepared or with an unseaworthy craft, convinced that they had no other responsibility than equipping themselves with standard safety gear, including a distress beacon. During 2007, no less than 40 solo-sailors were rescued on the high seas with the assistance of Cospas-Sarsat alert data after getting into severe trouble. Although running into a situation of imminent danger is not synonymous to unconsidered risk taking, these cases were a high proportion, over 10%, of all distress cases at sea reported during 2007, and it seems fair to note that solo sailing was an additional risk factor. The count is derived from reports submitted by national Administrations to the Cospas-Sarsat Secretariat. It does not include solo fishermen or other professionals in actual danger as a result of their activity [14]. Unconsidered risk-taking behaviours spread, together with a casual approach to sea safety by non-professional sailors. A solo-sailor in the Atlantic Ocean got lost and triggered his 406 MHz EPIRB. A tanker was requested by the RCC to reroute and assist in the rescue. After being reached by the tanker, the solo-sailor asked for his position, then casually decided to continue his solo voyage.

13/ 26 February 2006, 22 June 2006 and 18 November 2007.

14/ Cospas-Sarsat Report on System Status and Operations (C/S R.007 No.24 - January to December 2007).

5.5.3 The Impact of Personal Locator Beacons (PLBs)

121.5 MHz Personal Locator Beacons (PLBs) became increasingly popular in the 1980s for use at sea or in the wilderness. Their uncontrollable development and the associated risks of false alarms with no possible identification of the transmitter did play a role in the 1999 decision to terminate satellite processing at 121.5 MHz. However, in the 1990s, 406 MHz PLBs that could be identified and registered became an affordable and popular item among adventurers as well as pleasure craft sailors.[15]

In the view of some authorities, EPIRBs and especially PLBs encouraged irresponsible behaviours and therefore their use should have been strictly restricted to professionals. However, Cospas-Sarsat had no means and no mandate for imposing a restrictive policy on PLBs. This was the sole responsibility of Administrations. Furthermore, a restrictive policy would have been difficult to implement and maintain in the longer term. In the 1990s PLBs were not authorised in the U.K. and could not be purchased there. On 1 August 1998, when a party of young British tourists activated a distress beacon coded as a maritime EPIRB on the slopes of the Himalayas, confusion ensued for Indian police forces that, nevertheless, engaged in a rescue operation and later asked for reimbursement of the costs incurred.

The change of expectations by users was not encouraged by distress beacons only. A host of new mobile communication systems, including mobile phones, satellite phones and cheap GNSS technology, were also starting to have a profound impact on peoples' expectations, with very similar results. Satellite EPIRBs and their 'personal' variant, PLBs, were only the first and most spectacular example of the capabilities of modern mobile communication technologies and of their impact on people's behaviour.

The Cospas-Sarsat Council, therefore, decided to issue recommendations to Administrations with a view to limiting the possible impact of 406 MHz PLBs on the Cospas-Sarsat System and on SAR organisations, such as recommending that a proper registration system be established as well as national procedures for dealing with PLB alerts. Besides the encoded identification in 406 MHz beacons, the technical specifications and operational requirements imposed by Cospas-Sarsat, together with the applicable Cospas-Sarsat type approval procedure, were a major difference with 121.5 MHz PLBs. This helped ensure adequate System performance and prevented the proliferation of cheap, unreliable devices. Except for a very small number of malicious, undue activations, Cospas-Sarsat also noted from experience that PLBs, which by design could be activated only manually, were less prone to generating false alerts than automatically triggered ELTs and EPIRBs.

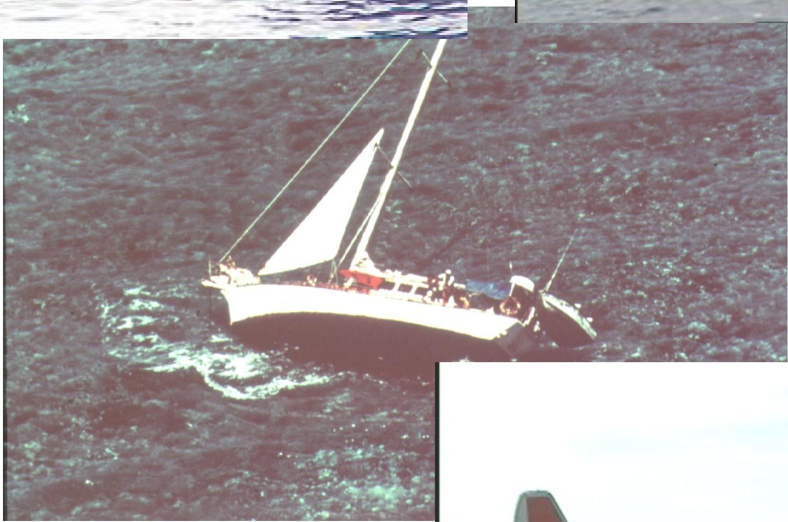
Russian PLB in the Arctic
Photo courtesy of Sergey Moroz - Morsviazsputnik

In summary, the termination of satellite processing for 121.5 MHz distress beacons eliminated the threat of cheap 121.5 MHz PLBs. Reliable 406 MHz PLBs probably encouraged some irresponsible behaviour, however, their deployment did not result in a surge of 'false', non-distress calls for assistance. The development of 406 MHz PLBs was swift, but also constrained over time by the quasi-global availability of mobile phones and the development of mobile satellite messaging systems, both featuring affordable GNSS receivers.

15/ A 121.5 MHz PLB would cost around US$ 150, while a 406 MHz PLB would cost around US$ 1,000 by the mid-1990s. 406 MHz PLB costs further decreased to 700 US$ or less by the year 2000.

SAR Exercise

Dolphin Helicopter with Basket
(Photo U.S. Coast Guard)



Running Aground

U.S. Coastguard "Hercules" C-130 Aircraft (Photo U.S. Coast Guard)

Crash Site

Photos courtesy of the International Cospas-Sarsat Programme

Arctic Expedition (Photo courtesy of CNES)

Chapter 6

The Economy of Satellite Distress Alerting

6.1 The Cost of SAR Operations and the Economy of Satellite-Aided SAR

Like other space application projects in the 1970s and the 1980s, Cospas-Sarsat was not launched for a commercial purpose and no pre-launch cost-benefit assessment was made. The objective was to provide a new response to a difficult operational challenge, locating overdue aircraft and sailors at sea in imminent danger, using the unique capabilities of space technology. For the space agencies in charge of research and development, pushing the limits of new technologies and experimenting with potentially useful applications was in itself a sufficient justification for the project. The transition to an operational system to be funded in the long term somewhat changed the perspective. In the United States, NASA and NOAA sponsored the first cost-benefit analysis, which concluded that the continuation of the System was highly beneficial to the U.S. tax payer (see section 6.1.3).

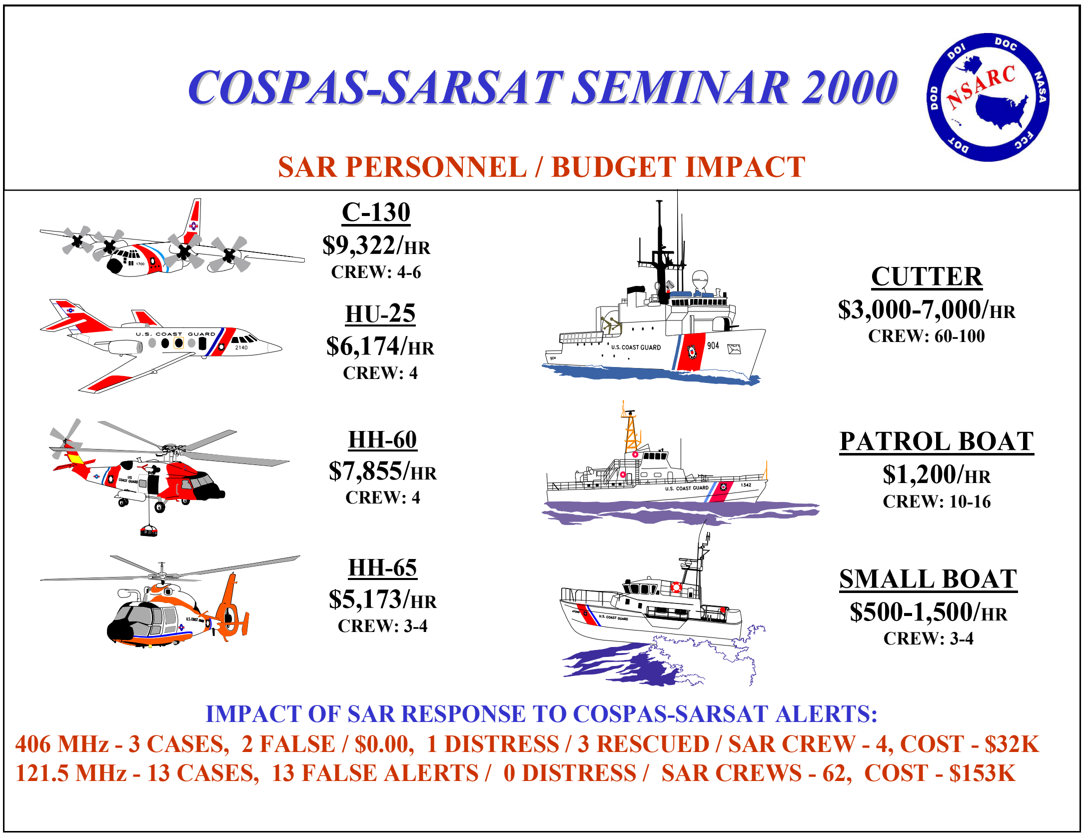
The system did not only have to be operationally effective, it had to be cost-effective from the point of view of its customers, the beacon users, sailors or aircraft owners, as well as Administrations which were called to fund its operation. The following sections provide a short analysis of the economics of satellite-aided search and rescue from both perspectives. It is limited in scope and is not an official assessment of the costs and benefits of the global Cospas-Sarsat System for Search and Rescue. Because of the chosen time-frame of this history study (1979-2009) and the experimental character of the System in the early years of operation, only data pertaining to the decades 1990 to 1999 and 2000 to 2009 have been considered. In addition, because of the diversity of conditions in the large number of countries involved and the complexity of adjusting cost figures over many years, inflation has not been taken into account.

6.1.1 SAR: Free of Charge for the End User in Distress, but Occasionally Costly to the Community

Historically, searching for missing people on land was a community responsibility assumed by local police forces seconded by volunteers. With the considerable growth of maritime and aeronautical trade, searching for missing mariners and aviators soon required a higher level of organisation and resources that were not available to local communities. Search and Rescue at sea and on land is now a State responsibility assumed by specialised personnel.

In many countries, volunteers in civil SAR organisations still provide an essential contribution to the SAR effort at sea and on land. Some examples are: the Mountain Rescue Organisations and the Royal National Lifeboat Institution (RNLI) in the UK; the ‘Société Nationale de Sauvetage en Mer’ (SNSM - sea rescue organisation) in France, or the Search and Rescue Volunteer Association of Canada (SARVAC). SAR operations, even when conducted by volunteers, have a cost which can be assessed, although with some uncertainty as the evaluation of cost elements associated with volunteers or occasional use of public assets has no firm ‘market’ basis. However, such costs can vary greatly from country to country. Therefore, it would be unrealistic to quote a global figure for the cost of SAR services worldwide and assessments must remain at national level, or for specific regions of the world.

State assets such as aircraft and vessels have occasionally been dedicated to SAR, but most often the service is provided using military, police, coastguard or other available government means. The cost figures shown below for illustration were quoted in a presentation by Lt Commander Paul Steward, United States Coast Guard International SAR Coordinator, during the 2000 Cospas-Sarsat Seminar [1].



Although no global assessment can be made, it is possible to assess the costs associated with a particular SAR operation. The U.S. Coast Guard cost data shown above illustrate the actual cost of false alerts at 121.5 MHz. In the example, a total of US$ 153,000 was spent for the use of SAR assets in 13 non-distress alerts at 121.5 MHz. For comparison, two false alerts at 406 MHz could be resolved at no cost (no SAR assets used) and US$ 32,000 were spent for the use of SAR assets in one real distress case supported by 406 MHz alert data, in which three survivors were rescued. These figures were meant to illustrate the potential benefits to SAR forces and the community of a future transition from 121.5 MHz analogue beacons to the new digital 406 MHz ELT/EPIRB technology.

The table below shows Canadian expenditures concerning searches for downed aircraft. It was presented during the Cospas-Sarsat 2000 Seminar [2] by Mr. R.W. Slaughter, Executive Director of the Canadian National SAR Secretariat.

1/ Cospas-Sarsat 2000 Seminar (12-14 October 2000, Laval, Quebec - Canada) - The Impact of 121.5 MHz Satellite Alerting on Search and Rescue Services - LCDR Paul Steward, United States Coast Guard Office of Search and Rescue (October 12, 2000)

2/ Cospas-Sarsat 2000 Seminar - Benefits, Advantages and Effectiveness of the Cospas/Sarsat System from the Canadian Perspective - R. William Slaughter, Executive Director NSS.

Within five years, for a total of 290 searches, the alert and location data provided by the Cospas-Sarsat 121.5 MHz system allowed a saving of Can$ 52 million in terms of flying hours alone, irrespective of other personnel and resource costs or any value assigned to additional crash survivors or actual property saved[3]. This was an average saving of more than Can$ 10 million per year, (about US$ 8.3 million assuming an average Can$/US$ exchange rate of 1.2 between 1990 and 1994).

Canada National SAR Secretariat
Searches for Downed Aircraft
1990-1994

	ELT Signal	**No ELT Signal**
Number	180	110
Search Hours	1,354	12,645
Average Search Hours	7.5	115
Flying Costs (Can$)	$4.4 M	$34.5 M
Average Costs (Can$)	$24.4 K	$313.6 K
Survivors Rescued	86%	33%
Saving since ELT Worked	$52 M	

October 12, 2000

RECHERCHE ET SAUVETAGE SEARCH AND RESCUE

The above savings figure was far above the annual cost incurred by Canada for the procurement of the SAR payload carried on NOAA satellites (see section 6.1.2 below). Without the assistance of 121.5 MHz ELT signals, the estimated total flying costs for searches over five years would have been about Can$ 91 million, i.e. over Can$ 18 million / US$ 15 million per year over the period 1990-1994.

Occasionally, searches can be far more expensive than the average quoted above. When the French solo sailor Alain Colas missed a radio contact on 17 November 1978, west of the Azores Islands in the Atlantic Ocean during an Atlantic-crossing race, a massive 20 day search was initiated over a 2 million square-km ocean area with French Breguet Atlantic long range maritime patrol aircraft[4]. The sailor did not have a distress beacon. The 400 flight hours spent with no success can be valued at over 3 million US$ (assuming flying costs of $ 8,000 per hour for this type of aircraft).

This magnitude of cost for a single search is not common, but more recent searches, such as the searches for missing flights AF 447 in the Atlantic Ocean and MH 370 in the Indian Ocean, have set

3/ The Can$ 52 million savings figure quoted in Mr. Slaughter's presentation was derived as follows:
180 events with ELT signals processed at an average cost of Can$ 24.4 K, instead of the 313.6 K average cost when no ELT signal was available, correspond to an actual savings of (313.6-24.4)*180 = 52,056 K.

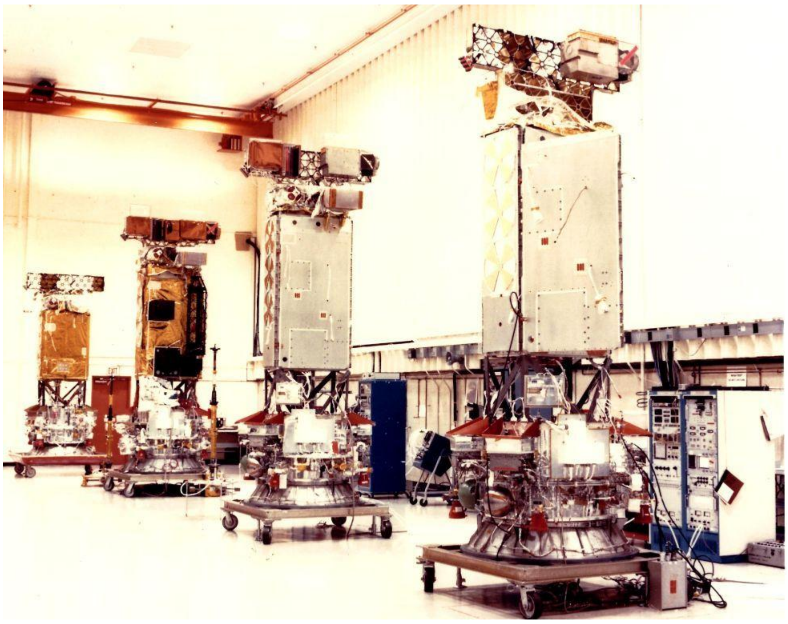
4/ Alain Colas was famous in France as a winner of big ocean races, including the 1972 Transat race (Plymouth to Newport) and setting a solo round-the-world sailing record in 1973. His celebrity status explains in part the extent and duration of the search effort.

new records[5]. Although no precise figure can be quoted for the assets tasked by a number of countries in the South Pacific and Indian Ocean regions during the search for MH 370, a tag of over 100 million Australian dollars by Australia alone has been quoted by the media for the year long search effort.

6.1.2 Cospas-Sarsat Costs

Only a rough evaluation of the magnitude of investment costs incurred by countries that provided space and ground segment equipment for the Cospas-Sarsat LEOSAR and GEOSAR systems can be provided here. Detailed costs for each Space Segment Provider or Ground Segment Provider are not available. Furthermore, the limited scope of this history study does not allow an exact comparison of costs incurred in the context of a cooperative programme shared by Eastern and Western countries at the time of the Cold War. The differences in economic reporting or accounting systems were considerable, making direct comparisons of cost figures impractical. Cospas-Sarsat was and still is a singular space programme and its actual cost cannot be precisely established on a global basis.

The LEOSAR Space Segment



NOAA Satellites - Tiros-N Series
The satellites are stored after production and testing until a 'call-up', when required for launch to replace an operational satellite.
Photo courtesy of the International Cospas-Sarsat Programme

The expenditures of the space segment providers, initially the USSR, the United States, Canada and France for the LEO and GEO systems, plus India for the 'INSAT' geostationary satellites, and EUMETSAT for 'Metop' LEO and 'MSG' GEO satellites, could probably be established, but identifying the exact share of the total cost of these multi-mission satellites which should be assigned to the Cospas-Sarsat mission would require detailed and lengthy analyses.

In the United States and to a lesser degree in France, the space segment components were presented as rather modest additions to a larger operational system, or an extension of an existing programme, and the associated costs were merged within the main development programme costs. Although costs can be quoted for pieces of equipment, such as additional U.S. satellite antenna systems, the Canadian repeater system or the French receiver-processor and memory unit, the actual costs associated with the integration of these payloads on the NOAA satellite bus, the launch of additional satellite mass and operational on-orbit costs (additional power requirements, additional command and control, etc.) are not readily available. Furthermore, these costs would be specific to each satellite bus.

5/ For details on flights AF 447 and MH 370: see Annex 2 on Aeronautical SAR

During Cospas-Sarsat partners' discussions, several cost figures were mentioned; for example in 1985 a rough estimate of the cost of the NOAA polar orbiting satellite bus, excluding the 8 to 9 payloads, was quoted at US$ 100 million, plus $ 50 million for its launch. The Sarsat payload accommodation could be estimated to represent no more than 10% of the total platform costs, hence a maximum of US$ 15 million (1985) per satellite [6].

French costs were estimated at US$ 2.5 to 3 million for a 406 MHz receiver-processor-memory unit [7] (SARP) to fly on NOAA satellites after 1985, with similar Canadian costs for the 121.5/243/406 MHz receivers and the 1544.5 MHz transmitter unit (SARR).

On the basis of the above figures, one operational Sarsat satellite and payload could be valued at about US$ 20 million [8]. With the assumption that, on average, Sarsat and Cospas LEO satellites could be used in orbit for four years or more [9] (rather than the 2 to 3 years of their nominal design life), the actual investment cost for the nominal four-satellite constellation was, therefore, less than US$ 20 million per year [10].

The GEOSAR Space Segment

As a rough estimate, the cost to modify an existing operational satellite design, manufacture and accommodate the 406 MHz receiver and the 1544.5 MHz transmitter, including antennas, can be quoted at about US$ 4 million, with the actual figure depending on the original platform design and equipment. For example, U.S. GOES platforms could share a receive antenna for the meteorological data collection system operating at 401 MHz. Assuming that similar costs were applicable to the Indian INSAT satellites, the Russian Luch / Electro spacecraft or the EUMETSAT Meteosat platform is rather arbitrary, but the only possible way forward in the context of this short analysis.

On that basis, assuming a complete GEO coverage over eight years could be achieved with four operational satellites plus four spares, the total expenditure would be about US$ 32 million. Therefore, a four-satellite operational system plus spares would lead to an annual investment in the order of US$ 4 million for the space segment, assuming only incremental costs are considered. If a share of the GEO platform costs were assigned to the GEOSAR payload (a 5% ratio of the platform costs, considering that the SAR payload is limited to the 406 MHz receiver plus the 1.5 GHz transmitter package, would be in the vicinity of US$ 5 million), the total cost for the 406 MHz

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6/ Quoted by Dr. John McElroy during an informal discussion at the CSSC-7 meeting in Leningrad - Oct. 1984.

7/ CNES - Toulouse Space Centre document (PMF/CLS dated July 1985) Évaluation indicative des coûts récurrents du système (tentative assessment of recurring costs for the operational system).

8/ In a note submitted by Cospas-Sarsat to IMO Radio-communications Sub-Committee (COM 30/WP.12 – October 1985) a figure of US$ 8 million was quoted for "*the manufacture and integration of instruments onto multi-purpose satellites and the incremental cost of operating these instruments*". This quote clearly did not assign a portion of the platform costs to the SAR mission, only taking into account the SAR instruments and additional SAR antenna costs. The cost figure used in this study can be seen as rather conservative.

9/ Between 1982 and 2002, a total of 19 LEO satellites were launched with a SAR payload. During these 20 years, the number of operational satellites in orbit was maintained over the minimum 4 satellites of a nominal constellation. Therefore, the average operational life time of a LEO satellite was well over 4 years.

10/ This very rough evaluation assumes that Cospas satellite bus and payload costs were similar to the Sarsat assessment. In the context of the Cold War, with U.S. and Soviet currencies exchanged at arbitrary rates, this is clearly a 'theoretical' approach, where Sarsat costs and the US$ are used as a common reference.

GEOSAR space segment (8 satellites including spares) would reach US$ 72 million, or an average annual investment of US$ 9 million over 8 years.

The Cospas-Sarsat Ground Segment

Hardware and software procurement plus installation costs for a LEOLUT system was typically about US$ 1 million, with the actual cost depending on the site configuration, specific national requirements, equipment redundancies, etc. A GEOLUT procurement could be in the range of US$ 0.5 million. Costs for MCCs would be more difficult to evaluate. In particular, nodal MCCs, which assume the role of communication nodes in the System, need more complex filtering software and additional communication capabilities with appropriate redundancies to provide the required availability. An estimate of US$ 0.5 million is assumed for the purpose of this analysis.

The optimum number of LEOLUTs required to ensure an operational service is a subjective matter, particularly for 121.5 MHz alert processing as world wide coverage was not achievable, even with a large number of LEOLUTs. Cospas-Sarsat never attempted to decide on the matter, which was left to each country's assessment of its own needs. In a fully integrated, centrally controlled system, about 20 LEOLUTs and 10 GEOLUTs would have been sufficient to provide a 'reasonable' service at 406 MHz (that is, with acceptable System redundancies and data acquisition, processing and transmission times). Many more LEOLUTs and GEOLUTs were installed, significantly reducing the LEO system alert data acquisition times and generally providing considerable redundancies [11]. However, national policy considerations were often the real drivers of decisions by individual countries to acquire a LUT and become a Ground Segment Provider. For obvious reasons, the Cospas-Sarsat Council did not attempt to streamline the LEOLUT/GEOLUT network and did not interfere with national decisions.

Assuming an 8-year renewal cycle, the investment required for a network of 20 LEOLUTs, 10 GEOLUTs and 10 MCCs would be in the vicinity of US$ 3.8 million annually [12].

Differences in the management of operational systems as well as labour costs in various parts of the world are another obstacle for the evaluation of a global cost for the operation of the Cospas-Sarsat satellite system. In developed countries, costs attached to 24-hour operations can be very significant. Because of the diversity of Cospas-Sarsat participating countries, no assessment has been made of global operating costs.

Cospas-Sarsat System Cost Summary

In summary, the average annual investment costs for the complete LEOSAR and GEOSAR space segment plus a basic ground segment would be typically US$ 33 million per year, assuming all procurement costs were based on United States, Canadian and French procurement expenditures for the Sarsat system. No meaningful estimates can be established for operating costs which were borne by ground segment operators in many diverse countries. The additional costs for in orbit SAR payload operations (payload monitoring, management and control) are not known.

11/ See Chapter 3 and Chapter 5, section 5.3

12/ Possible Ground Segment investment costs in US$ millions:
20*1 (LEOLUTs) + 10*0.5 (GEOLUTs) + 10*0.5 (MCCs) = US$ 30 M over 8 years, or US$ 3.8 M annually.

6.1.3 Cost-Benefit Assessment

Several major difficulties have been highlighted in the assessment of Cospas-Sarsat cost items, particularly for ground segment investment and operating costs which were not under the control of the Cospas-Sarsat organisation. Similar difficulties would frustrate any attempt to compute a global cost for SAR operations. The diversity of labour/social costs as well as the diversity of operational environments preclude a global approach and only 'regional' cost assessments would be meaningful.

The same remarks are applicable to benefits that could be derived from the use of the Cospas-Sarsat System. Furthermore, the potential benefits of using the System in countries such as Canada, the United States or Russia with large expanses of scarcely populated and inhospitable territory are bound to be much greater than in the countries of Western Europe with a high population density.

UK Rescue Helicopter Sea King
Photo courtesy of the International Cospas-Sarsat Programme

If the economic value of the lives saved were accounted for, the estimated benefit of the system for countries with highly developed economies would dramatically increase. The U.S. study presented at the 1996 Cospas-Sarsat Seminar [13] showed that a full transition from 121.5 MHz ELTs to more reliable, higher performance 406 MHz ELTs implemented on all general aviation aircraft in the United States could result in 134 additional lives saved every year. In terms of SAR resources, the U.S. study indicated an associated saving of US$ 3.6 million [14] every year. However, with the rate of 2.5 million per life saved as applied in the U.S. 1996 study, the additional benefit was US$ 335 million per year for the United States alone, that is more than 10 times the annual investment cost for the global Cospas-Sarsat System. The assessment of such savings is obviously dependent on the 'currency value' assigned to a human life saved, for which there cannot be a universally accepted standard.

A number of other regional factors would also have to be taken into consideration in a global assessment of benefits. For the proposed Cospas-Sarsat cost-benefit assessment in this document, only estimated savings in search costs (flight hours) resulting from the use of Cospas-Sarsat alert and location data, versus search costs incurred when no Cospas-Sarsat data was available, have been considered. The actual benefit of a greater number of lives saved is not ignored, but the evaluation of associated 'currency gains' has not been carried out.

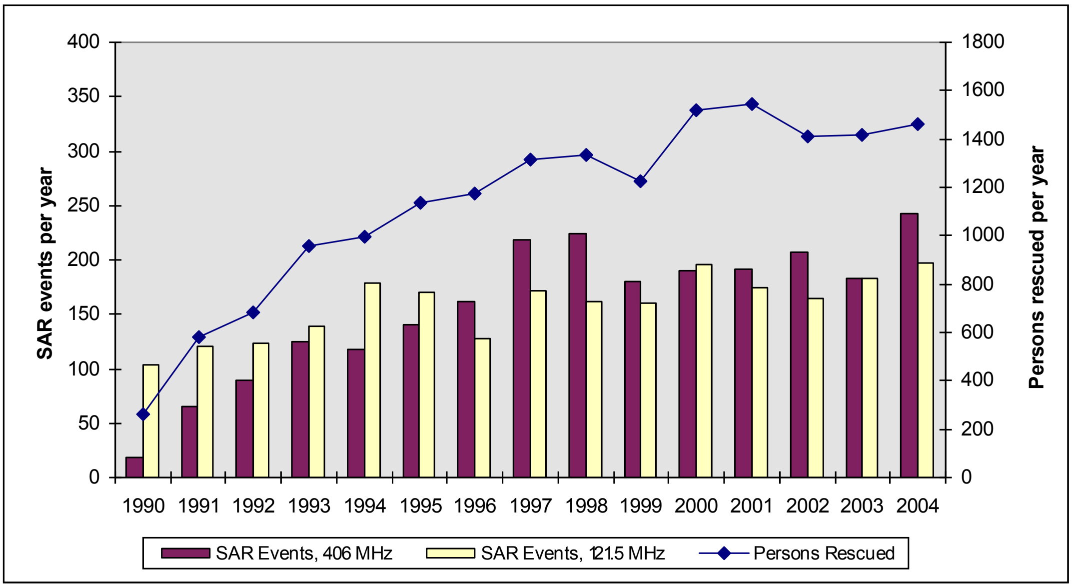
The Canadian assessment of savings in terms of flying hours was used as a benchmark (see Canada NSS costs and savings table shown in section 6.1.1, concerning searches for downed aircraft over the period 1990-1994). If the average cost of a search without an ELT signal was US$ 260 K

13/ 1996 Cospas-Sarsat Seminar (23-25 October 1996, IMO Headquarters, London UK) - Status of 406 MHz ELTs in the United States and Cost Benefit Study to Gain Regulatory Approval - James Bailey, NOAA; B. Trudell, CSC, USA.

14/ The savings figures given in the U.S. study addressed the additional benefits that would result from a switch from 121.5 to 406 MHz ELTs, not the total savings brought in by the use of all types of ELTs, EPIRBs, and PLBs, at 121.5 or 406 MHz, operating with the Cospas-Sarsat system.

(Can$ 318 K) versus US$ 20 K (Can$ 24.4 K) when the ELT signal was available, the reduction in search costs with Cospas-Sarsat alert data was a factor of 13.

The number of SAR events assisted by Cospas-Sarsat over 10 years (from 1990 to 1999) reported to the Cospas-Sarsat Council by Administrations in participating countries was 2,792 events (406 MHz and 121.5 MHz, all categories of ELTs, EPIRBs and PLBs). This is an average of 279 events per year and this number kept growing after 1999.



Actual SAR Events with Cospas-Sarsat Alert Data and Persons Rescued (1990 to 2004)
(Source Cospas-Sarsat Secretariat)

Applying an average search cost of US$ 10 K per SAR event supported by Cospas-Sarsat alert data [15], the total annual savings in search costs would amount to:

US$ 10 K x 12 x 279 = US$ 33.5 million [16]

This figure of annual savings in search costs is of the same order and actually greater than the annual investment cost for the global System quoted in section 6.1.2 (US$ 33 million).

Between 2000 and 2009, Cospas-Sarsat provided alert and notification data for 4,385 SAR events; an average of 438 per year. With the same approach as above and assuming identical search costs and System investment cost (no inflation factor) the average annual savings for SAR would have been US$ 52.5 million, 1.6 times the annual investment for the Cospas-Sarsat System.

15/ Half the Canadian cost estimate shown above is used here to reflect the fact that search costs in other parts of the world might be lower than in Canada, and to keep a conservative approach in the evaluation of potential benefits. The U.S. Coast Guard document shown in section 6.1.1 quotes a cost of US$ 34,000 for a single SAR event at sea with 406 MHz alert and location data. This is 3.4 times the average cost used in this assessment.

16/ Using the Canadian cost reduction factor of 13, the actual savings are 13.X-X = 12.X, where X is the average search cost for a SAR event using Cospas-Sarsat alert data.

Although the above calculation is clearly a very rough assessment, it is rather conservative regarding System costs as well as potential benefits. It ignores the additional benefits of the use of 406 MHz beacons rather than 121.5 MHz beacons in terms of search costs, for instance the reduced number of false alerts, higher location accuracies, better beacon reliability, better chance of a successful rescue effort, etc.

Furthermore, the estimate completely neglects the actual benefits of reduced operational costs for other elements of the SAR services (RCC operations, communications costs, personnel costs, etc.) and most importantly any valuation of the lives saved. Its purpose is only to show that during the time periods considered, even in a limited and conservative approach, the magnitude of SAR savings resulting from the use of Cospas-Sarsat alert data was greater than the average System investment costs on an annual basis.

Even if the currency value of human lives saved is not quantified in the above analysis, the additional benefit is clearly very significant and worth noting:

- during the ten-year period from 1990 to 1999, Cospas-Sarsat Secretariat statistics show that 9,667 persons were rescued in SAR events assisted by Cospas-Sarsat, an average of 967 per year; and

- during the ten-year period from 2000 to 2009, 17,148 persons were rescued with the help of Cospas-Sarsat alert data, an average of 1,715 each year.

Photos courtesy of the International Cospas-Sarsat Programme

6.2 Regulations and the Distress Beacon Market

The previous cost-benefit analysis only addressed the costs incurred and the savings realised by States as providers of the Cospas-Sarsat System and of SAR services. A third stakeholder must also be considered: the SAR service 'customer' who eventually may become the beneficiary of the investment made in establishing the Cospas-Sarsat System. From the customer's perspective, the use of Cospas-Sarsat System capabilities is free of charge in case of distress, but first requires investing in a Cospas-Sarsat beacon, either on a voluntary basis or as imposed by national regulations.

Chapter 5 illustrates the diversity of the SAR customer responses to the regulatory environment. An evaluation of the size of the beacon market, both in beacon numbers and US$ value, is provided from a historical perspective. No cost-benefit analysis can realistically be proposed from the customer's point of view. The swift growth of the unregulated PLB market, as seen over the time period considered, is probably the best confirmation of the value of the System for these customers.

6.2.1 121.5 MHz ELTs

First generation 121.5 MHz ELTs were fairly inexpensive (a few hundred dollars), but rather unreliable. They were first installed on the United States' commercial air transport aircraft as well as general aviation, private aircraft in accordance with U.S. regulations, but users' trust was soon shaken for reasons explained in Chapter 1. Revised industry standards (RTCA DO-168) and new regulation by the FAA (TSO-C91a) [17] improved the situation and revived confidence among United States' aircraft owners. The rapid growth of the number of ELTs and other types of 121.5 MHz beacons worldwide, after the beginning of Cospas-Sarsat operations, is also testimony to the positive impact of appropriate performance requirements. However, the 121.5 MHz system limitations were still there and the false alarm problem ultimately led to the termination of governments' support for the 121.5 MHz alerting system.

From an estimate of 220,000 in 1982, the worldwide population of 121.5 MHz distress beacons of all types grew to about 650,000 by the year 2000. It started to decrease slowly around 2003, as a result of the announcement of the Cospas-Sarsat decision to terminate 121.5 MHz processing in 2009.

6.2.2 406 MHz EPIRBs, ELTs and PLBs

406 MHz beacons use a digital technology, far more sophisticated than the analogue 121.5 MHz beacon technology, but they are more expensive. Unlike the 121.5 MHz products, 406 MHz beacons have to meet stringent specifications and demonstrate compliance in a thorough type-approval procedure controlled by Cospas-Sarsat.

The Regulated EPIRB Market

Mandatory installation of EPIRBs on fishing vessels in a number of countries from 1988, and on commercial fleets from 1993 per IMO GMDSS requirements, clearly encouraged a healthy competition among manufacturers. Ten EPIRB models from ten manufacturers had been developed

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17/ The United States Federal Aviation Administration (FAA) issued a new Technical Standard Order (TSO-91a) for 121.5 MHz ELTs in 1987, introducing revised requirements: the Minimum Operational Performance Standard - MOPS of document DO-168 prepared by the Radio Technical Commission for Aeronautics (RTCA).

when the formal type approval process was made official in July 1989 with the delivery of 19 Cospas-Sarsat type approval certificates for these models, including variants. By January 1993, a total of 76 type approval certificates had been awarded by the Cospas-Sarsat Secretariat: 63 for EPIRBs, 7 for ELTs and 6 for PLBs. The competition and developing expertise of manufacturers led to significant price reductions. Maritime EPIRBs initially retailed for US$ 2,000 or more, and their price had decreased to less than US$ 1,000 by 1996 [18].

Typical 406 MHz EPIRB Models (1990)

The Regulated ELT Market

406 MHz ELTs did not enjoy such favourable circumstances. ICAO did not mandate their carriage on transport aircraft under its jurisdiction until 2005 and Administrations were not keen on imposing new equipment so soon after mandating the use of 121.5 MHz ELTs. Furthermore, technical complications plagued the early acceptance of 406 MHz ELTs. The lithium battery chemistry (LiSO2) used in early 406 MHz EPIRBs was considered too dangerous for aircraft and was not authorised in ELTs. New installation requirements increased reliability, but made retrofitting old aircraft costly, adding significantly to the overall price tag of the 406 MHz ELT.

In the year 2000, when Cospas-Sarsat made the final decision to terminate 121.5 MHz signal processing on 1 February 2009, the price differentials in US$ between ELTs, EPIRBs and PLBs in Australia were as follows [19]:

US$ (year 2000)	406 MHz Price Range	406 MHz Average Price	121.5 MHz Average Price
EPIRB	800 - 1,550	1,180	150
EPIRB with GPS	1,800 - 2,000	1,940	
ELT		2,060	590
PLB	800 - 1,550		150

Year 2000 average prices for 406 MHz Beacons in Australia (US$)
(quoted by Mr. Chris Payne, AusSAR, Australia in Cospas-Sarsat Seminar 2000 paper - WP1.3)

These Australian prices, converted to US$ at the rate of 1.7 AU$/US$ and rounded off, are only an illustration and do not necessarily reflect the exact picture of retail prices in other countries. For comparison, prices quoted in a Canadian paper at the 2000 seminar indicated US$ 500 for the lower cost EPIRB in Canada [20]. However, the figures also show that the price ratio between 406 MHz and

18/ A quote of US$ 700 for 406 MHz EPIRBs is given in document 'Status of 406 MHz ELTs in the U.S. and Cost Benefit Study to Gain Regulatory Approval' - J. Bailey, NOAA; B. Trudell, CSC, USA / 1996 Cospas-Sarsat Seminar.

19/ Cospas-Sarsat Seminar 2000 / WP 1-3: Preparations within Australia on Phasing-out Satellite Processing of 121.5 MHz in 2009 (Annex A: Comparison of the 406 MHz and 121.5 MHz Beacons) - Chris Payne, AusSAR, Australia.

20/ Cospas-Sarsat Seminar 2000 / WP 1-4: Canada's Strategy to Gain Acceptance of 406 MHz ELTs - Don MacCaul, National SAR Secretariat, Canada.

121.5 MHz beacons was 7.8 for EPIRBs and 3.5 for ELTs. Therefore, the price differential is probably not the only explanation for the reluctance of small aircraft owners to transition to 406 MHz ELTs. The costs for retrofitting 406 MHz ELTs on older aircraft, which cannot be quoted with any precision because of great variations, was certainly an issue for all aircraft owners and probably tipped the balance against transitioning to 406 MHz ELTs when there was no mandatory requirement.

Cospas-Sarsat and manufacturers' efforts to further reduce the cost of 406 MHz beacons by 2009 (see Chapter 5, section 5.4 on 'Phasing-out 121.5 MHz Satellite Alerting Services') were successful, but did not significantly change the terms of the equation or the response of small aircraft owners (see Chapter 5, section 5.5 on the 'Distress Beacon Users' Response'). The result was an incomplete transition from 121.5 to 406 MHz ELTs.

The Unregulated PLB Market

While EPIRBs and ELTs were mandatory safety equipment for boats and aircraft under international or national regulations, no such regulation exists for personal beacons. Actually, some national regulations preclude the sale and sometimes the use of Personal Locator Beacons (PLBs) whether operating at 121.5 MHz or at 406 MHz [21]. However, PLBs soon became popular among trekkers, canoeists and other adventurers. The growth of the number of 121.5 MHz devices, including PLBs, was one of the reasons for terminating the satellite processing of that frequency.

Sample of PLB Models (C/S Secretariat)
By the year 2000, 406 MHz PLBs were clearly 'portable'. The most recent models are 'pocket-size'.
Photos courtesy of the International Cospas-Sarsat Programme

Since prohibiting the production or use of 406 MHz PLBs was not feasible, and actually not desirable in light of the increasing number of unidentified 121.5 MHz PLB users, Cospas-Sarsat chose to ensure that such PLBs would meet its performance requirements. The first type approval certificate (C/S TAC No 38) for a 406 MHz PLB was issued on 20 August 1990 to MPR Teltech Ltd in Canada. Most of the early PLBs were variants of EPIRBs, with a compact packaging and no release mechanism, or of ELTs, with no G-switch for automatic activation. Consumer demand soon led manufacturers to develop ultra-compact designs, and by 2009 a number of 406 MHz PLB models were truly pocket-size.

With simplified requirements excluding automatic activation, costs could be tightened and prices decreased to a few hundred US$, around US$ 400 for simpler models. Even with no regulation imposing their use, the 406 MHz PLB population grew to over 295,000 by 2009.

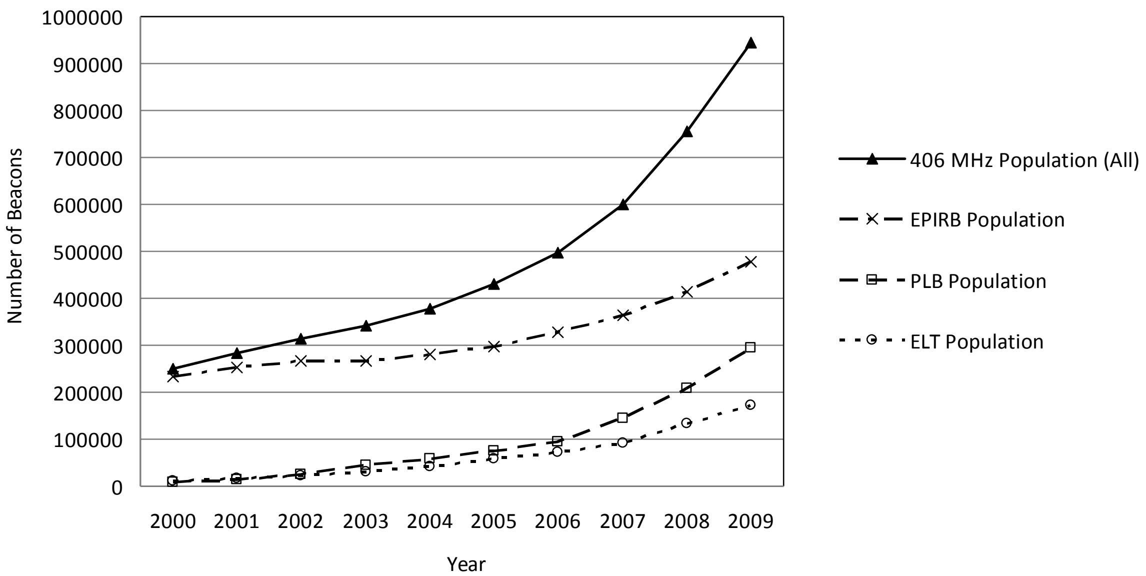
21/ There were two major reasons for the opposition of some Administrations to allowing PLBs:
- Before termination of the satellite processing of 121.5 MHz alerts, the multiplication of cheap 121.5 MHz PLBs and a possible flood of unidentified 'false' (non-distress) alerts were seen as a real threat to the SAR system. Allowing only 406 MHz PLBs would be very difficult to enforce (see Chapter 5, section 5.5).
- Maritime and aeronautical administrations in charge of SAR did not wish to take responsibility for individual persons' alerts on land. No legislation, no formal organization and no operational procedures had been established to deal with alerts from 'persons' received through the Cospas-Sarsat System.

6.2.3 Annual Customers' Investment in 406 MHz Beacons

Using the average prices quoted by Australia for year 2000 (see above) together with the statistics on beacon populations provided by the Cospas-Sarsat Secretariat, the magnitude of the total investment by beacon users worldwide, in US$, would typically be around US$ 377.8 million.

	Year 2000			Year 2009		
	Estimated Beacon Population	Average Retail Price US$	Investment Costs US$ million	Estimated Beacon Population	Average Retail Price US$	Investment Costs US$ million
EPIRBs	232,000	$1,500	348.00	477,300	$1,000	477.30
PLBs	7,200	$1,000	7.20	295,200	$500	147.60
ELTs	11,300	$2,000	22.60	173,300	$1,500	259.95
Total Investment Costs (US$ million)			**377.80**			**884.85**

Assuming a 10 year average beacon life cycle[22], the average annual investment by users for the purchase of 406 MHz beacons (US$ 37.8 million) was of the same magnitude as the estimated annual investment in the space and ground segments of the Cospas-Sarsat satellite system (US$ 33 million) over the 1990 to 1999 period. Between 2000 and 2009, the average annual investment in 406 MHz beacons was about US$ 88 million, almost 2.7 times the annual satellite system investment.



406 MHz Beacon Population Growth 2000 - 2009
(Source: Cospas-Sarsat Secretariat)

22/ The 10 year average life cycle for 406 MHz beacons is used by the Cospas-Sarsat Secretariat to derive the beacon population, using annual production data reported by manufacturers. The turn over could be higher for some types of beacons exposed to difficult environmental conditions. The assessment does not take into account the cost of beacon reconditioning linked to the need for battery replacement, generally after five years.

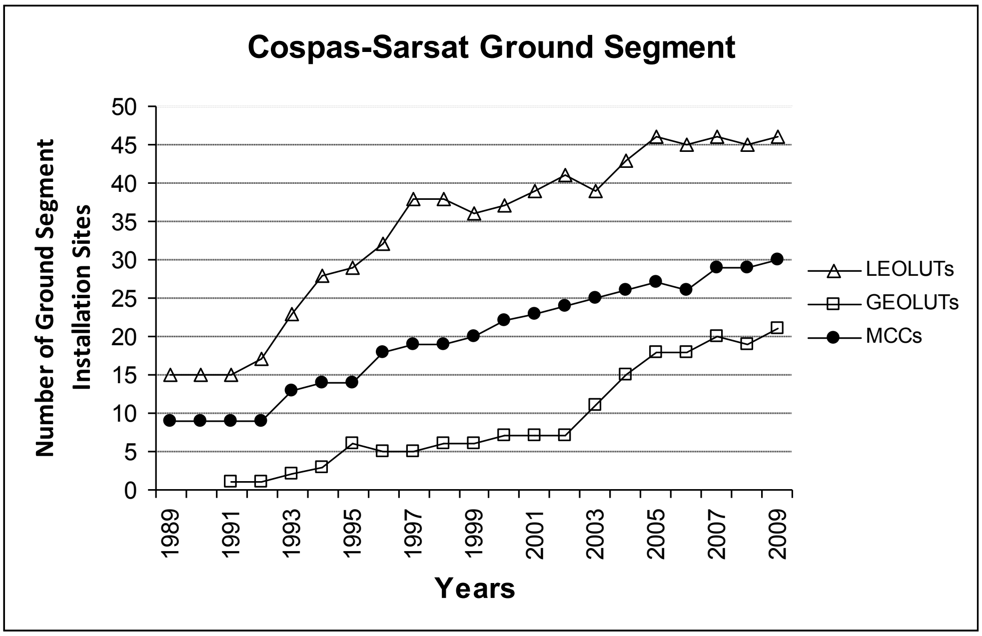
6.3 Cospas-Sarsat LUTs and MCCs: a Niche Market

Some figures have been quoted in section 6.1 regarding the typical costs of a LEOLUT, a GEOLUT or an MCC. However, the actual purchase and installation costs for this type of equipment could vary significantly depending on the stated requirements of the client.

The amount of ground segment equipment needed to operate the Cospas-Sarsat System was rather small, which limited the number of manufacturers. Historically, each Cospas-Sarsat partner (Canada, France, the USSR and the United States) encouraged national providers. By 2009, only two manufacturers provided the vast majority of Cospas-Sarsat operational ground segment equipment (LUTs and MCCs).

For manufacturers, the equipment sale price was only one aspect of the equation. In reality, the global market was too small to ensure steady production activity for new equipment. A significant share of the manufacturers' activity was tied to on-going System changes, software updates, etc., required by a rapidly changing operational environment. Annual maintenance contracts for the equipment also provided regular, substantial income.

Cospas-Sarsat ground segment equipment was a niche market for highly sophisticated products tailored to the needs of customers. The growth of LUT and MCC numbers between 1989 and 2009 is shown below to illustrate this point[23].



23/ Source: Cospas-Sarsat System Data documents published by the Cospas-Sarsat Secretariat (1989 to 2009). Until 1995, GEOLUTs were considered experimental systems, not part of the operational Cospas-Sarsat System. The table shows the number of operational LEOLUT locations, dual equipment operating in parallel or as spare systems were installed at some of these sites, increasing the number of equipment provided by manufacturers. In 2009, dual LEOLUT equipment was installed at 11 of these sites. A number of MCCs were also dual systems. Some of the secondary MCCs were co-located with the primary installation, while others were complete off-site back-up systems.

Chapter 7

Beyond 2009 - the Future of the Cospas-Sarsat System

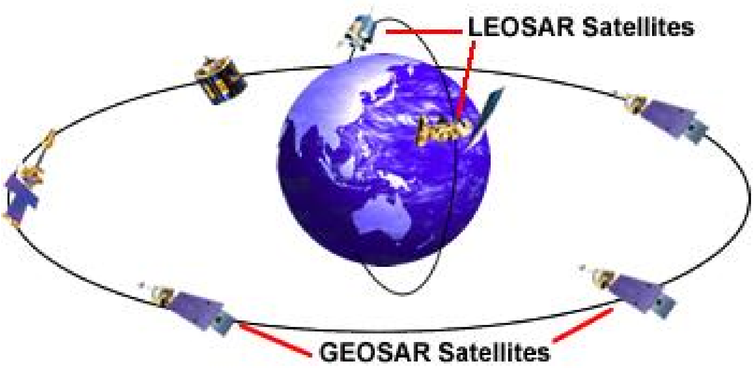
The First Cospas-Sarsat MOU was signed in Leningrad in 1979. Thirty years later, the international environment had changed dramatically, both politically and in the domain of space technology. Major changes impacted mobile satellite communication systems in the 1990s. In the early years of the twenty-first century, the prospects for the future of Cospas-Sarsat had to be reconsidered in light of the changing international context of mobile satellite communications and SAR.

The Cospas-Sarsat System was designed in the 1970s as the answer to a pressing need: the monitoring of analogue 121.5 MHz ELT emissions, already a 20 year old technology by 1979. The System designers also addressed the prospect of a more recent technology, digital data transmissions at 406 MHz, which allowed enhanced performance such as user identification, higher Doppler location accuracy, global coverage, etc. The LEOSAR system became available globally in the 1980s and the 406 MHz technology enjoyed a significant boost in the 1990s with the introduction of the 406 MHz GEOSAR system providing quasi real-time distress alerting.

The only competitor to the 406 MHz system, the GEOSAR L-band EPIRB service provided by Inmarsat, was terminated on 1 December 2006 [1] and the Cospas-Sarsat 121.5 MHz LEOSAR satellite service was shut down on 1 February 2009 (see chapter 5, section 5.4). The Cospas-Sarsat 406 MHz system became the sole global standard for satellite distress alerting using Emergency Position Indicating Radio Beacons, per the ITU terminology, under their various implementations (aviation ELTs, maritime EPIRBs and portable PLBs).

However, by 2009 the 406 MHz system was 30 year old technology. Mobile communication systems, including satellite navigation and mobile satellite communication systems had moved ahead in a spectacular way. The landscape of international cooperation in space had changed significantly and independent entrepreneurs were proposing new commercial services, including mobile satellite communication and positioning services. GPS, the U.S. global navigation satellite system, was a huge success that entirely changed the game in terms of mobile navigation and positioning. After a difficult spell in the 1990s, Russia had revived its own Glonass system. Both Europe and China were following the same path, proposing to implement independent, global GNSS constellations. It is not difficult to imagine that a global mobile satellite communication system coupled with a global navigation satellite system could provide the services required for distress alerting and positioning.

The role and long term relevance of the International Cospas-Sarsat System for distress alerting was a legitimate concern for the sponsoring States.



Picture courtesy of the International Cospas-Sarsat Programme

1/ See Chapter 2, section 2.4 - GEOSAR Systems

7.1 Mobile Telecommunication System Revolution in the 1990s

By 1990, both Inmarsat mobile communication satellite services and Cospas-Sarsat distress alerting satellite services were successfully established on a global basis, using satellite systems managed and operated by inter-governmental organisations. In parallel, while serving a wider market for personal mobile communications without the constraint of global coverage, mobile telephone services were developing quickly in many regions of the world. However, in the early 1990s, mobile telephone cellular networks were suffering a number of limitations. Service quality was not always very good, coverage in sparsely populated areas could be patchy or simply unavailable, roaming costs were high and switching between networks was often impossible.

The above considerations led private entrepreneurs in the telecommunications business to propose new mobile satellite systems for voice, data, paging and positioning. Mobile satellite systems using LEO or MEO constellations were expected to overcome the limitations of terrestrial cellular networks and solve a few delicate technical issues that affect GEO mobile satellite systems: e.g. the weakness of the signal reaching a satellite 36,000 km away from Earth, which necessitates either pointing a directional antenna or providing for higher power transmissions from the mobile handset. In addition, the length of the up and down path to a GEO satellite introduces a small delay in the transmission, which some customers find uncomfortable for voice communications.

Major Mobile Satellite System Proposals in the 1990s

	Planned Satellite Constellations	**Services**	**Date project launched**	**Date Open for Service**	**Date of filing for Chapt. 11[2]**	**Current Status (as at January 2016)**
MSAT	2 / 3 GEO sat. / 36,000 km / L band	Voice, Data, Messaging.	1983	1995	-	In operation, regional N/S Americas coverage
Orbcomm	36 then 48 LEO in 6 orb. planes / 720 km / VHF + UHF	Data, Messaging.	1990	1998	2000	In operation - 18 OG2 satellites. Machine to Machine - Vessels' AIS (2009)
Globalstar	48 LEO in 8 orb. planes / 52^0 Inc. / 1,408 km / L band & S band	Voice, Data Positioning, Paging.	1991	1998 (limited operation)	2002	In operation, 24 second generation sat. / SPOT messenger
Iridium	66 LEO + spares in 6 orb. planes / 86.4° Inc. / 780 km / L band	Voice, Data, Positioning, Paging, Fax.	1991	1998	1999	In operation since 2001, global coverage (20,000 U.S. Gov. users)
Odyssey (TRW)	12 MEO in 3 orb. planes / 55° Inc. / 10,000 km / L & S bands	Voice, Data, Paging, Messaging.	1991	-	Terminated 1998	Never in business
ICO Global Com. (Pendrell Corp.)	10 MEO + 2 spares in 2 orb. planes / 45° Inc. / 10,000 km / L band	Voice, Data.	1995	-	1999	MEO not in operation New ICO G1 (GEO) system launched in 2008
Teledesic / 1	840 LEO in 21 orb. planes / 98.2° Inc. - 700 km / Ka band	Voice over IP, Data.	1994	-	-	No satellite launched
Teledesic / 2	288 LEO in 12 orb. planes / 98.2^0 Inc. - 1,400 km / Ka band	Same	1997	-	Terminated 2002	Never in business

2/ Chapter 11 of the U.S. bankruptcy law provides legal protection from creditors' claims while restructuring a failing business. This usually results in financial losses for investors in the initial business.

Frequency spectrum availability was scarce, particularly in VHF or at L-band, already used by Inmarsat. Under the pressure of governments and industry lobbyists, in 1992 the World Administrative Radio Conference (WARC) opened new frequency bands for use by mobile satellite systems. Industry proposals for new satellite systems flourished. At least a dozen projects hit the headlines fighting for venture capital and government licences. LEO and MEO systems did not have the same drawbacks as GEO systems, but they had other specific challenges. A much higher number of orbiting satellites was needed to ensure global coverage, consequently huge capital investment was required in space hardware before the advertised communication service could be provided to the first paying customer.

Only a handful of these satellite systems took off from the drawing board and a lesser number were still in business by the end of the 1990s (see table above). Except for the MSAT regional system, all new ventures that managed to launch a service had to file for 'Chapter 11 bankruptcy protection' under the U.S. legal system. The new mobile satellite ventures were victims of a rapidly changing market. Terrestrial mobile networks had expanded very fast and service quality had improved. Furthermore, competition had driven customers' costs down, both for the handset and the communication service. Because of the huge capital investment required, mobile satellite service costs were too high and few customers could afford to pay the premium required for worldwide satellite services.

Except for Inmarsat, already established, and MSAT in Canada, both based on geostationary satellite constellations, all new systems were based on LEO and MEO constellations. By 2009, no MEO system was surviving. After restructuring, one 'little LEO' system, Orbcomm, was still operating for 'machine to machine' messaging and AIS[3], a new maritime application for the automatic identification of vessels. Other more ambitious LEO systems (Iridium, Globalstar) managed to resurface after filing for 'Chapter 11' protection, with considerable financial losses for their initial investors.

An alerting and positioning service was proposed by Globalstar with the SPOT messenger system as an ancillary function to its primary commercial messaging and tracking service, using a handheld terminal coupled with a GPS receiver. However, by 2009, Globalstar coverage was not global and the system could not compete with the global Cospas-Sarsat service. As the only truly global LEO mobile satellite communication system, Iridium was striving to obtain acceptance at IMO for GMDSS safety communications.

Iridium Phone Motorola 9500
(with extended antenna)
Source: Wikimedia"Iridium phone2". Licensed under CC BY-SA 3.0 via Commons - https://commons.wikimedia.org/ wiki/

The Cospas-Sarsat LEO and GEO System remained unique in several aspects. It provided a truly global coverage for the distress alerting and positioning service, free of charge for the user in distress. The LEO Doppler positioning service could be provided independently of any external navigation device, that is, without the need for an integrated GNSS receiver in the transmitting beacon. It was internationally accepted from a regulatory perspective and endorsed by international organisations such as ICAO and IMO. Furthermore, through its close co-operation with SAR authorities worldwide, Cospas-Sarsat had implemented a unique global, automatic and secure alert data distribution system, with direct access to responsible SAR forces.

3/ AIS: Automatic Identification System.

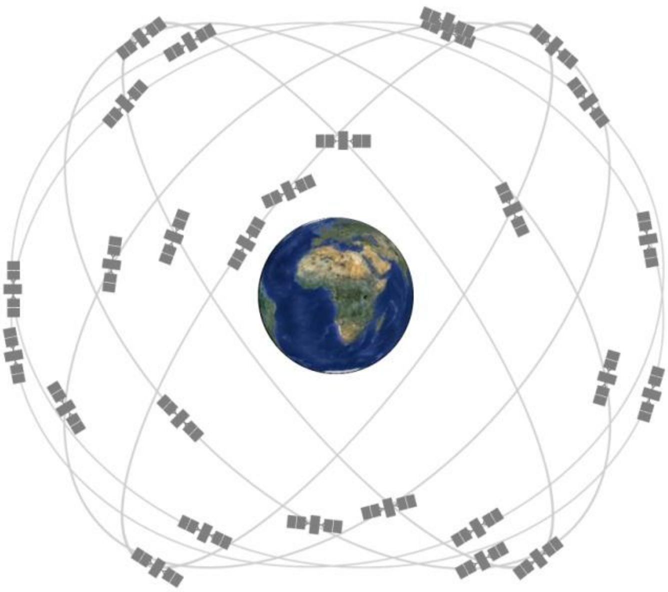
When human life is in "*grave and imminent danger*" all means of alerting are permissible. This principle is generally accepted in the SAR community. Therefore, in the future, commercial mobile communication satellite systems might be considered a viable alternative to the Cospas-Sarsat System in the regulated aeronautical and maritime domains where, currently, 406 MHz beacons are mandatory safety equipment. By 2009, existing commercial applications such as the 'SPOT Messenger' of Globalstar were already competing with Cospas-Sarsat 'Personal Locator Beacons' (PLBs). Commercial communication systems could provide extra messaging and tracking services to customers, which were not permitted using Cospas-Sarsat PLBs since, per the ITU regulation, the 406 MHz frequency band was strictly reserved for distress radio-communications. The messaging and tracking applications available from commercial satellite service providers were actually limiting the growth of the 406 MHz PLB population. They were also proof that an overly restrictive policy regarding PLBs, as discussed in Chapter 5, would have been a futile exercise.

For the Cospas-Sarsat partners, the message was clearly that their System had to continue to evolve to remain relevant to its users' needs.

US Coast Guard Helicopter HH 60
(Photos courtesy of the U.S. Coast Guard)

GEOSAR Antenna
(Photo courtesy of CNES)

MEOSAR Antenas
(Photo courtesy of CNES)



GPS Satellite Constellation (Photo: GPS.gov)

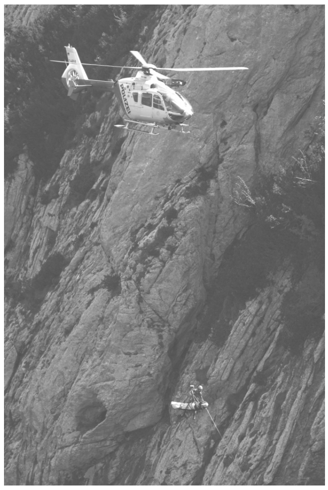
7.2 MEOSAR and the Future of Cospas-Sarsat

A 1997 Canadian 'Follow-On SAR System (FOSS)' study [4] investigated possible methods to improve satellite SAR services. The study, presented to the Open Meeting of the Cospas-Sarsat Council in 1999 (CSC-23) showed that SAR payloads on navigation satellites in medium-altitude Earth orbit (MEO) at approximately 20,000 km altitude, such as GPS, would potentially provide significant advantages compared to using LEO satellites. In addition to providing for an independent positioning capability, potentially with enhanced performance compared to the LEO Doppler location technique, a MEOSAR system based on a host navigation satellite constellation could ensure the continuity of global coverage, hence the prospect of a quasi real-time, independent, alerting and locating capability.

Noting that such continuity of coverage was desirable, but not achievable with the small number of possible host platforms for the SAR payload in low-altitude Earth orbit, the MEOSAR concept was further pursued by Canada's Cospas-Sarsat partners, France, Russia and the United States.

At the CSC-25 Council session held in Laval, Quebec, Canada, in 2000, a meeting was organised, alongside the CSC session, between the four Cospas-Sarsat Parties and European Commission (EC) representatives, where the United States and the EC made presentations of their plans to include 406 MHz repeaters on future MEO satellites of their respective GNSS constellations: GPS and Galileo. The United States and the EC both declared their intention to make their systems backward compatible with Cospas-Sarsat 406 MHz distress beacons, while opening prospects for new developments.

A MEOSAR Experts Working Group (EWG), under the Chairmanship of Mr. Claude Gal of CNES, France, met from 10 to 12 July 2001 in Canada and again in London, UK, from 15 to 17 October 2001. The EWG report was presented to the Council at the CSC-27 Council session in October 2001. The representatives of the EC and the European Space Agency (ESA) in charge of the Galileo GNSS project had been invited to attend the EWG report presentation to the Council and the discussion on follow-on actions, starting a coordination process that would become official in December 2006 through the signing of a joint "*Declaration* [5] *of Intent for Co-operation on the Development and Evaluation of the Medium Earth Orbit Search and Rescue (MEOSAR) Satellite System between the Co-operating Agencies of the International Cospas-Sarsat Programme and the Galileo Joint Undertaking*" [6].



Mountain Rescue
(Photo courtesy of CNES)

At CSC-27, the Russian delegation also announced Russia's intention to consider the installation of 406 MHz repeaters on their renewed Glonass K GNSS project.

4/ Renner, R.C., (1997), Follow-On SAR System (FOSS) Final Report, document CAL-RP-0890-10016, CAL Corporation, submitted to DND/NSS, March 1997, Ottawa, Canada

5/ The Declaration of Intent for Co-operation on the Development and Evaluation of the Medium Earth Orbit Search and Rescue (MEOSAR) Satellite System (…) is available from the Cospas-Sarsat Secretariat under the reference C/S P.014.

6/ The Galileo Joint Undertaking (GJU) was established by the Council of the European Union, through Council Regulation (EC) No 876/2002 on 21 May 2002, for the implementation of the development phase of the Galileo Programme. It was replaced in January 2007 by the European Global Navigation Satellite System Supervisory Authority (GSA).

From that time, NASA in the United States, DOC in Canada, CNES in France and Morsviazsputnik in Russia, together with the EC and ESA [7], actively pursued the objective of promoting the 406 MHz MEOSAR concept as the long-term future of the Cospas-Sarsat System.

In the MEOSAR concept, the 406 MHz beacon transmissions are not processed on-board the satellites, but are merely 'repeated' for reception and processing by ground receiving stations (the MEOLUTs). The independent position computation technique is also different from the Doppler technique used with LEO satellites. As in GNSS systems (GPS, Glonass or Galileo), it is based on measurements of propagation times via four different transmission paths from the beacon to the receiving MEOLUT (i.e., the same beacon message relayed by four different satellites)[8].

Preliminary studies showed that, in addition to providing continuous global coverage, a suitably designed MEOSAR system would allow:

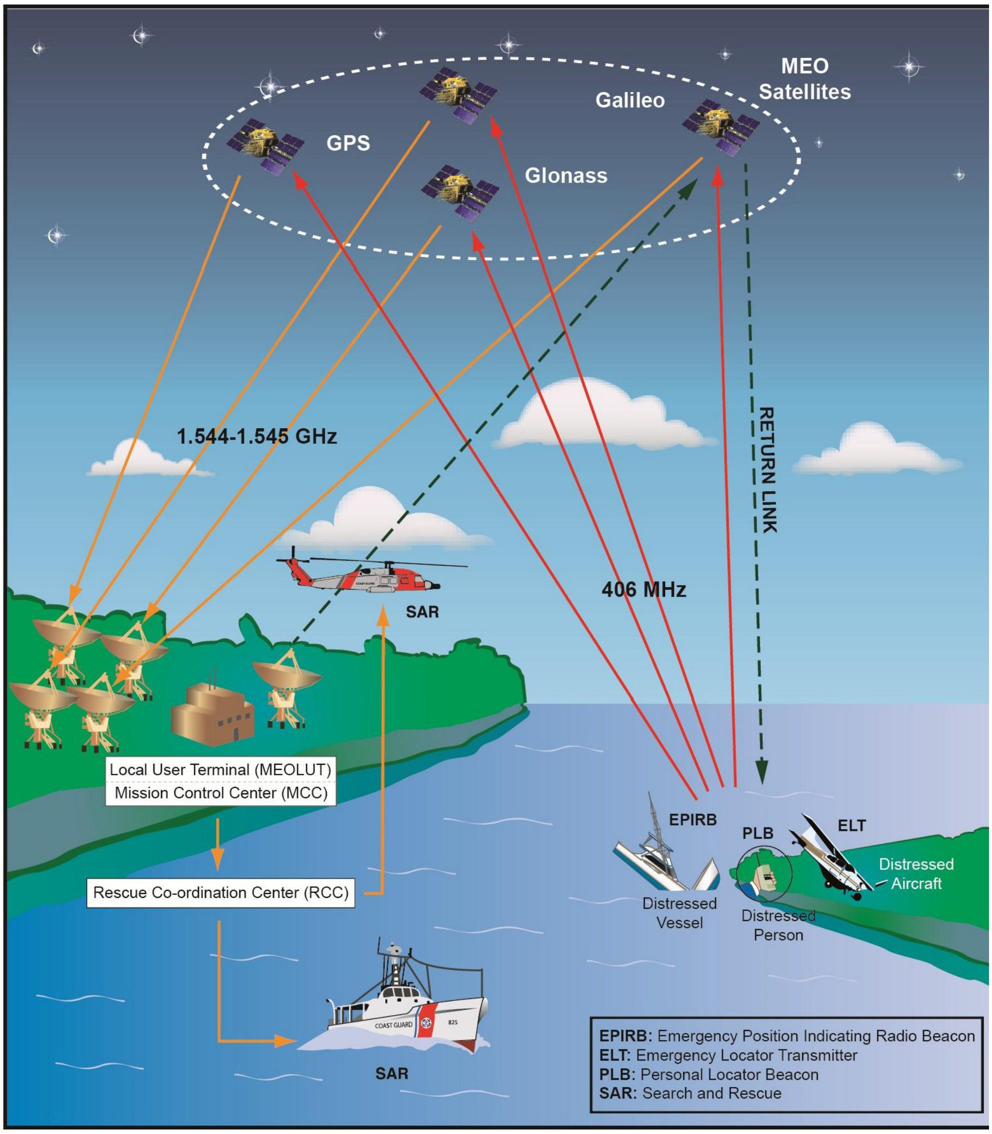
- full backward compatibility with existing Cospas-Sarsat 406 MHz beacons and the possibility of providing enhanced performance with existing beacons;
- second generation 406 MHz distress beacons with new signal characteristics;
- additional data transmission capabilities in the digital message of second generation 406 MHz beacons; and
- a possible return link capability, as proposed by ESA for the SAR Galileo system, to send back to the transmitting beacon a confirmation of the reception of the alert, as well as possibly implementing other SAR functionalities.

To operate with the expected performance, the planned MEOSAR system required the beacon to have simultaneous visibility of at least four satellites at any given time. Each one of the proposed MEO constellations (GPS, Galileo and Glonass), when completed with the planned number of satellites, would provide the required simultaneous coverage with a minimum of four satellites, almost continuously. Unfortunately, for each of these proposed constellations, the horizon of a suitable space segment with a sufficient number of satellites carrying the appropriate 406 MHz repeater kept slipping away as time went by. Therefore, ensuring interoperability among the three constellations was clearly desirable to allow beacons and MEOLUTs to operate using any available satellite in the three MEO constellations, suitably equipped with the appropriate 406 MHz repeater. Interoperability of the three constellations would provide the required number of operational MEOSAR satellites at the earliest opportunity.

Preliminary studies also showed that, if compatibility between the proposed MEOSAR systems and the existing Cospas-Sarsat System could be ensured in terms on non-interference between the satellite systems, full interoperability was still a challenge. The potential benefits to be provided by completely inter-operable MEOSAR systems would require in-depth analyses, feasibility studies and detailed co-ordination to define precise specifications and interoperability parameters.

7/ The MEO distress alerting satellite system 'DASS' project in NASA was led by Dave Affens. The DASS system was also referred to as the Global Personnel Recovery System (GPRS) in early Cospas-Sarsat discussions. Daniel Ludwig at the EC and Igor Stojkovic, Head of the Galileo Project at ESA were leading the SAR-Galileo effort. Richard Renner at CAL in Ottawa, Canada actively contributed through a feasibility study sponsored by ESA. Jim King at CRC also contributed to the preliminary studies, actively promoting the concept in Canada. Vladislav Rogalski with RISDE in Russia coordinated the development of the inter-operable Glonass-K MEOSAR system.

8/ This basic positioning technique (TDOA: Time difference of arrival) can be enhanced using additional frequency shift measurements on the same transmissions (FDOA), or measurement data from other MEOLUTs, or data from earlier transmissions from the same beacon.



The 406 MHz MEOSAR System Concept
Source: Cospas-Sarsat Information Bulletin No. 26 (2015).

By 2009, the development of interoperable 406 MHz MEOSAR constellations was well under way. The first issue of a 'Cospas-Sarsat 406 MHz MEOSAR Implementation Plan' [9] had been approved by the Cospas-Sarsat Council in 2004. The Council decision clearly acknowledged that the 'Cospas-Sarsat 406 MHz MEOSAR System' was the future replacement of the Cospas-Sarsat LEO system. A co-ordinated frequency plan for the MEOSAR downlink at L-band was agreed among the MEOSAR space segment providers, ensuring compatibility with the existing LEO and GEO space segments and allowing future MEOLUTs to operate with the three MEOSAR constellations. Experimental 406 MHz repeaters were available on eight GPS Block IIR satellites. Although not fully representative of the operational 406 MHz payloads, as they did not feature the planned L-band downlink of future operational satellites, these GPS satellites allowed experimenting with the MEOSAR system in a 'Proof-of Concept / In-orbit Validation' phase.

9/ System Document C/S R.012

7.3 Tentative Conclusion to the Cospas-Sarsat History Study

At the time of writing a conclusion to this history study, the International Cospas-Sarsat Programme is alive and pushing ahead with the development and implementation of the Cospas-Sarsat 406 MHz MEOSAR system.

Compatibility between the three MEO constellations is assured. Inter-operability parameters and performance objectives for the future operational System have been defined and agreed. The exact configuration of the ground segment is yet to be finalised to ensure optimum operation and continuity of service globally. Similarly, specifications for second generation 406 MHz beacons are still debated, as well as the actual operational use of the new return-link concept, which will require a thorough demonstration and evaluation with the participation of SAR authorities.

The cut-off date of the Cospas-Sarsat history study was chosen as the year 2009, which marked a major milestone of the Programme evolution: the termination of the 121.5 MHz LEO system. The purpose was also to avoid interfering with on-going work by the Cospas-Sarsat partners. For the same reason, it would be inappropriate to draw definite conclusions and make predictions concerning the future of the Cospas-Sarsat Programme.

However, by 2009, although the actual performance of the MEOSAR system was still to be fully characterised, it was generally agreed that the future of Cospas-Sarsat would be based, at least initially, on a combination of GEO and MEO satellites. Such combination would potentially provide all of the required services for both existing and future 406 MHz distress beacons, including continuous monitoring, global alerting, independent and co-operative/dependent positioning of the distress site, and potentially a return link to active distress beacons.

From its initial operation in 1982 until the end of 2014, the Cospas-Sarsat satellite system for Search and Rescue helped SAR forces in rescuing almost 40,000 persons [10]. The future operational capabilities of the Cospas-Sarsat System should ensure that it remains, for the foreseeable future, the cornerstone of automatic alerting and locating on land and at sea, assisting SAR authorities worldwide, free of charge and with no discrimination, for the rescue of any person in distress.

Looking back at the history of the Cospas-Sarsat adventure, its uniqueness should be highlighted. Designed in the 1970s and built through an inter-governmental East-West cooperative endeavour in the context of the Cold War, the experimental satellite system has evolved into a global operational system managed co-operatively by a group of 42 countries and organisations. This accomplishment is clearly the result of the foresight of a small number of space pioneers and their firm belief that international co-operation was the answer to the challenge of distress alerting and locating on land and at sea. These pioneers were followed by a large number of professionals in industry as well as governmental organisations, whose dedication over more than thirty years allowed the transformation of the experiment into a global operational satellite system serving the international SAR community. The continuation of the Cospas-Sarsat adventure to this day, with promising new developments, is testimony to their success.

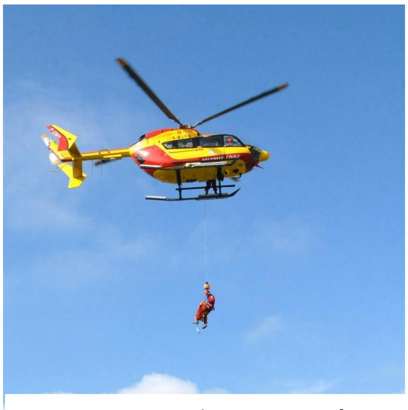


Photo courtesy of CNES

10/ From September 1982 to December 2014, the Cospas-Sarsat System provided assistance in rescuing at least 39,565 persons in 11,070 SAR events (source Cospas-Sarsat System Data No. 41 - December 2015).

ANNEX 1

Abbreviations and Acronyms

ACC	Air-traffic Control Centre
AEROSAT	Aeronautical satellite communication project
AFTN	Aeronautical Fixed Telecommunication Network
AMSAT	Amateur radio satellite organisations (worldwide)
ARCC	Aeronautical RCC (see RCC)
Argos	CNES environmental data collection and Doppler location system operated in cooperation with NOAA
CCIR	former 'Comité Consultatif International pour la Radio' / International Consultative Committee for Radio - now part of the ITU-R Sector
CNES	Centre National d'Études Spatiales (French national space agency)
CGMS	Coordination Group for Meteorological Satellites
COPUOS	UN Committee on the Peaceful Use of Outer Space
COSPAR	Committee on Space Research of the International Council for Science (ICSU)
COSPAS	"Коспас" acronym for "Космическая система поиска аварийных судов" meaning 'Space system for the search of vessels in distress'
CPI	Crash Position Indicator (automatically deployable Canadian system for aircraft)
CRC	Communications Research Centre (Canada)
CSC	Cospas-Sarsat Council (from October 1988)
CSCG	Cospas-Sarsat Coordinating Group (1979-1984)
CSIP	Cospas-Sarsat Implementation Plan
CSSC	Cospas-Sarsat Steering Committee (1985-1988)
DDP	Cospas-Sarsat Data Distribution Plan
DFVLR	Deutsche Forshungs- und Versuchsanstalt für Luft und Raumfahrt (German research and development institute for air and space travel)
DGAC	Direction Générale de l'Aviation Civile (France's civil aviation administration)
DOC	Department of Communications (Canada)
DND	Department of National Defence (Canada)
DSC	Digital Selective Calling - IMO standard for transmission of pre-defined digital messages in the MF, HF and VHF frequency bands.
D&E	Cospas-Sarsat Demonstration and Evaluation phase
ELT	Emergency Locator Beacon (aviation)
Ephemeris	Set of parameters defining the position of a satellite on its orbit
EPIRB	Emergency Position Indicating Radio Beacon (ITU generic / maritime distress beacon)
EPS	EUMETSAT Polar System (see METOP)
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EWG	Exercise Working Group of the Cospas-Sarsat Joint Committee

FAA	Federal Aviation Administration (USA)
FCC	Federal Communications Commission (USA)
FGMDSS	Future Global Maritime Distress and Safety System (renamed GMDSS in 1999)
FIR	Flight Information Region
Galileo	European GNSS
GEO	Geostationary Earth Orbit
GEOLUT	Local User Terminal in the GEOSAR satellite system
GEOSAR	Geostationary Earth Orbiting satellite system for Search and Rescue
GHz	Giga Hertz (10^9 Hertz)
Glonass	Global Navigation Satellite System (Russia's GNSS)
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GOES	NOAA Geostationary Operational Environmental Satellite (USA)
GPS	Global Positioning System (United States' GNSS)
GSFC	Goddard Space Flight Center - NASA (USA)
HF	High Frequency band (3 to 30 MHz)
Hz	Hertz (frequency unit)
IATA	International Air Transport Association
IBRD	Cospas-Sarsat International Beacon Registration Database
ICAO	International Civil Aviation Organization
ICSAR	Interagency Committee on Search and Rescue (USA)
ICSPA	International Cospas-Sarsat Programme Agreement
ICTs	Information Communication Technologies
IFRB	International Frequency Registration Board - now part of the ITU-R sector
IJPS	Initial Joint Polar System (NOAA/EUMETSAT co-ordinated dual polar meteorological satellite system)
IMCO	Intergovernmental Maritime Consultative Organisation (renamed IMO in 1982)
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite Organisation (1979 to 1994) International Mobile Satellite Organization (1994 to 1999, prior to INMARSAT's privatisation in 1999, Inmarsat Ltd. after 15/04/1999)
IMSO	International Mobile Satellite Organization (after 15/04/1999 and INMARSAT's privatisation)
INSAT	Indian geostationary communication satellite series
ISRO	Indian Space Research Organisation
ITDC	International Telecommunications Development Corporation of Taipei, China
ITU	International Telecommunications Union
ITU-R	Radiocommunication Sector of the ITU
JC	Cospas-Sarsat Joint Committee (from 1989)
JRCC	Joint (aviation and maritime) Rescue Coordination Centre
JWG	Joint Working Group of the CSSC (prior to 1989)
K-band	Frequency band: 18 to 26.5 GHz
Ka-band	Frequency band: 26.5 to 40 GHz
kHz	Kilo Hertz (10^3 Hertz)

L-band	Frequency band: 1 to 2 GHz
LEO	Low-altitude Earth Orbit
LEOLUT	Local User Terminal tracking LEOSAR satellites
LEOSAR	Low-altitude Earth Orbiting satellite system for Search and Rescue
LUT	Cospas-Sarsat Local User Terminal (ground receiving station in the Cospas-Sarsat System)
MCC	Cospas-Sarsat Mission Control Centre
MEO	Medium-altitude Earth Orbit
MEOSAR	Medium-altitude Earth Orbiting satellite system for Search and Rescue
METOP	Meteorological Operational satellite (LEO satellite series of EUMETSAT's polar system - see EPS)
MF	Medium Frequency band (300 to 3,000 kHz)
MHz	Mega Hertz (10^6 Hertz)
MORFLOT	USSR Ministry of Merchant Marine
Morsviasputnik	MORFLOT subsidiary agency for maritime mobile satellite communications (USSR / Russia)
MOU	Memorandum of Understanding
MRCC	Maritime RCC (see RCC)
MSC	IMO Maritime Safety Committee
MSG	Meteosat Second Generation (second generation satellite series of EUMETSAT's geostationary system)
MSI	Maritime Safety Information
NASA	National Aeronautics and Space Administration (USA)
NDB	Non-Directional Beacon (MF aeronautical navigation aid)
NESDIS	National Environmental Satellite, Data and Information Service of NOAA
NOAA	National Oceanic and Atmospheric Administration (USA)
NSS	National SAR Secretariat (Canada)
NTSB	National Transportation Safety Board (USA)
OST	Outer Space Treaty / Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies
OWG	Operations Working Group of the Cospas-Sarsat Joint Committee
PLB	Personal Locator Beacon
RCC	Rescue Coordination Centre (responsible for SAR coordination in an SRR)
RISDE	USSR Research Institute of Space Devices Engineering
RR	ITU Radio Regulations
S-band	Frequency band: 2 to 4 GHz
SAR	Search and Rescue
SARSAT	Search and Rescue Satellite Aided Tracking
SARP (Cospas-Sarsat)	Search and Rescue Processor (406 MHz on-board receiver-processor-memory unit carried on Cospas-Sarsat satellites)
SARPs (ICAO)	International Standards and Recommended Practices
SARR	Search and Rescue Repeater (121.5 MHz repeater system on Cospas satellites; 121.5 MHz, 243 MHz and 406MHz repeater system on Sarsat satellites)
SART	Search and Rescue Transponder (homing device for EPIRBs)

SERES	L-band MEO satellite system concept in polar orbit developed by the German company MBB/ERNO for the DFVLR
SOLAS	Safety of Life at Sea convention
SPOC	SAR Point of Contact
SRR	Search and Rescue Region
SSG	Sarsat Steering Group (1979-1984)
TSO	Technical Standard Order (FAA, USA)
TWG	Technical Working Group of the Cospas-Sarsat Joint Committee
UHF	Ultra High Frequency band (300 to 3,000 MHz)
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations organization
UNCLOS	UN Convention on the Law of the Sea
USA	United States of America
USSR	Union of Soviet Socialist Republics
UTC	Coordinated Universal Time (French: Temps universel coordonné, abbreviated UTC)
VFR	Visual Flight Rules (aviation - operation of aircraft)
VHF	Very High Frequency band (30 to 300 MHz)
WARC	World Administrative Radio Conference (renamed WRC: World Radiocommunication Conference in 1992)
WMO	World Meteorological Organisation

ANNEX 2

The Background of International Cooperation on Search And Rescue (SAR)

Search and rescue (SAR) is the search for, and provision of aid to, people who are in distress or imminent danger. This definition applies to all sorts of circumstances: maritime distresses, aeronautical distresses that can occur over land or over sea areas, and persons on land in remote or inhospitable areas. SAR also applies to specific military operations and is then referred to as 'combat search and rescue'. This last aspect of SAR is not usually covered under the topic of international cooperation and will not be addressed further in this section.

1. Maritime SAR

When the British passenger liner Titanic sank in the early morning of 15 April 1912 after colliding the day before with an iceberg, 375 miles south of Newfoundland in the North Atlantic Ocean, she was equipped with a powerful radio transmitter and distress signals were received by a number of ships. None were close enough to reach the Titanic before she sank. There were an insufficient number of life rafts for the 2,200 passengers and crew, and over 1,500 were lost at sea when the ship Carpathia arrived on scene to recover survivors. Another nearby ship, "Californian", had seen flares, but failed to respond.

1.1 The "Safety of Life at Sea" (SOLAS) Convention

Two enquiries into the disaster that were run in the United States and the United Kingdom, respectively, issued recommendations including the need for major changes in maritime regulations to implement new safety measures. The international response to the disaster led to the establishment of the International Ice Patrol to monitor the presence of icebergs in the North Atlantic, and maritime safety regulations were harmonised internationally through a new 'International Convention for the Safety of Life at Sea' (the SOLAS convention) adopted on 20 January 1914. Because the First World War had broken out, the SOLAS convention failed to enter into force in 1915. Only five States had ratified the convention at the time. Nevertheless the work done on the SOLAS convention led to the adoption of new safety regulations by major maritime States.

Photo courtesy The International Cospas-Sarsat Programme

The International Ice Patrol is still in full operation today. SOLAS has entered into force and has been amended a number of times to reflect current practices and the evolution of technology. In 1988, the International Maritime Organisation approved amendments to SOLAS which, among other things, replaced the Morse code with the carriage requirements of the Global Maritime Distress and Safety System (GMDSS). In 1993, satellite Emergency Position Indicating Radio Beacons (EPIRBs) became mandatory on all ships under SOLAS jurisdiction.

The carriage of mandatory safety equipment on ships is only one aspect of SAR and other international agreements are required to set up a working SAR system at sea. Agreements among States are necessary to build and co-ordinate the use of facilities and equipment on the coast, including means and resources for receiving distress alerts and rules for processing such alerts. Global and local agreements are also required to establish the principles to be followed in planning and coordinating responses to distress alerts, and to assign responsibilities for SAR operations in international waters.

1.2 UNCLOS [1] and the Principle of Mutual Assistance at Sea

The principle of free international waters beyond the three nautical miles limit off the coast was established in the 17th century. The legal principle reflected the very factual ‘cannon ball rule’ which recognised the State’s exclusive authority over waters that could be reached by a cannon ball fired from the coast. This rule was challenged in the 20th century by States looking to protect national claims on natural resources at sea (minerals, fish stocks, pollution control, etc.). In 1945, U.S. President Truman declared that the USA would control the whole continental shelf to protect natural resources. Other countries followed the U.S. example and extended their territorial waters to 12 NM or declared a 200 NM (370 km) exclusive economic zone. In an effort to harmonise the legal basis of State regulations, a series of conferences on the law of the sea were convened by the United Nations between 1973 and 1982. The diplomatic effort resulted in the adoption of the UN Convention on the Law of the Sea (UNCLOS) which entered into force in 1994, after its ratification by 60 States.

The duty to render assistance to ships in distress was first spelled-out in Article 11 of the ‘1910 Brussels Convention for the Unification of Certain Rules with Respect to Assistance and Salvage at Sea’ [2] and repeated in Article 98 of the UNCLOS which states that:

> “*Every State shall require the master of a ship flying its flag, in so far as he can do so without serious danger to the ship, the crew or the passengers:*
>
> - *to render assistance to any person found at sea in danger of being lost;*
> - *to proceed with all possible speed to the rescue of persons in distress, if informed of their need of assistance, in so far as such action may reasonably be expected of him;*
> - *after a collision, to render assistance to the other ship, its crew and its passengers and, where possible, to inform the other ship of the name of his own ship, its port of registry and the nearest port at which it will call.*”

1.3 The International Convention on Maritime Search and Rescue

UNCLOS has no specific provision on the detailed organisation of SAR. This matter was addressed in the 1979 International Convention on Maritime Search and Rescue adopted in Hamburg, Germany, on 27 April 1979. The Annex to the 1979 maritime SAR convention defined the basic terminology applicable to maritime SAR agreements, including emergency phases, search and rescue services, search and rescue regions (SRRs), rescue co-ordination centres

1/ UNCLOS: UN Convention on the Law of the Sea.

2/ Convention pour l’unification de certaines règles en matière d’assistance et de sauvetage maritimes (Brussels, 23 September 1910).

(RCCs), etc. It also included requirements in terms of signatories' responsibilities for the provision and co-ordination of SAR services, principles to be followed for co-operation between States, operating procedures and the co-ordination of activities on-scene.

An SRR is a sea area in which a State volunteers to exercise responsibility for the provision of SAR services. The issue of jurisdiction boundaries at sea significantly complicates the definition of adjacent SRRs that "*should be contiguous and, as far as practicable, not overlap*"[3]. The SAR convention also states that such SRRs "*shall be established by agreement among Parties concerned*"[4]. In case those Parties concerned cannot reach agreement, they "*shall use their best endeavours to reach agreement upon appropriate arrangements under which the equivalent overall co-ordination of search and rescue services is provided in the area*"[5]. This rather diplomatic wording essentially means that a disagreement on SRR boundaries cannot stand as an excuse to refuse co-operation with a neighbouring State on a particular rescue operation within a disputed sea area. If no agreement exists on which country should actually be in charge, appropriate 'local' arrangements must be put in place to ensure the provision of effective and efficient assistance.

Finally, the 1979 Convention states that "*the delimitation of search and rescue regions is not related to and shall not prejudice the delimitation of any boundary between States*"[6].

For most sea areas of the globe, adjacent and contiguous maritime SRRs have been agreed and States have implemented appropriate facilities for the provision of SAR services. These efforts are recorded in the international maritime SAR Plan maintained by the International Maritime Organisation (IMO). However, although the 1979 SAR convention declares that accepting responsibility for SAR does not convey any form of sovereignty rights over an SRR, the matter is highly sensitive in some parts of the world due to political competition and the States' desire to preserve exclusive rights on potential resources. In spite of sustained efforts by the IMO to coordinate responsibilities, disagreements exist on SRR boundaries and can generate conflicts among States concerned.

Photo courtesy The International Cospas-Sarsat Programme

The Cospas-Sarsat partners did face such difficulties when the issue of sharing responsibilities for the distribution of Cospas-Sarsat distress alerts at sea was addressed at Cospas-Sarsat meetings, with the additional twist of having to address simultaneously the distribution of aeronautical distress alerts over maritime areas. This question is reviewed in further detail in Chapter 5.

3/ Annex to the Maritime SAR convention, Chapter 2, paragraph 2.1.3.

4/ Annex to the Maritime SAR convention, Chapter 2, paragraph 2.1.4.

5/ Annex to the Maritime SAR convention, Chapter 2, paragraph 2.1.5.

6/ Annex to the Maritime SAR convention, Chapter 2, paragraph 2.1.7.

1.4 IMO and the Global Maritime Distress and Safety System (GMDSS) Revolution

The Convention on the Inter-governmental Maritime Consultative Organisation (IMCO) was adopted at a conference sponsored by the United Nations in Geneva on 6 March 1948. The IMCO Assembly met for the first time in London, UK on 6 January 1959. The term used in the organisation's name, 'consultative', may have been a reflection of diplomats' concerns that the principle of free open seas with minimum international regulation, which had so far prevailed, could eventually be threatened. The change of name in 1982 to the 'International Maritime Organisation (IMO)', probably acknowledged the necessity of detailed international safety regulations, applicable to all States as well as ship owners, for all aspects of the rapidly increasing sea trade, including ship building, radio-communications, seafarers' training and qualifications, ocean pollution risks, etc.

By the end of the 1970s, international regulations concerning ship radio-equipment for safety and distress alerting, as well as the provision of coastal facilities by States, were widely seen as inadequate and sometimes obsolete. These included terrestrial radio communication systems in medium frequencies (MF) supporting the transmission of alerts using the Morse code, and high frequency (HF) long range radio communication systems supporting telephony, telex and telegram. The ship radio station must be manned 24 hours a day by skilled radio operators. New digital communication technologies and mobile satellite communication capabilities were expected to become available soon[7], but were not acknowledged in international safety standards. In 1979, the experts drafting the SAR convention in Hamburg adopted a resolution calling for the development by IMO of a new global distress and safety system to support the global SAR Plan. The development of the 'Future Global Maritime Distress and Safety system', or FGMDSS, soon became a major item on the agenda of the IMO Maritime Safety Committee and stayed there until the full implementation of the GMDSS on 1 February 1999. Because of the need for early improvements to distress and safety regulations, some components of the GMDSS, in particular Navtex[8] and satellite EPIRBs, became mandatory equipment from 1 August 1993.

A vessel in distress
Photo: SMIT Amandla Marine (Pty) Ltd.

GMDSS Provisions for Distress Alerting

The GMDSS includes a variety of radio-communication systems and equipment designed to perform several basic safety functions: distress alerting, including position

7/ The convention creating the Inmarsat organisation (see Chapter 1, section 1.2) entered into force in 1979 and the Inmarsat system began to operate in 1982. The first Cospas-Sarsat MOU was signed in 1979 and the first Cospas satellite was launched in 1982.

8/ Navtex is an international, automated system for instantly distributing maritime safety information (MSI), which includes navigational warnings, weather forecasts and weather warnings, search and rescue notices, etc.

determination of the unit in distress and locating/homing, search and rescue coordination, maritime safety information broadcasts, general communications and bridge-to-bridge communications. To achieve these functions, detailed carriage requirements are specified depending on the ship's area of operation. The GMDSS requirements apply only to ships above 300 Gross Tons.

The ships' areas of operation, or sea areas, are defined according to the range of radio-communication equipment for DSC[9] alerting; i.e., VHF (area A-1), MF (area A-2), geostationary mobile satellite coverage areas (area A-3), and worldwide (area A-4), including polar regions (beyond Inmarsat satellite coverage) where HF radio and a polar-orbiting satellite EPIRB system are required. A satellite EPIRB alerting capability is required in all sea areas. Initially, outside sea area A-4, the satellite EPIRB requirement could be fulfilled using either a Cospas-Sarsat 406 MHz EPIRB or an Inmarsat-E EPIRB operating in L-band (1.6 GHz). Following the termination of the Inmarsat-E service in 2006 (see section 2.5.7), only Cospas-Sarsat 406 MHz EPIRBs satisfy the GMDSS requirement for carriage of a satellite EPIRB.

The mandatory carriage of a collection of equipment using modern digital technology also brought a radical change to alerting procedures at sea. Because of the limitations of analogue radio telephony, traditionally, most distress alerts were directed to other ships in the vicinity of the distressed unit, who were assumed to be best situated to provide immediate assistance. In the GMDSS, although the ship-to-ship distress alerting capability remains available and is used to relay alerts when needed, the priority is for ship-to-shore alerting and the Rescue Coordination Centre (RCC) is the initiator and coordinator of SAR operations. DSC radio alerting enhances the range and efficiency of radio alert transmissions and facilitates follow-on radio telephony communications. Information on vessel traffic in the sea area is generally available to the RCC and is used to plan the SAR response, which most often involves re-routing other ships in the vicinity. In the case of satellite EPIRB alerts, the RCC is the first and only recipient of the automatic alert message, with authority for initiating a SAR operation. Similarly, Inmarsat system alerts are directly relayed by the coast receiving station to an RCC.

In the context of maritime safety, automatic distress alerting using satellite EPIRBs is only one among a number of alerting methods available to mariners and rescuers. The unique capabilities of satellite EPIRBs, in comparison with other devices and alerting methods, are to:

- survive a ship sinking event and to automatically deliver position data, independently from other devices; and
- identify the unit in distress and provide a homing capability (to complement the satellite system independent positioning capability), anywhere on the globe.

9/ Digital selective calling is a standard for sending pre-defined digital messages via Medium Frequency (MF), High Frequency (HF) and Very High Frequency (VHF) maritime radio systems. A DSC alert includes the ship's MMSI (maritime mobile service identity) and, when available, its position. It can be transmitted over one or several frequency channels simultaneously.

2. Aeronautical SAR

The International Civil Aviation Organization (ICAO) is a specialised agency of the United Nations charged with coordinating and regulating international air travel. It came into being on 4 April 1947, when the Convention on International Civil Aviation, also known as the Chicago Convention, signed by 52 states on 7 December 1944, went into effect after the 26th ratification. The Convention establishes "*principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically*".

The 19 Annexes to the convention provide the details of these principles and arrangements, known as 'international standards and recommended practices' or SARPs. They address all aspects of air travel safety, including: Annex 1 - Personnel Licensing; Annex 2 - Rules of the Air; Annex 6 - Operation of Aircraft; Annex 8 - Airworthiness of Aircraft; Annex 10 - Aeronautical Telecommunications; and Annex 12 - Search and Rescue.

2.1 Aircraft Incidents, Distress Alerting and the SAR Response

Aircraft losing radio contact and disappearing from radar screens are not uncommon events for Rescue Co-ordination Centres in charge of aeronautical incidents. Although these events mostly affect general aviation (that is, small aircraft) rather than large airliners, recent disappearances show that the risk cannot be ignored, even for commercial air transport.

On 1 June 2009, Air France Flight 447 flying from Rio de Janeiro, Brazil to Paris, France was lost in the middle of the Atlantic Ocean. A large international SAR effort was launched, but only floating debris and bodies were recovered. The crash site was found in 2011, after two years of considerable effort and expenditure, allowing the recovery of the flight data recorders. The analysis and interpretation of recordings finally allowed investigators to understand and clarify the circumstances of the disaster.

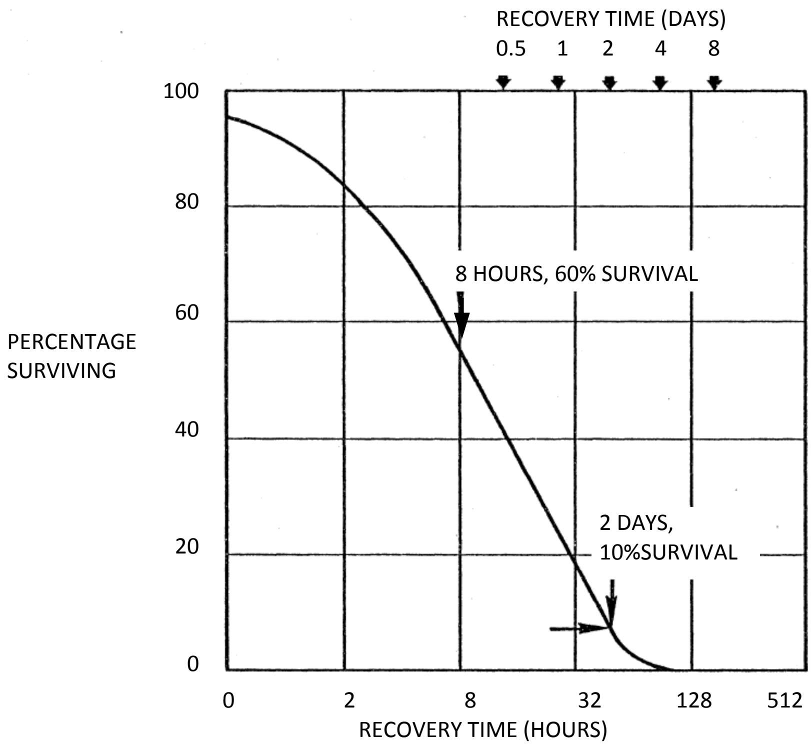
In March 2014, Malaysia Airlines 370 flying from Kuala Lumpur, Malaysia to Beijing, China disappeared in mysterious circumstances. Many countries contributed to the SAR effort which to date has been fruitless. Although the general sea area where the aircraft is likely to have crashed was determined to be off the western coast of Australia, far from the planned flight path of the aircraft, no single material evidence linked to the crash was found until August 2015 [10], and the possible crash area is still debated.

The disappearance of a large aircraft as a result of catastrophic failure or extreme weather in remote, inhospitable areas or at sea, is a rare event which usually does not leave much hope for many survivors. This outcome is the consequence of flight conditions (speed, altitude) and the size of the aircraft, which has not been designed to sustain major shocks, or to float.

The situation is fairly different for lighter aircraft and, often, a number of crew members or passengers survive moderate crashes or hard landings, including on water. However, because of

10/ While the aircraft was assumed to be lost at sea in the Indian Ocean, west of the coast of Australia, a 'flaperon' from the aircraft was found on the shores of Reunion Island, on the other side of the Indian Ocean, in August 2015.

injuries, the speed of the response is instrumental in terms of survival after an aircraft incident. It is generally admitted that the first hours after the incident are critical to ensure the survival of wounded passengers as the survival rate decreases rapidly after that time (see diagram below).



REF: DOD & NSC DATA GIVEN IN C. MUNDO, L. TAMI & G.LARSON, FINAL REPORT PROGRAM PLAN FOR SEARCH AND RESCUE ELECTRONICS ALERTING & LOCATING SYSTEM. DOT-TSC-OST-73-42, FEB., 1974.

Survival Probability as a Function of Time

The diagram at left shows the evolution of the percentage of persons who survive a crash as a function of the time required to recover the survivors. Time is shown in hours (bottom) and days (top) on a logarithmic scale.

The percentage of survivors is 60% if the time to recovery is 8 hours, but decreases to less than 10% after two days.

The diagram is copied from the "Report on Satellites for Distress Alerting and Locating - Oct. 1976 - U.S. Interagency Committee on SAR (ICSAR) - NTSB data from 121 accidents in 1974, involving 264 people."

Most aircraft incidents occur over land, in the vicinity of airports or on airfields. However, even close to an airport, distress sites on land can be extremely difficult to locate when no precise information or location data is available to rescuers. Furthermore, search operations, even on a modest scale can quickly become extremely costly to society.

2.2 Aircraft Emergency Locator Transmitters (ELTs) and Flight Data Recorders

Under the rules of ICAO Annex 6, Emergency Locator Transmitters (ELTs) are required for international air travel to assist, where possible, with the transmission of a quick alert and with the location of the distress site. Lighter aircraft, when no border is crossed during a flight, are not subject to international regulations. However, small aircraft in a Visual Flight Rules (VFR) regime are not under permanent radio contact. In case of a crash, it can be hours before the aircraft is reported overdue and the alert is raised. It is therefore understandable that ELTs became mandatory equipment on light aircraft through national regulations, first in the United States from 1971, and later in most countries with a developed general aviation community. A detailed analysis of the benefits and limitations of first generation 121.5 MHz ELTs is presented in Chapter 1, section 1.3.

ELTs should not be confused with flight data recorders, usually referred to as the “black boxes”, which are also required on airliners according to ICAO SARPs. Their purposes are totally separate and their modes of operation are different; almost opposite. An ELT is meant to remain inactive during the flight, until a distress situation occurs and radio transmissions are triggered, automatically or manually. Flight data and cockpit voice recorders are always active during the flight to record voices and noises in the cockpit, as well as a selection of major flight data generated by aircraft instruments.

After a crash, voice and data recorders are inactive, except for a locator signal which can be detected underwater. While the data recorder can be destroyed on impact, its recording medium has a high probability of survival.

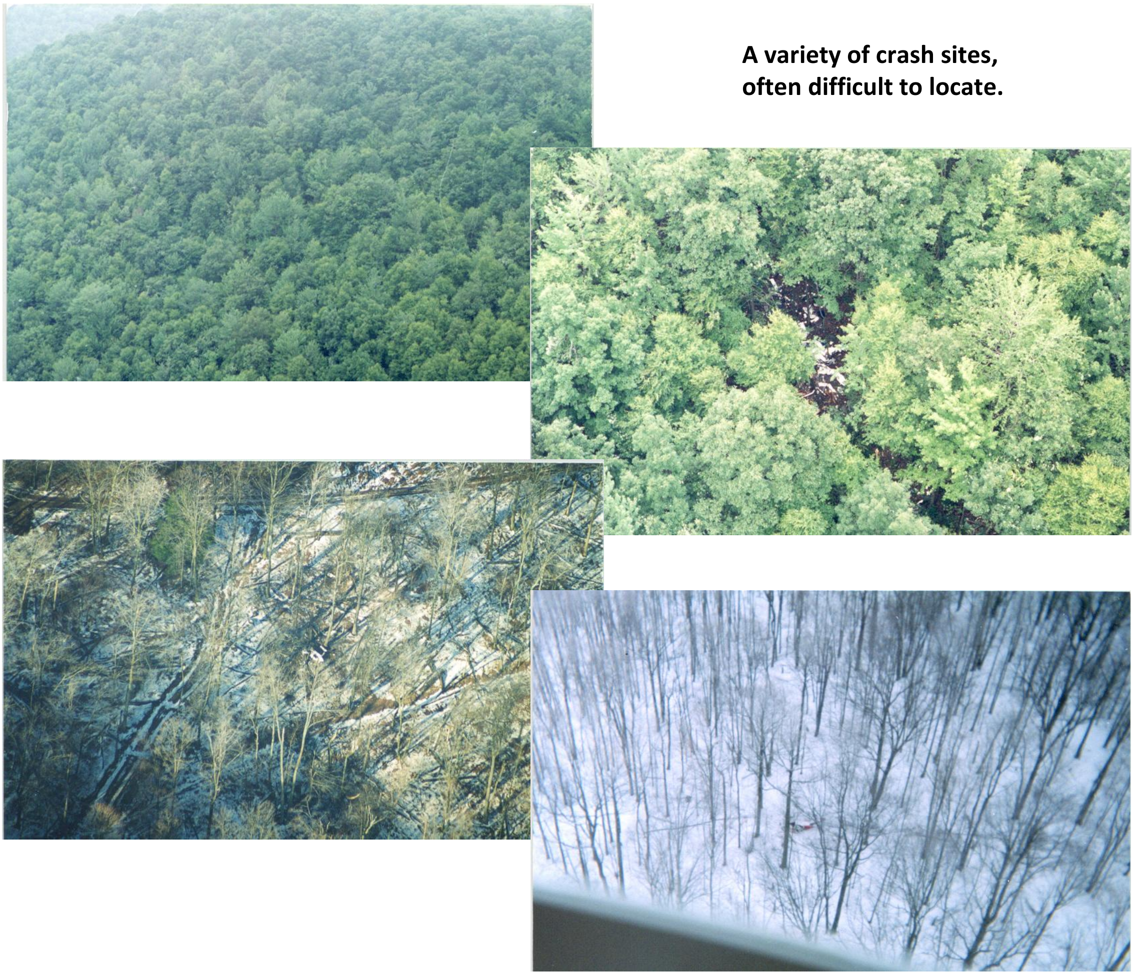
ELT survival in a crash cannot be guaranteed
Photo courtesy The International Cospas-Sarsat Programme

The normal performance of an ELT after a crash cannot be guaranteed for a variety of obvious reasons. This raises questions regarding the effectiveness of the system and the current mandatory carriage requirements. The matter is still at the centre of a debate within the aviation community. Nevertheless, the efficiency of 406 MHz ELTs using digital technology and operating with the Cospas-Sarsat system has been demonstrated, particularly for general aviation incidents. 406 MHz ELTs are now the ICAO standard. Various evolutions are under consideration to enhance their performance when used on larger aircraft. This includes automatic in-flight triggering on detection of abnormal flight configurations and the possible automatic release of the ELT before a crash, in association with flight data recorders.

2.3 Aeronautical and Maritime SAR Co-ordination

The territorial organisation of aeronautical SAR follows a similar pattern to the maritime SAR organisation. It is based on Aeronautical Rescue Co-ordination Centres (ARCCs) exercising responsibility for the provision of SAR services over a designated SRR (Search and Rescue Region), generally coincident with the ICAO defined Flight Information Region (FIR). On land, SRRs and FIRs generally follow agreed national boundaries. Over sea areas, the maritime and aeronautical SRRs are designed to coincide wherever possible. Due to various political constraints and because States may have different responsibilities with regard to maritime or aeronautical traffic, this harmonisation is not always possible.

ICAO and IMO cooperation on SAR has been enhanced with the establishment of an ICAO/IMO Joint Working Group on SAR which meets annually and reports to the appropriate bodies of both organisations. A joint maritime and aviation SAR Manual has been published. Some States (such as Australia) have implemented a Joint RCC responsible for both aeronautical and maritime SAR activities. This joint organisation of SAR for aeronautical and maritime distresses is still an exception among States.



A variety of crash sites, often difficult to locate.

Photo courtesy The International Cospas-Sarsat Programme

3. Other SAR Operations on Land

The response to a distress situation on land is the exclusive responsibility of the State that exercises jurisdiction over the land. When the distress situation does not involve an aircraft, no international convention regulates the organisation of the SAR response, nor the means to be used. No international standard defines the safety equipment required for exploring inhospitable or remote areas, nor recommends any particular SAR organisation to be established by a State. As a consequence, States have developed a variety of approaches to SAR on land, depending on local needs and resources. The response to emergencies on land is therefore highly dependent on the means available to a State and the local environment and climate.

This situation and the absence of specific regulations in most countries resulted in some confusion when new technologies such as automatic tracking and alerting devices were offered to consumers. This was the case when "Personal Locator Beacons" (PLBs) using the analogue technology of 121.5 MHz ELTs, or developed to meet the Cospas-Sarsat 406 MHz standard, were proposed by industry. The principle that any means of alerting can be used in case of an actual distress situation, when human life is in "*grave and imminent danger*", is generally accepted although not precisely defined from a legal perspective. Some States have regulations that preclude the possession or use of unauthorised electronic alerting devices. The swift evolution of technology will make this type of regulation difficult to implement and maintain. However, there is no short term prospect for an international effort to harmonise national legislation and regulations regarding SAR on land.

4. The Role of the International Telecommunication Union (ITU)

The International Telecommunication Union (ITU) is the most senior of all international organisations in the United Nations' system. It actually pre-dates the creation of the UN in 1947. Its precursor, the International Telegraph Union was established in 1865. Acknowledging the development of new technologies, such as the telephone, it changed its name to International Telecommunication Union in 1934 and was integrated into the UN system in 1947.

As radio waves do not stop at State boundaries, conflicting national assignments could compromise the efficient operation of any radio system. In the radio-communications sector, the ITU mandate is to co-ordinate the sharing of the frequency spectrum for all applications and to define frequency allocations to radio services. In particular, the ITU has responsibility for allocating frequencies to maritime and aeronautical radio communication "mobile" services, including distress and safety services. The table of frequency allocations, defined in the Radio Regulations (RR), is regularly updated by World Radio Conferences.

The 121.5 MHz frequency in the VHF aeronautical band is reserved for distress and safety communications. It is the standard aviation distress channel for voice transmissions, also used by the aircraft Emergency Locator Transmitters (ELTs) developed in the 1960s. The Radio Regulations define the exclusive allocation of the frequency band 406.0 to 406.1 MHz to low-power satellite Emergency Position Indicating Radio-Beacons (satellite EPIRBs). The detail of frequency allocations for emergency communications, including satellite ELTs and EPIRBs is presented in Chapter 1, section 1.3.

Other ITU responsibilities include the development of the technical standards that ensure networks and technologies seamlessly interconnect. The ITU has also in its mandate the objective of "*improving access to Information Communication Technologies (ICTs) to underserved communities worldwide*"[11].

11/ Quoted from the ITU official website : http://www.itu.int.

ANNEX 3

States and Organisations Associated with or Contributing to the Cospas-Sarsat Programme

Per Articles 11 and 12 of the International Cospas-Sarsat Programme Agreement (ICSPA), States that are not a Party to the ICSPA can notify their formal association with the International Cospas-Sarsat Programme as Ground Segment Providers or as User States (see Chapter 4, section 4.3).

Ground Segment Providers are those States that procure and install at least one ground receiving station (a Local User Terminal or LUT) and a Mission Control Centre (MCC) to track Cospas-Sarsat LEOSAR or GEOSAR satellites, process the satellite data and forward distress alerts in accordance with the provisions of the Cospas-Sarsat Data Distribution Plan (document C/S A.001). Per Article 11 of the ICSPA, Ground Segment Providers must notify their association with the International Cospas-Sarsat Programme. When their association becomes effective, they are entitled to attend the 'Open Meetings' of the Council and the meetings of its subsidiary organs to participate in the management of the System.

User States are those States that notify their formal association with the International Cospas-Sarsat Programme per Article 12 of the ICSPA to participate in the management of the System, but do not install ground segment equipment. User states are entitled to attend the 'Open Meetings' of the Council and the meetings of its subsidiary organs.

Pursuant to the provisions of Articles 3 and 7 of the ICSPA, if deemed appropriate for the enhancement of Cospas-Sarsat System operation and subject to a specific Council decision, non-State entities, including international organisations, can enter into a formal arrangement with the International Cospas-Sarsat Programme for the provision of System components.

Several such entities (the Marine Department of the Hong Kong, China, government and the International Telecommunications Development Corporation (ITDC) of Taipei, China) have signed letters of association for participation as Ground Segment Operators, with similar entitlements and obligations as for Ground Segment Provider States. In addition, the Cospas-Sarsat Parties have signed in 2007 an "*Understanding between the States Parties to the ICSPA and the Republic of India concerning the Association of the Republic of India as a Provider of Geostationary Satellite Services for Search and Rescue (GEOSAR)*" - document C/S P.009 - and in 2010 an "*Arrangement on Cooperation between the Cooperating Agencies of the Parties to the ICSPA and the EUMETSAT organisation on the EUMETSAT Contribution to the Cospas-Sarsat GEOSAR System*" - document C/S P.008.

The table below provides the list of the 40 States and 2 organisations that were formally associated with the Cospas-Sarsat Programme, as of December 2010. Organisations that contribute to the System through special arrangements are also listed[1]. The up-to-date list of associated States and Organisations can be obtained from the Cospas-Sarsat website as document C/S P.010.

1/ EUMETSAT and the European Commission

States and Organisations Associated with or Contributing to the Cospas-Sarsat Programme (as at End December 2010)

States / Organisations	Status	Effective Date of Association	System Contribution	Cooperating Agency
Algeria	Ground Segment Provider	10 May 1996	2 LEOLUTs (Ouargla, Algiers) 1 GEOLUT (Algiers)	Ministère de la Défense Nationale - Service SAR
Argentina	Ground Segment Provider	9 January 2002	2 LEOLUTs (El Palomar, Rio Grande) 1 GEOLUT (El Palomar)	Servicio de Comunicaciones Navales
Australia	Ground Segment Provider	22 June 1991	2 LEOLUTs (Albany, Bundaberg)	Australian Maritime Safety Authority (AMSA)
Brazil	Ground Segment Provider	10 July 1992	3 LEOLUTs (Brasilia, Manaus, Recife) 2 GEOLUTs (Brasilia, Recife)	Air Space Control Department (DECEA)
Canada	ICSPA Party / Space Segment Provider	30 August 1988	Sarsat SARR instruments on Sarsat satellites 3 LEOLUTs (Churchill, Edmonton, Goose Bay) 2 GEOLUTs (Edmonton, Ottawa)	National SAR Secretariat (NSS)
Chile	Ground Segment Provider	23 February 1990	3 LEOLUTs (Easter Island, Punta Arenas, Santiago) 1 GEOLUT (Santiago)	Servicio de Búsqueda y Salvamento de la Fuerza Aérea de Chile
China (P.R. of)[2]	Ground Segment Provider	28 March 1997	1 dual LEOLUT (Beijing)	Maritime Safety Administration
Cyprus	User State	6 October 2006		Larnaca Joint RCC
Denmark	User State	8 March 1991	1 Sarsat orbitography beacon (Thule)	Civil Aviation Administration
EUMETSAT	Space Segment Provider	25 October 2010	2 Metop LEO satellites (Sarsat platforms) & 4 MSG GEO satellites with 406 MHz payload.	EUMETSAT
European Commission	MEOSAR D&E	14 December 2006	Demonstration and Evaluation of the Galileo MEOSAR System	E.C. DG Enterprise & Industry, E.U. Satellite Navigation Programme Management
Finland	User State	7 March 2010		Ministry of the Interior, Border Guard
France	ICSPA Party / Space Segment Provider	30 August 1988	Sarsat SARP instruments on Sarsat satellites 1 dual LEOLUT + 1 GEOLUT (Toulouse)	Centre National d'Études Spatiales (CNES)
Germany	User State	17 December 1992		Min. of Transport, Aeronautical Dept.
Greece[3]	Ground Segment Provider	13 May 2006	1 LEOLUT + 1 GEOLUT (Penteli)	Ministry of Citizen Protection - Safety of Navigation Division

2/ The P. R. of China originally joined as a User State on 18 November 1992
3/ Greece originally joined as a User State on 13 September 1992.

States and Organisations Associated with or Contributing to the Cospas-Sarsat Programme (as at End December 2010)

States / Organisations	Status	Effective Date of Association	System Contribution	Cooperating Agency
Hong Kong	Ground Segment Operator	28 June 1998	1 dual LEOLUT (Hong Kong)	Hong Kong Marine Department
India[4]	Space Segment & Ground Segment Provider	23 May 1991	INSAT GEO satellites with 406 MHz payloads 2 LEOLUTs (Bangalore, Lucknow) 1 GEOLUT (Bangalore)	Indian Space Research Organisation (ISRO)
Indonesia	Ground Segment Provider	27 June 1992	1 LEOLUT (Jakarta)	National SAR Agency (BASARNAS)
Italy	Ground Segment Provider	27 January 1991	1 LEOLUT (Bari)	Dipartimento della Protezione Civile
ITDC[5]	Ground Segment Operator	4 June 1992	1 dual LEOLUT (Keelung)	Chunghwa Telecom Co. Ltd.
Japan	Ground Segment Provider	10 July 1993	1 LEOLUT (Gunma)	Japan Coast Guard
Korea (Rep. of)	Ground Segment Provider	25 October 1995	1 LEOLUT (Incheon)	Korea Coast Guard
Netherlands (The)	User State	3 March 1995		Netherlands Coastguard
New Zealand	Ground Segment Provider	15 May 1993	1 LEOLUT & 2 GEOLUTs (Wellington)	Rescue Coordination Centre New Zealand (RCCNZ)
Nigeria[6]	Ground Segment Provider	20 May 2004	1 LEOLUT (Abuja)	National Emergency Management Agency
Norway	Ground Segment Provider	30 Dec. 1990	2 LEOLUTs (Tromsoe, Spitsbergen) 1 GEOLUT (Fauske)	Ministry of Justice
Pakistan	Ground Segment Provider	13 October 1991	1 LEOLUT (Karachi)	Space & Upper Atmosphere Research Commission
Peru	Ground Segment Provider	27 Nov. 1996	1 LEOLUT (Callao)	Dirección General de Capitanias y Guardacostas

4/ India became associated as a Ground Segment Provider on 23 May 1991 and as a Space Segment Provider on 23 February 2007
5/ ITDC: International Telecommunication Development Company (Taipei – China)
6/ Nigeria originally joined as a User State on 3 March 2001.

States and Organisations Associated with or Contributing to the Cospas-Sarsat Programme (as at End December 2010)

States / Organisations	Status	Effective Date of Association	System Contribution	Cooperating Agency
Poland	User State	16 Sept. 2005		Civil Aviation Office
Russia[7]	ICSPA Party / Space Segment Provider	30 August 1988	Cospas satellites with SARR & SARP payloads 3 LEOLUTs (Arkhangelsk, Moscow, Nakhodka)	MORSVIAZSPUTNIK
Saudi Arabia	Ground Segment Provider	19 August 2000	1 dual LEOLUT (Jeddah)	General Authority of Civil Aviation
Serbia	User State	17 July 2010		Civil Aviation Directorate
Singapore	Ground Segment Provider	23 October 1992	1 LEOLUT (Singapore)	Civil Aviation Authority of Singapore
South Africa	Ground Segment Provider	2 November 2000	1 LEOLUT (Cape Town)	South African Maritime Safety Authority (SAMSA)
Spain	Ground Segment Provider	8 July 1992	1 LEOLUT + 2 GEOLUTs (Maspalomas)	Instituto Nacional de Técnica Aeroespacial (INTA)
Sweden	User State	24 October 1990		Swedish Civil Contingencies Agency
Switzerland	User State	14 February 1991		Federal Office of Civil Aviation
Thailand	Ground Segment Provider	19 Nov. 1999	1 dual LEOLUT (Bangkok)	Department of Aviation
Tunisia	User State	5 August 1994		Ministère des Transports
Turkey	Ground Segment Provider	11 June 2005	1 dual LEOLUT + 1 GEOLUT (Ankara)	General Directorate of Maritime Transportation
United Arab Emirates	Ground Segment Provider	26 Nov. 2009	1 LEOLUT (under development n 2009) 1 GEOLUT (Abu Dhabi)	Telecommunication Regulatory Authority
United Kingdom	Ground Segment Provider	9 March 1990	1 dual LEOLUT +1 GEOLUT (Combe Martin)	Maritime and Coastguard Agency
United States	ICSPA Party / Space Segment Provider	30 August 1988	Sarsat LEO & GEO satellites . - 5 dual LEOLUTs (Alaska, California, Florida, Guam, Hawaii) - 2 GEOLUTs (Maryland)	NOAA
Vietnam	Ground Segment Provider	26 June 2002	1 LEOLUT (Haiphong)	Vietnam Maritime Administration (VINAMARINE)

7/ Russia replaced the USSR as a Party to the ICSPA in 1992. Russia also provided GEOSAR satellites (Electro & Louch) and associated GEOLUTs after 2011.

ANNEX 4

Study Bibliography: Contributions and Reference Documents

A large collection of background documentation is available at the Cospas-Sarsat Secretariat in Montréal, Canada, in paper or electronic form, particularly regarding the Cospas-Sarsat Programme management and the System for the years following the establishment of the Secretariat in London, UK (July 1987). It includes all Council Summary Records and Joint Committee Reports, which have not been listed in this annex. Similarly, the documents 'Cospas-Sarsat Information Bulletin' and 'Cospas-Sarsat System Data', which are published annually by the Cospas-Sarsat Secretariat and made available on the Cospas-Sarsat website, have been used extensively during the preparation of this Cospas-Sarsat history study report. These documents are not listed below.

For the years preceding 1987, CNES and NASA archives have been used, together with personal archives and unpublished personal notes for the period 1979 to 1987. The 'Summary of Discussions of the Cospas-Sarsat Coordinating Group', for CSCG meetings held between 1980 and 1984 were made available by CNES in Paris, France, together with a number of original documents held in CNES archives. Copies of the documents 'Summary of Discussions of the Cospas-Sarsat Steering Committee' for CSSC-1 to CSSC-4 meetings (1985 to 1988) were made available by CNES and are also available from the Cospas-Sarsat Secretariat in Montreal, QC, Canada.

Unpublished individual contributions submitted to the Study Leader have been recorded in the table below.

Origin	**Authors; Document Title - Reference & Date of publication**
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ANNEX 5

History Study Participants and Acknowledgements

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Daniel LEVESQUE
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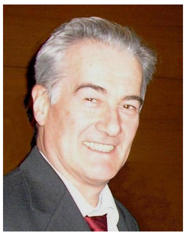

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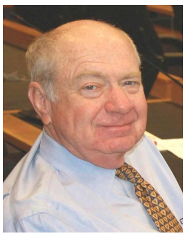

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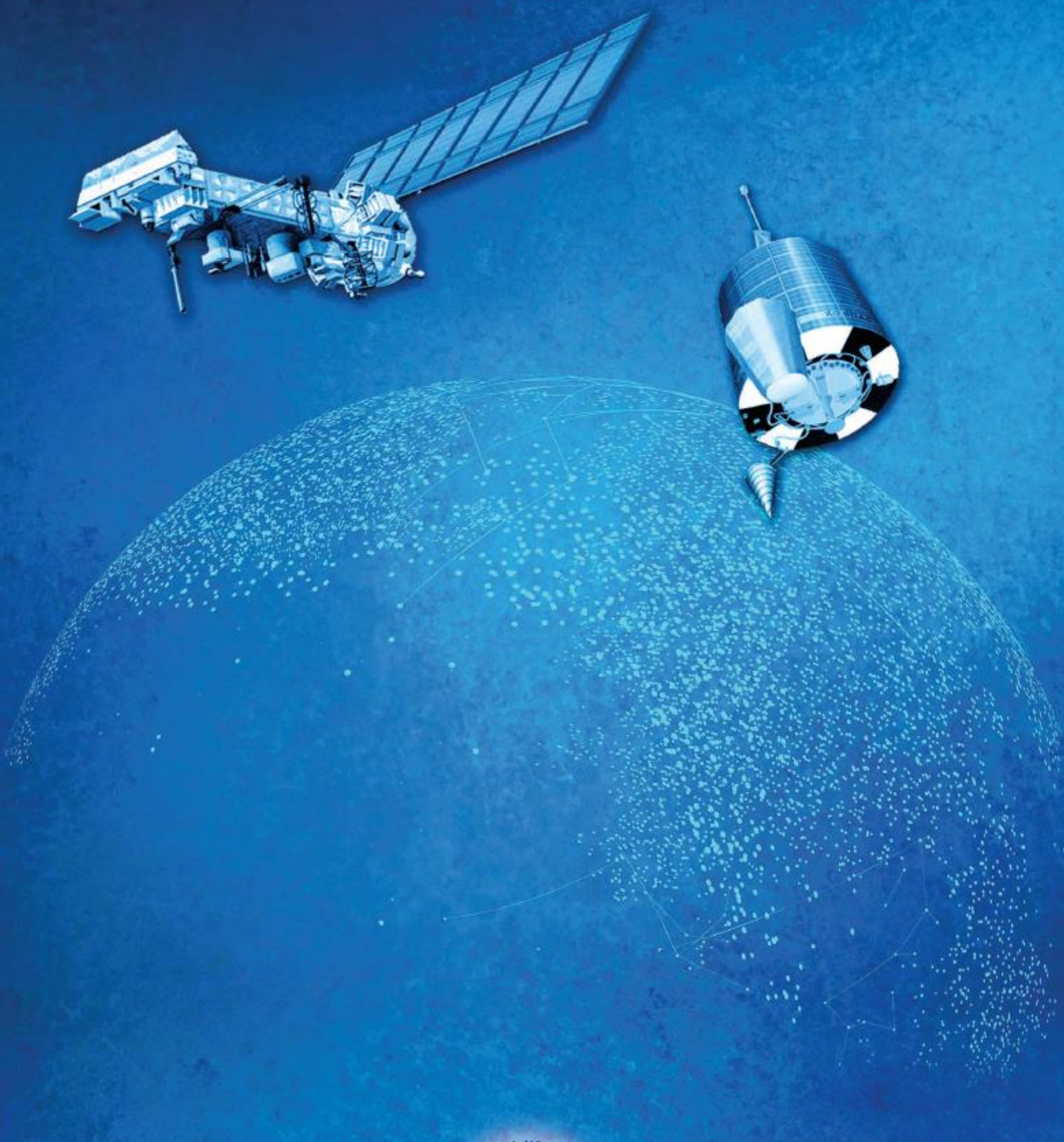

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