INTRODUCTION TO THE COSPAS-SARSAT SYSTEM

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COSPAS SARSAT

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1. INTRODUCTION

1.1 Overview

Cospas-Sarsat[1] is a satellite system designed to provide distress alert and location data to assist search and rescue (SAR) operations, using spacecraft and ground facilities to detect and locate the signals of distress beacons operating on 406 Megahertz (MHz). The position of the distress and other related information is forwarded by the responsible Cospas-Sarsat Mission Control Centre (MCC) to the appropriate national SAR authorities. Its objective is to support all organisations in the world with responsibility for Search and Rescue (SAR) operations, whether at sea, in the air, or on land.

The purpose of this document is to acquaint potential users with the Cospas-Sarsat System. Although only introductory, it covers the significant points, including procedures for participation of States in the System. More detailed descriptions of various aspects of the system are available in other documents which can be obtained from the Cospas-Sarsat Secretariat.

1.2 Document Organisation

Chapter 2 briefly outlines the scope and background of the system.

Chapter 3 gives a brief overview of the system operation with 406 MHz beacons, while Chapter 4 describes each segment of the system in greater detail.

Chapter 5 provides background information relating to system performance and operations. Performance parameters are defined, and measured values are given for each segment of the system.

Chapter 6 addresses the question of data flow and exchange, both within the Cospas-Sarsat System and to and from various outside agencies (SAR authorities).

Chapter 7 covers type approval procedures of 406 MHz beacons, and commissioning standards for ground segment elements.

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[1] COSPAS : (Cosmicheskaya Sistyema Poiska Avariynich Sudov)
Space System for the Search of Vessels in Distress
SARSAT : Search and Rescue Satellite-Aided Tracking

Chapter 8 is mainly an overview of the programme management structure including the principles governing other States' participation in the System and their association with the Programme. It also provides basic information about the Cospas-Sarsat Secretariat and the International Cospas-Sarsat Programme Agreement.

- END OF SECTION 1 -

2. SCOPE OF THE SYSTEM

The detection and location of an aircraft crash or maritime distress is of paramount importance to the search and rescue (SAR) teams and to the potential survivors. Studies show that while the initial survivors of an aircraft crash have less than a 10% chance of survival if rescue is delayed beyond two days, the survival rate is over 60% if the rescue can be accomplished within eight hours. Similar urgency applies in maritime distress situations, particularly where injuries have occurred. Furthermore, accurate location of the distress can significantly reduce both SAR costs and the exposure of rescue forces to hazardous conditions, and clearly improve efficiency. In view of this, Canada, France, Russia and the USA established the Cospas-Sarsat satellite system to reduce the time required to detect and locate SAR events world-wide.

2.1 The International Co-operative Programme

This satellite system was initially developed under a Memorandum of Understanding among Agencies of the former USSR, USA, Canada and France, signed in 1979. Following the successful completion of the demonstration and evaluation phase started in September 1982, a second Memorandum of Understanding was signed on 5 October 1984 by the Centre National d'Etudes Spatiales (CNES) of France, the Department of National Defence (DND) of Canada, the Ministry of Merchant Marine (MORFLOT) of the former USSR and the National Oceanic and Atmospheric Administration (NOAA) of the USA. The System was then declared operational in 1985. On 1 July 1988, the four States providing the space segment signed the International Cospas-Sarsat Programme Agreement which ensures the continuity of the System and its availability to all States on a non-discriminatory basis. In January 1992, the government of Russia assumed responsibility for the obligations of the former Soviet Union. A number of States, Non-Parties to the Agreement, have also associated themselves with the Programme and participate in the operation and the management of the System.

2.2 Distress Beacons

The use of satellites to detect and locate special-purpose radiobeacons, either manually activated or automatically activated by an aircraft crash or maritime distress situation, reduces the time required to alert the appropriate authorities and for final location of the distress site by the rescue team. The International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) recommend that ships and aircraft carry Emergency Position Indicating Radio Beacon (EPIRBs) and Emergency Locator Transmitters (ELTs) respectively. In November 1988, the Conference of Contracting Governments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS Convention) on the Global Maritime Distress and Safety System (1988 GMDSS Conference) adopted several amendments to the 1974 SOLAS Convention whereby, inter-alia, carriage of satellite EPIRBs on all convention ships of 300 tons and over became mandatory from 1 August 1993.

Various national requirements also exist for the carriage of ELTs/EPIRBs on different types of craft not otherwise subject to international conventions, and some countries have authorised the use of Personal Locator Beacons (PLBs), 406 MHz emergency beacons for use on land, in remote or rugged areas.

2.3 The LEOSAR and GEOSAR Satellite System Concepts

Cospas-Sarsat has demonstrated that the detection and location of distress signals can be greatly facilitated by global monitoring based on low-altitude spacecraft in near-polar orbits. Complete coverage of the Earth, including the Polar Regions, can be achieved using simple emergency beacons operating on 406 MHz to signal a distress. With an older type of beacon operating at 121.5 MHz, the System coverage was not global as the detection of the distress depended on the availability of a ground receiving station in the satellite field of view at the same time it receives the beacon signal.

Satellite processing at 121.5/243 MHz was terminated on 1 February 2009. Cospas-Sarsat made the decision to cease satellite processing at 121.5/243 MHz in response to guidance from the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). These United Nations organisations mandate safety requirements for aircraft and maritime vessels and recognised the limitations of the 121.5/243 MHz beacons and the superior capabilities of the 406 MHz alerting system.

Operational use of Cospas-Sarsat by SAR agencies started with the crash of a light aircraft in Canada, in which three people were rescued (September 9, 1982). Since then, the System has been used in thousands of SAR events and has been responsible for the saving of several thousands of lives world-wide.

The Cospas-Sarsat system of satellites in low Earth orbit (LEO) is referred to as the Cospas-Sarsat LEOSAR System. Polar orbiting satellites used in the Cospas-Sarsat LEOSAR System can provide a global, but non continuous coverage, for the detection and the positioning of distress beacons using a Doppler location technique. However, the non continuous coverage introduces delays in the alerting process since the user in distress must “wait” for a satellite pass in visibility of his distress beacon.

Cospas-Sarsat participants also experimented with payloads on satellites in geostationary Earth orbit (GEO) together with their associated ground stations to detect the transmissions of Cospas-Sarsat 406 MHz radiobeacons. These experiments demonstrated the possibility of almost immediate alerts at 406 MHz, providing the identity of the transmitting beacon and other encoded data, such as the beacon position derived from a global satellite navigation system. This development is referred to as the 406 MHz GEOSAR system.

The 406 MHz GEOSAR system was formally integrated into the Cospas-Sarsat System in 1999, after the approval of the 406 MHz GEOSAR Demonstration and Evaluation (D&E) Report, which highlights the enhancements provided by a geostationary complement to the Cospas-Sarsat polar-orbiting system in terms of alerting time advantage, and the benefits to

SAR services of this rapid alerting capability. However, GEOSAR alerts produced by emissions from the first generation 406 MHz beacons do not include any position information as the Doppler location technique cannot be applied to signals relayed through geostationary satellites. A new type of 406 MHz second-generation of beacon allows for the encoding of position data in the transmitted 406 MHz message, thus providing for quasi-real time alerts and position information from the GEOSAR system.

The 406 MHz GEOSAR D&E Report also highlights the complementary aspects of GEO and LEO systems for SAR, particularly on land where obstructions may prevent direct visibility of a geostationary satellite.

The Cospas-Sarsat ground receiving stations are called LUTs (i.e. Local User Terminals). This generic designation may refer either to LEOLUTs in the LEOSAR system, or to GEOLUTs in the GEOSAR system. The term LUT will be used in the remainder of this document, unless possible ambiguity imposes the use of LEOLUT or GEOLUT.

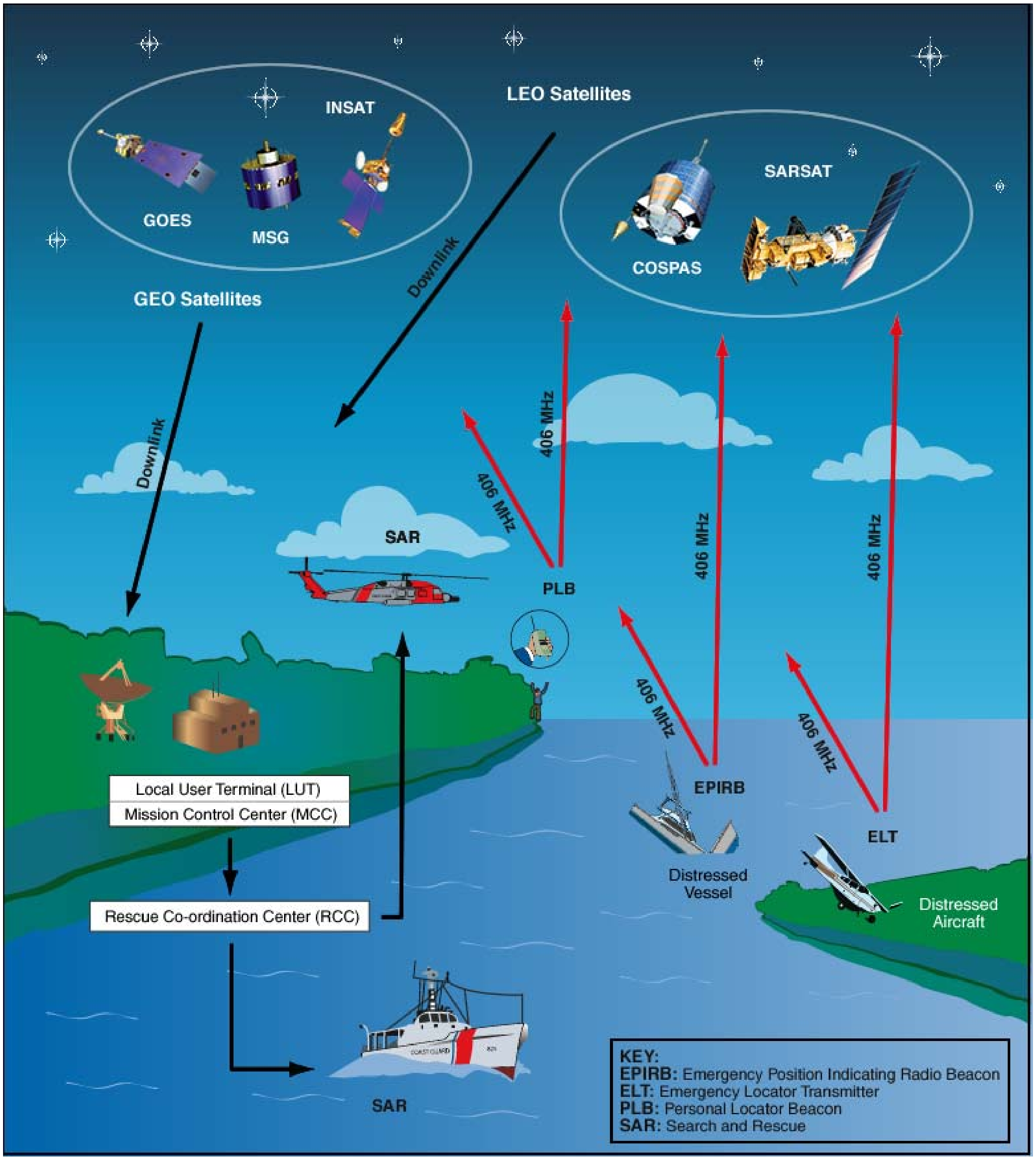

Figure 2.1 : Basic Concept of the Cospas-Sarsat System

- END OF SECTION 2 -

3. SYSTEM OVERVIEW

3.1 The Cospas-Sarsat System

The Cospas-Sarsat System is composed of:

- 406 MHz radiobeacons carried aboard ships (EPIRBs), aircraft (ELTs), or used as personal locator beacons (PLBs);
- polar-orbiting satellites in low Earth orbit from the LEOSAR system and geostationary satellites from the GEOSAR system; and
- the associated LUTs for the satellite systems (referred to as LEOLUTs or GEOLUTs).

3.1.1 Distress Beacons

Frequencies in the 406.0 - 406.1 MHz band have been exclusively reserved for distress beacons operating with satellite systems. The Cospas-Sarsat 406 MHz beacons have been specifically designed for use with the LEOSAR system to provide improved performance in comparison with the older obsolete 121.5 MHz beacons. They are more sophisticated than the 121.5 MHz beacons because of specific requirements on the stability of the transmitted frequency, and the inclusion of a digital message which allows the transmission of encoded data such as a unique beacon identification.

A second generation of 406 MHz beacons have been introduced since 1997 which allow for the transmission in the 406 MHz message of encoded position data acquired by the beacon from global satellite navigation systems, using internal or external navigation receivers. This feature is of particular interest for GEOSAR alerts which, otherwise, would not be able to provide any position information.

3.1.2 The LEOSAR System

The Cospas-Sarsat LEOSAR system uses polar-orbiting satellites and has basic constraints which result from the non-continuous coverage provided by LEOSAR satellites. The use of low-altitude orbiting satellites provides for a strong Doppler effect in the up-link signal which allows the use of Doppler positioning techniques.

The Cospas-Sarsat LEOSAR System operates in two coverage modes for the detection and location of beacons, namely the local coverage mode and the global coverage mode. In the local mode, a LUT tracking a satellite receives and processes signals from transmitting beacons in the field of view of the satellite. In the global mode, LUTs receive and process data from distress beacons transmitting from anywhere in the world.

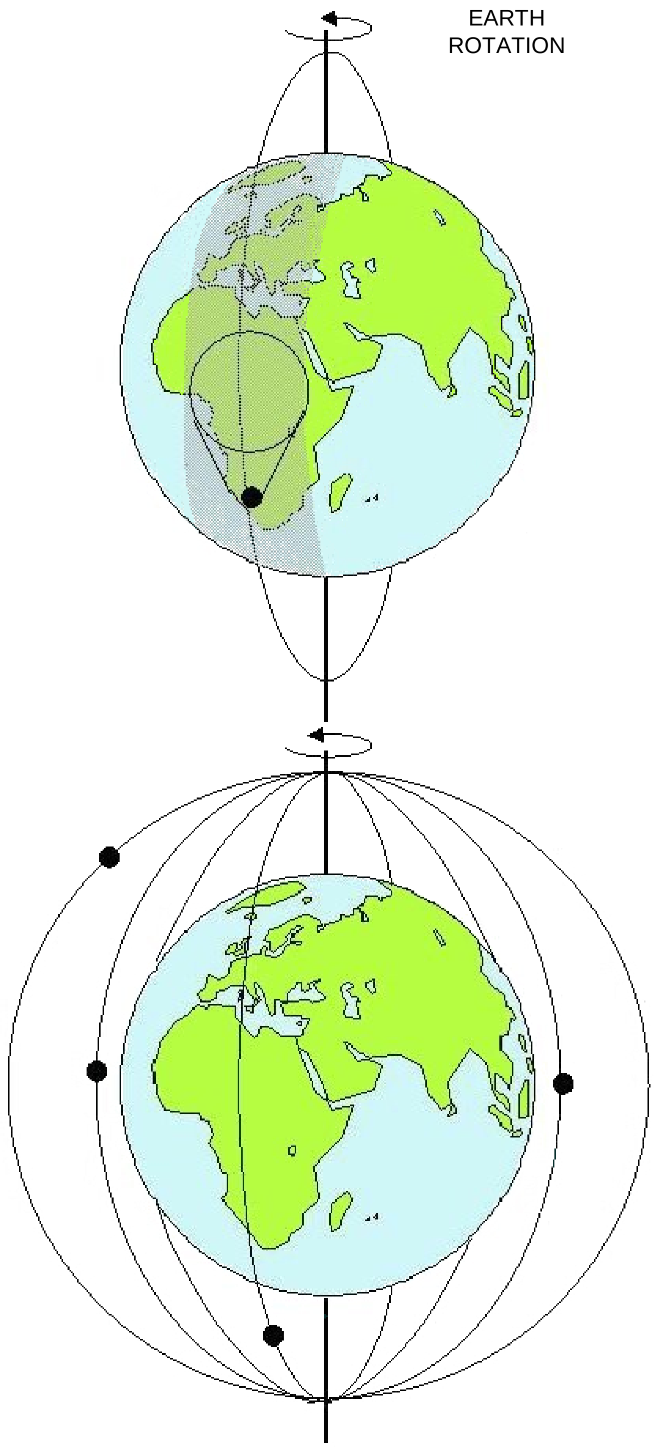

Figure 3.1: Satellites in Polar Orbit showing a single satellite (top) and a four satellite constellation (bottom)

3.1.2.1 Local Mode

When the satellite receives distress beacon signals, the on-board Search and Rescue Processor (SARP) recovers the digital data from the beacon signal, measures the Doppler shift and time-tags the information. The result of this processing is formatted as digital data, and transferred to the repeater downlink for transmission to any LUT in view. The data are also simultaneously stored on the spacecraft for later transmission and ground processing in the global coverage mode.

In addition to the local mode provided by the 406 MHz SARP instruments, a 406 MHz repeater, on Sarsat satellites only, can also provide a local coverage mode of operation.

3.1.2.2 Global Mode

The 406 MHz SARP system provides global coverage by storing data derived from on-board processing of beacon signals, in the spacecraft memory unit. The content of the memory is continuously broadcast on the satellite downlink. Therefore, each beacon can be located by all LUTs which track the satellite. This provides the 406 MHz global coverage and introduces ground segment processing redundancy.

The 406 MHz global mode also offers an additional advantage over the local mode in respect of alerting time when the beacon is in a LUT coverage area. As the beacon message is recorded in the satellite memory at the first satellite pass in visibility of the beacon, the waiting time is not dependent upon achieving simultaneous visibility with the LUT. The total processing time can be considerably reduced through the broadcast of the beacon message to the first available LUT.

3.1.3 The GEOSAR System

The basic GEOSAR System is illustrated by Figure 3.2. It consists of 406 MHz repeaters carried on board various geostationary satellites and the associated ground facilities called GEOLUTs. GEOLUTs have the capability to detect the transmissions from Cospas-Sarsat type approved distress beacons relayed by the geostationary satellites.

Geostationary satellites orbit at an altitude of 36,000 km, with an orbit period of 24 hours, thus appearing fixed relative to the Earth, at approximately 0 degrees latitude (i.e. over the equator).

A single geostationary satellite provides GEOSAR uplink coverage of about one third of the globe, except for Polar Regions. Therefore, three geostationary satellites equally spaced in longitude can provide continuous coverage of all areas of the globe between approximately 70^{o} North and 70^{o} South.

As a GEOSAR satellite remains fixed relative to the Earth, there is no Doppler effect on the received frequency and the Doppler positioning technique cannot be used to locate the distress beacon. To provide rescuers with beacon position information, such information must be either:

- acquired by the beacon through an internal or an external navigation receiver and encoded in the beacon message, or
- derived, with possible delays, from the LEOSAR system.

3.1.4 Complementarity of the LEOSAR and GEOSAR Systems

The use of satellites in low-altitude Earth orbit does not permit continuous coverage. This results in possible delays in the reception of the alert. The waiting time for detection by the LEOSAR system is greater in equatorial regions than at higher latitudes.

Geostationary satellites provide continuous coverage, hence have an immediate alerting capability, but access to the geostationary satellite can be masked due to ground relief or obstructions, particularly on land, at high latitudes. GEOSAR satellites do not provide coverage of the Polar Regions. LEOSAR satellites will eventually come into visibility of any beacon at the surface of the Earth, whatever the terrain and the obstructions which may mask the distress transmission. Therefore, in terms of coverage, the specific characteristics of LEOSAR and GEOSAR systems are clearly complementary.

The rapid alerting capability of the GEOSAR system can be used by SAR forces, even when no position information is provided in the beacon message. Such information can be used effectively to resolve a false alarm without expending SAR resources, or to initiate a SAR operation on the basis of information obtained through the beacon registration data.

406 MHz beacon signals from LEOSAR and GEOSAR systems can also be combined to produce Doppler locations, or to improve location accuracy. These are two examples of combined LEOSAR/GEOSAR operations. Other aspects to the complementarity of the GEOSAR and the LEOSAR system are highlighted in the report of the 406 MHz GEOSAR Demonstration and Evaluation (D&E) performed by Cospas-Sarsat Participants from 1996 to 1998.

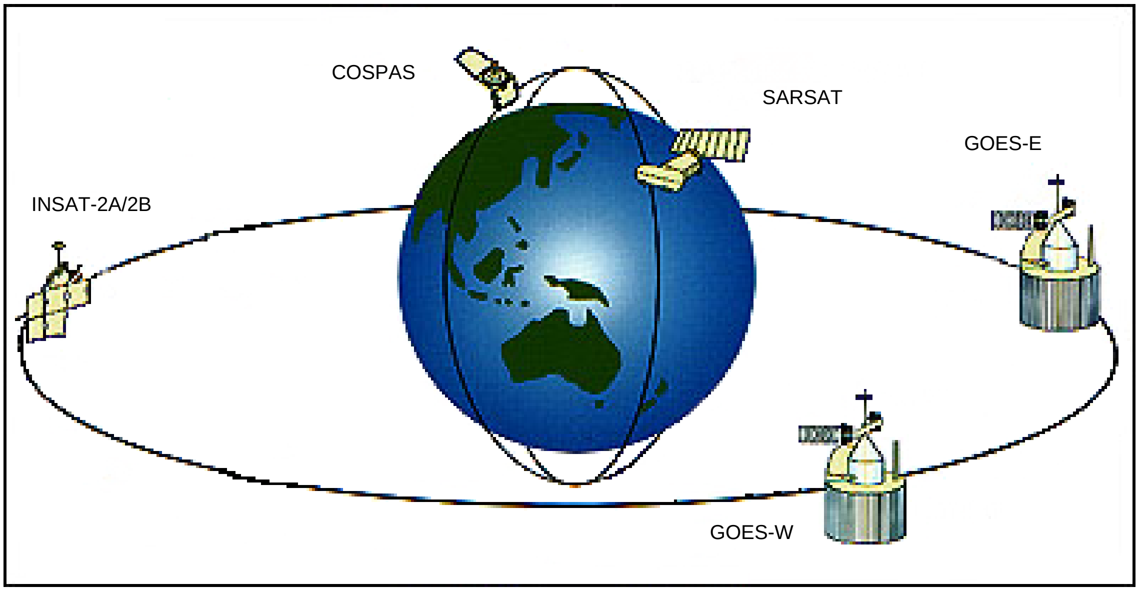

Figure 3.2: Combined LEOSAR - GEOSAR Operations

3.2 Distribution of Alert and Location Data

The alert and location data generated by LEOLUTs or GEOLUTs are forwarded to appropriate SAR Points of Contact (SPOCs) through the Cospas-Sarsat MCC network.

Since a single distress incident is usually processed by several LUTs, in particular in the 406 MHz global mode of the LEOSAR system, the alert and location data are sorted by MCCs to avoid unnecessary transmission of identical data. The principle of continuous downlink transmission to all LEOLUTs in visibility of a satellite results in simpler downlink transmission procedures and a high level of redundancy in the ground processing system, world-wide. Distress alerts are always distributed to the RCC or SPOC which has responsibility for the area where the distress is located.

The same principle applies to alerts generated by the GEOSAR system, since several GEOLUTs can detect the same 406 MHz beacon transmission. When a GEOSAR alert is received with encoded position information, that alert is forwarded to the RCC or SPOC which has responsibility for the area where the beacon is located.

When no location is available in the alert (if insufficient data does not allow a LEOLUT to compute a Doppler position or when no position data is encoded in the beacon message received by a GEOLUT), the alert is forwarded to the SAR authorities of the country where the beacon has been registered.

An overview of distress alert data distribution is presented below in Figure 3.3.

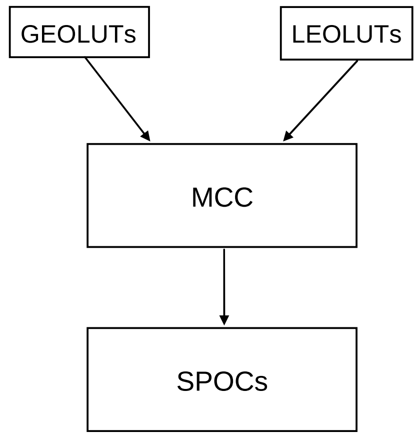

Figure 3.3: Cospas-Sarsat Alert Data Distribution

- END OF SECTION 3 -

4. DESCRIPTION OF SYSTEM SEGMENTS

4.1 Overview of System Segments

The Cospas-Sarsat System comprises three segments: the radiobeacon, space and ground segments, as shown in Figure 4.1. These segments are described briefly below and in more detail in section 4.2 to section 4.4.

The first segment is the radiobeacon. These emergency beacons are designed to transmit distress signals on 406 MHz. Most distress beacons also include a 121.5 MHz homing transmitter. Position information, from external or internal navigation devices, can also be included in the message of some beacons.

The second segment is the space segment. Beacon messages are partially processed on board LEOSAR satellites and then the data are directly transmitted on the satellite downlink as well as being stored on board for retransmission in the global mode. Both local and global mode 406 MHz data are transmitted on the 1544.5 MHz downlink. Satellites in the GEOSAR system relay beacon transmissions on the downlink frequency which may vary depending on the satellite provider.

The third segment is the ground segment which comprises LUTs and MCCs. LEOLUTs in the LEOSAR system process relayed distress signals to provide a beacon location and then transmit alert messages to the associated MCC. GEOLUTs in the GEOSAR system have the capability to immediately detect transmissions from distress beacons. The data in the beacon message is also forwarded to the associated MCC.

The MCC functions are the validation and exchange of alert data and system (technical) information, both within the Cospas-Sarsat System and with the SAR networks. MCCs are established in most of the countries that have LUTs. Specifically, they receive distress alert data from LUTs and other MCCs, geographically sort and redistribute them to appropriate SAR authorities.

4.2 Radiobeacon Segment

Beacons transmitting at 406 MHz were introduced at the beginning of the Cospas-Sarsat project in 1979. By 2007, the number of 406 MHz beacons in use had grown to over 600,000. The 406 MHz units were designed specifically for satellite detection and Doppler location, and provide the following:

- improved Doppler location accuracy and ambiguity resolution;
- increased system capacity (i.e. capability to process a greater number of beacons transmitting simultaneously in field of view of satellite);
- global coverage; and

- unique identification of each beacon.

In addition, second generation 406 MHz beacons introduced from 1997 provided for the transmission of position data in the digital message.

System performance is greatly enhanced both by the improved frequency stability of the 406 MHz units and by operation at a dedicated frequency.

The basic characteristics of 406 MHz beacons are given in Table 4.2. These beacons transmit a 5 Watt RF burst of approximately 0.5 seconds duration every 50 seconds. The carrier frequency is very stable and the pulse is phase-modulated with a digital message as shown in Table 4.2. Frequency stability assures accurate location, while the high peak power increases the probability of detection. The low duty cycle provides a multiple-access capability of more than 90 beacons simultaneously operating in view of a polar orbiting satellite and low mean power consumption.

An important feature of 406 MHz emergency beacons is the addition of a digitally encoded message, which provides such information as the country of origin and the identification of the vessel or aircraft in distress, and optionally, position data derived from internal or external navigation receivers.

An auxiliary transmitter (homing transmitter) can be included in the 406 MHz beacon to enable suitably-equipped SAR forces to home on the distress beacon. Most EPIRBs and ELTs include a 121.5 MHz homing transmitter in accordance with the requirements of IMO and ICAO. However, the performance characteristics of the homing transmitter are not covered by the Cospas-Sarsat system specification.

Beacons can be activated either manually or automatically by immersion or shock. These particular features required by national administrations authorising the use of 406 MHz beacons, are not included in the Cospas-Sarsat specifications defined in document C/S T.001.

Performance of the 406 MHz system depends on actual transmission characteristics of the beacons. Consequently, Cospas-Sarsat has developed a type approval procedure for 406 MHz beacons which is defined in document C/S T.007. National administrations should authorise only type approved 406 MHz beacons for use with the Cospas-Sarsat System. The list of manufacturers and type approved beacon models is given in the document Cospas-Sarsat System Data which is published periodically by the Cospas-Sarsat Secretariat.

Table 4.1: Basic Characteristics of Cospas-Sarsat 406 MHz Beacons

Parameter	Value
RF Signal:	
Carrier frequency	406.025 – 406.037 MHz (Specific transmit frequency channel assigned in accordance with the Cospas-Sarsat 406 MHz Frequency Management Plan, (C/S T.012))
Frequency stability:	
• Short term	$\leq 2 \times 10^{-9}$ /100 ms
• Medium term	
- Mean slope	$\leq 1 \times 10^{-9}$ /minute
- Residual freq. variation	$\leq 3 \times 10^{-9}$
Power output	5 W ±2 dB
Data encoding	Bi-phase L
Modulation	Phase modulation of ±(1.1) radians peak
Failure mode	Continuous transmission of carrier not to exceed 45 s
Digital Message:	
Repetition Period	50 s ±5%
Transmission Time	440 ms (short message) 520 ms (long message)
CW Preamble	160 ms
Digital Message	
• short message	112 bits (280 ms)
• long message	144 bits (360 ms)
Bit Rate	400 bps
Operating Temperature Range:	
• Class 1	- 40°C to + 55°C
• Class 2	- 20°C to + 55°C
Thermal shock	30°C temperature difference
Operating Life Time:	at least 24 hours at minimum temperature

Message Structure:

Synchronisation Pattern	Country Code No.	Identification or Ident. + Position Data	Error Correcting Code	Supplementary Data	Additional Data (optional)
Short Message (112 bits)					Long Message Extension (32 bits)

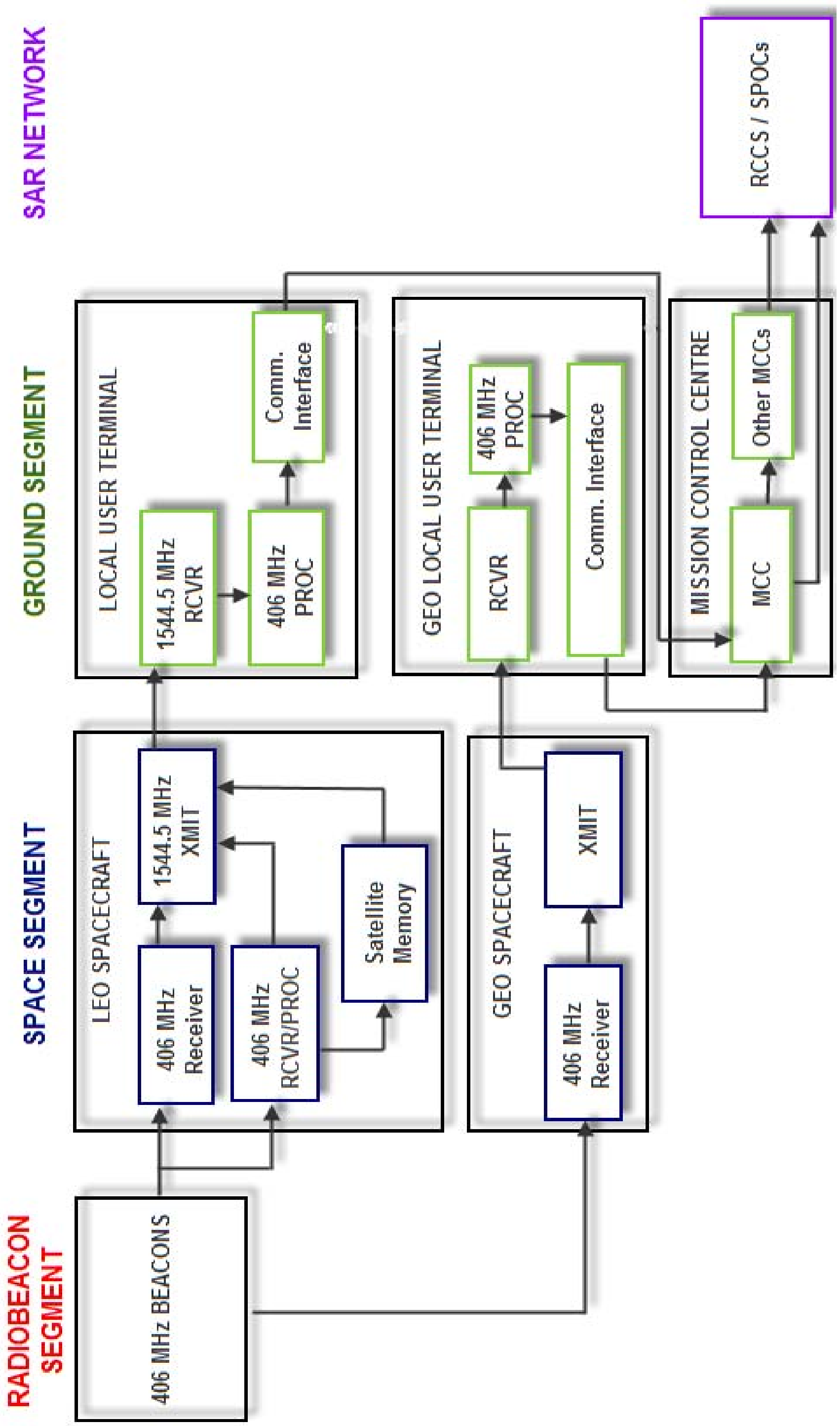

Figure 4.1: System Block Diagram and Radiobeacon/Space/Ground Segment Interfaces

4.3 Space Segment

4.3.1 LEOSAR Space Segment

The nominal LEOSAR system configuration comprises four satellites, two Cospas and two Sarsat.

Russia supplies two Cospas satellites placed in near-polar orbits at 1000 km altitude and equipped with SAR instrumentation.

The USA supplies the two NOAA meteorological satellites of the Sarsat system placed in sun-synchronous, near-polar orbits at about 850 km altitude, and equipped with SAR instrumentation supplied by Canada and France.

Each satellite makes a complete orbit of the earth around the poles in about 100 minutes, travelling at a velocity of 7 km per second. The satellite views a "swath" of the earth over 4000 km wide as it circles the globe, giving an instantaneous "field of view" about the size of a continent. When viewed from the earth, the satellite crosses the sky in about 15 minutes, depending on the maximum elevation angle of the particular pass.

The satellites of the LEOSAR space segment consist of three basic units:

- a platform moving in low earth polar orbit as a mounting for the other units (this platform is not dedicated to the SAR mission and generally carries other payloads);
- a 406 MHz repeater unit on satellites designed for retransmission of distress signals in the local coverage mode; and
- a receiver-processor and memory unit (SARP) on Cospas and Sarsat satellites designed to receive, process and store signals received on 406 MHz for retransmission in the local and the global coverage mode.

The repeater unit and the receiver-processor and memory unit are described below.

4.3.1.1 Repeater Unit

The repeater unit receives 406 MHz signals transmitted by activated distress beacons. After amplification and frequency conversion, the signals are retransmitted on the 1544.5 MHz downlink, as depicted in Figure 4.2. Automatic level control (ALC) is provided to maintain a constant output level.

The 1544.5 MHz transmitter on the repeater unit:

- accepts input from the uplink receivers;
- adjusts the relative power level in accordance with ground command;
- phase modulates a low frequency carrier with the composite signal;
- multiplies the frequency to produce 1544.5 MHz;

- amplifies the power level; and
- transmits the composite baseband signal via the spacecraft downlink antenna.

4.3.1.2 Receiver-Processor and Memory Unit

The functions of the receiver-processor are as follows:

- demodulating the digital messages received from beacons;
- measuring the received frequency; and
- time tagging the measurement.

All these data are included in the output signal frame for transmission to LUTs on the 1544.5 MHz downlink shown in Figure 4.2.

The frame is transmitted at 2400 bits per second in the processed data mode, and simultaneously stored in memory.

The data from the satellite on-board memory are transmitted on the downlink in the same format and at the same bit rate as local mode data. LUTs thus receive the stored beacon messages acquired during previous orbits. If a beacon signal is received during the stored memory dump, the dump is interrupted so that the signal can be processed and the resultant message interleaved with the stored data. Appropriate flag bits indicate whether the data are real-time or stored and the time at which full playback of the stored data was accomplished.

4.3.2 GEOSAR Space Segment

The GEOSAR space segment is composed of geostationary satellites with the capability to relay the transmissions of the Cospas-Sarsat 406 MHz beacons. Geostationary satellites orbit the Earth at an altitude of 36,000 km.

The geostationary satellites of the GEOSAR space segment carry various payloads in addition to the payload of the 406 MHz SAR mission. The GEOSAR payload consists of the 406 MHz antenna and receiver, and the downlink transmitter. The frequency of the downlink transmitter may vary with the geostationary platform carrying the 406 MHz payload.

GEOSAR payloads are available on board geostationary satellites provided by the USA, Europe, and India.

4.4 Ground Segment

4.4.1 LEOSAR Local User Terminals (LEOLUTs)

The configuration and capabilities of each LUT may vary to meet the specific requirements of the participating countries, but the Cospas and Sarsat spacecraft downlink signal formats ensure interoperability between the various spacecraft and all LUTs meeting Cospas-Sarsat specifications. All Cospas-Sarsat LEOLUTs must, as a minimum, process the 2.4 kbps processed data stream (PDS) of the 406 MHz receiver-processor system (SARP) which provides the 406 MHz global coverage.

Processing of 406 MHz SARP data (i.e. those generated from 406 MHz transmissions processed by the satellite SARP) is relatively straightforward since the Doppler frequency is measured and time-tagged on-board the spacecraft. All 406 MHz data received from the satellite memory on each pass can be processed within a few minutes of pass completion.

In the 406 MHz repeater band (SARR) each beacon transmission is detected and the Doppler information calculated. A beacon position is then determined using these data which can be processed by LEOLUTs either separately or combined with the 406 MHz SARP data.

LEOLUTs can improve their Doppler processing of SARP or SARR data by combining it with GEOSAR data. The combined LEO/GEO processing allows the Cospas-Sarsat System to produce Doppler locations in some cases where the data from one LEOLUT is insufficient to produce a location. The combined LEO/GEO processing can also lead to an improvement in Doppler location accuracy.

In order to maintain location accuracy, a correction of the satellite ephemeris is produced each time the LUT receives a satellite signal. The downlink carrier can be monitored to provide a Doppler signal using the LUT location as a reference, alternatively highly stable 406 MHz calibration beacons at accurately known locations can be used to update the ephemeris data.

LEOLUT operators are expected to provide the SAR community with reliable alert and location data, without restriction on its use and distribution. The Cospas-Sarsat Parties providing and operating the space segment supply LEOLUT operators with System data required to operate their LUT. To ensure that data provided by a LUT are reliable and can be used by the SAR community on an operational basis, Cospas-Sarsat has developed LEOLUT performance specifications (document C/S T.002) and LEOLUT commissioning procedures (document C/S T.005). LEOLUT operators provide regular reports on their LUT operation for review during Cospas-Sarsat meetings.

4.4.2 GEOSAR Local User Terminals (GEOLUTs)

GEOLUTs receive and process distress alerts from 406 MHz beacons relayed by the geostationary satellites of the GEOSAR system and provide permanent monitoring of the frequency band.

The GEOLUT consists of the following components:

- antenna and radio frequency subsystem (antenna electronics and receiver);
- processor;
- time reference subsystem; and
- MCC interface.

Almost as soon as a beacon is activated in the monitored GEOSAR satellite coverage area, it can be detected by the LUT. As there is no relative movement between a transmitting beacon and the satellite, it is not possible to use the Doppler effect to calculate the beacon position. However, when location information provided by external or internal navigation devices is included in the digital message of a 406 MHz beacon, this position data can be sent with the alert message to the MCC for retransmission to the appropriate MCC, RCC or SPOC.

GEOLUT operators are expected to provide the SAR community with reliable alert data, without restriction on use and distribution. To ensure that data provided by a LUT are reliable and can be used by SAR services on an operational basis, Cospas-Sarsat has developed GEOLUT performance specifications (document C/S T.009) and commissioning procedures (document C/S T.010). GEOLUT operators provide regular reports on their operation for review during Cospas-Sarsat meetings.

4.4.3 Mission Control Centres (MCCs)

MCCs have been set up in most of those countries operating at least one LUT. Their main functions are to:

- collect, store and sort the data from LUTs and other MCCs;
- provide data exchange within the Cospas-Sarsat system; and
- distribute alert and location data to associated RCCs or SPOCs (see Figure 4.3).

Most of the data fall into two general categories: alert data and system information.

Alert data is the generic term for Cospas-Sarsat 406 MHz data derived from distress beacons. Alert data always include the beacon identification and may comprise Doppler and/or encoded location data and other coded information.

System information is used primarily to keep the Cospas-Sarsat System operating at peak effectiveness and to provide users with accurate and timely alert data. It consists of satellite ephemeris and time calibration data used to determine beacon locations, the current status of the space and ground segments and co-ordination messages required to operate the Cospas-Sarsat System.

All MCCs in the system are interconnected through appropriate networks for the distribution of system information and alert data. To ensure data distribution reliability and integrity, Cospas-Sarsat has developed MCC performance specifications (document C/S A.005) and MCC commissioning procedures (document C/S A.006). Regular reports on MCC operations are provided during Cospas-Sarsat meetings. World-wide exercises are performed from time to time to check the operational status and performance of all LUTs and MCCs, and data exchange procedures.

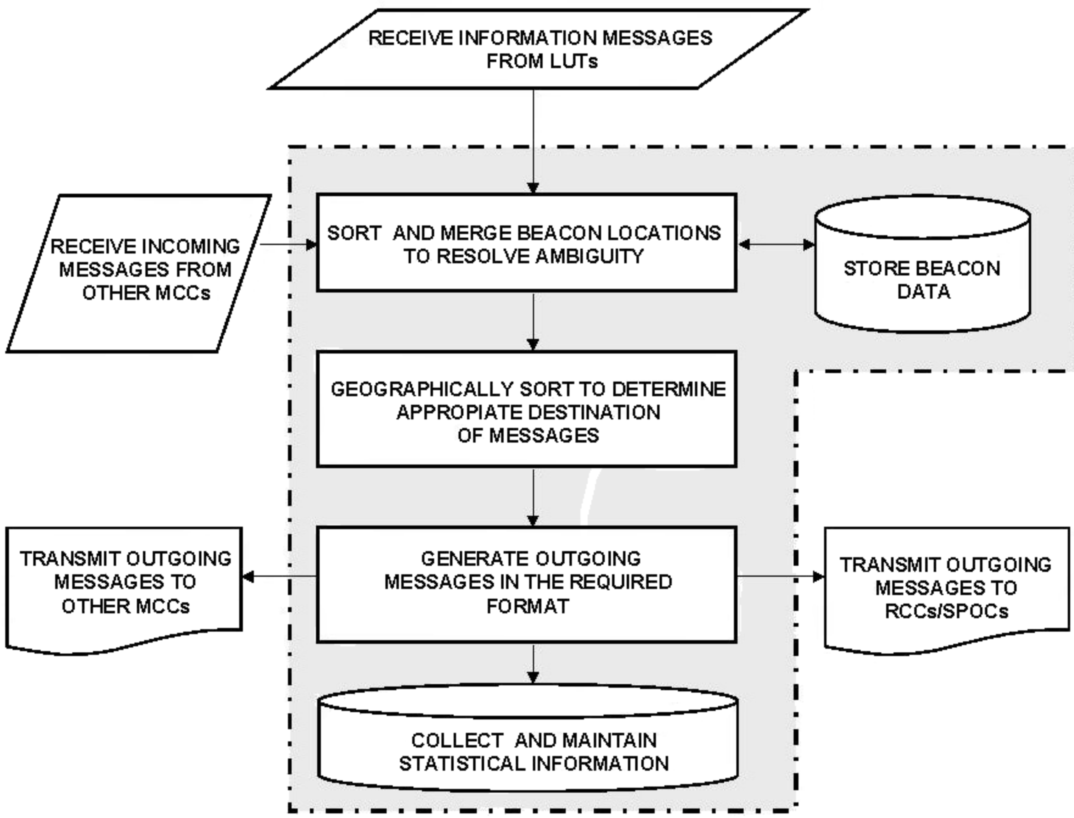

Figure 4.2: Functional Diagram of Alert Data Processing by MCCs

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5. SYSTEM PERFORMANCE AND OPERATION

5.1 Introduction

The performance of the LEOSAR system was determined during a two-phase test programme implemented from 1982 to 1984. The first phase, the Technical Evaluation, consisted of engineering tests conducted under controlled conditions. The second phase, the Demonstration and Evaluation (D&E) phase, was carried out by the agencies responsible for SAR operations in the various participating countries. Additional information was obtained through actual operation of the system, where the now obsolete 121.5 MHz system was used in actual distress events, and world-wide exercises of the 406 MHz System conducted in 1986 and 1990 to evaluate data exchange procedures and MCC communication links.

The performance of the GEOSAR system was assessed during the GEOSAR D&E phase conducted in 1996 and 1997, which included a number of technical and operational objectives and specific data collection procedures.

The performance data presented in section 5.3 are based on results from these two D&E phases and the System exercises.

5.2 Performance Parameters

The following are significant measures of Cospas-Sarsat performance:

- Beacon identification probability
- Doppler location probability
- Doppler location error
- Doppler ambiguity resolution
- Capacity
- Coverage
- Notification time

Beacon identification probability is the probability of detection by a LUT of at least one beacon message with a correct identification code for the first tracked satellite.

The Doppler location probability at 406 MHz is the probability of detecting and decoding at least four individual message bursts during a single satellite pass so that a Doppler curve estimate can be generated by the LUT. The Doppler location probability relates to the two solutions, "true" and "image", and not to a single unambiguous result.

The Doppler location error is the difference between the location calculated by the system using measured Doppler frequencies and the actual location as reported by field personnel.

Doppler ambiguity resolution: For each real signal, the Doppler location calculation generates two solutions that are mirror images relative to the satellite ground track. Ambiguity resolution is the ability of the system to select the "true" rather than the "mirror" location.

Capacity is the number of active beacons in common view of a satellite that the system can process simultaneously.

Coverage refers to the areas of the earth where the Cospas-Sarsat System can detect beacons.

Notification time is the period from activation of a beacon, i.e. first transmission, to reception of a valid alert message by the appropriate RCC. Depending on the system mode of operation, the notification time may include the following elements:

- The waiting time for the first satellite pass in visibility of a transmitting beacon, resulting in the detection or location of that beacon. In the LEOSAR local mode of operation the waiting times are affected by the latitude of the beacon, the location of LUTs and the geometry of the satellite passes. In the LEOSAR global mode of operation, the waiting time is not dependent upon the location of LUTs. There is no waiting time in the GEOSAR system.
- The processing time from the first satellite pass in visibility of a beacon to the completion of all MCC processing. In the LEOSAR global mode of operation, the alert processing time varies depending on the storage time of data on board the satellite before retransmission of the data to a LUT.
- The transmission time from the completion of all MCC processing to the reception of the alert by the appropriate RCC.

Detailed information on the LEOSAR System tests, the 1986 and 1990 Exercises, and the 406 MHz GEOSAR D&E are contained in the following documents:

C/S R.001 “Cospas-Sarsat Project Report”

C/S R.002 “Cospas-Sarsat Exercise of 1986”

C/S R.005 “1990 Exercise of the Cospas-Sarsat 406 MHz System”

C/S R.008 “Report of the Demonstration and Evaluation of the 406 MHz Geostationary System”

5.3 Performance of the Cospas-Sarsat System

In November 1986, a world-wide exercise of the 406 MHz LEOSAR System was conducted. This involved 26 beacons being activated in 15 countries around the globe, four operational satellites, 11 LUTs, 6 MCCs and associated ground communications networks. A similar exercise was conducted in October 1990 in which 25 beacons were activated in 34 countries or areas, three fully operational satellites (a fourth satellite was not processing global data at that time), 20 LUTs and 10 MCCs were used.

During 1996 and 1997, a 406 MHz GEOSAR demonstration and evaluation was conducted to characterise the technical performance of the GEOSAR components, evaluate the operational effectiveness of the GEOSAR system, and determine the benefits to search and rescue services of combined LEOSAR/GEOSAR operations. Six LEOSAR satellites (including three with no global mode capability) and three GEOSAR satellites were in orbit during the D&E, and the ground segment consisted of 39 LEOLUTs, 6 GEOLUTs and 22 MCCs.

The Cospas-Sarsat 406 MHz system typical performance is summarised as follows:

- LEOSAR single pass identification probability .... > 98%
- LEOSAR single pass Doppler location probability...98%

  On successive passes, these probabilities are 100%.

- LEOSAR Doppler location accuracy.. 87% within 5 km

The use of second generation 406 MHz beacons providing encoded position data acquired from global satellite navigation systems allows a resolution of the encoded position up to 4 seconds (about 150 m).

- LEOSAR single pass Doppler ambiguity resolution 95%
- System capacity:
  - LEOSAR system..> 90 beacons
  - GEOSAR system .... 14 in 6 kHz bandwidth
    > 50 in 60 kHz bandwidth
- Coverage:
  - LEOSAR system... world-wide coverage
  - GEOSAR system ....in GEO satellite footprint to 4 degree elevation
    (see GEO satellite footprint at Annex B)
- Notification time:
  - LEOSAR system:

    Computer simulations of the LEOSAR 406 MHz global mode waiting time have shown that maximum waiting times (at 95% probability) could vary from less than one hour at high latitude to less than 2 hours near the equator. The 1990 Exercise results show an average waiting time of 44 minutes and an average processing time for the first alert message of 43 minutes. These results were achieved with only three fully operational satellites.

  - GEOSAR system:

    The D&E showed that the processing time required to produce an alert after beacon activation is only a few minutes (less than 10 minutes for a 99% probability to detect an error free message), confirming the near-instantaneous GEOSAR alerting capability for 406 MHz beacons in the footprint of the geostationary satellites. The GEOSAR D&E also showed that GEOSAR alerts were received on average 46 minutes before the corresponding LEOSAR alerts.

5.4 System Operation

Much of the early operational experience acquired by Cospas-Sarsat in the 1980s relates to the 121.5 MHz system, but since then the use of the 406 MHz system has continued to rise with an increasing number of 406 MHz beacons in use. Statistical information on the number of beacons in use, operational satellites, LUTs and MCCs, and on the annual numbers of SAR events and persons rescued with the assistance of Cospas-Sarsat alert data, is published periodically by the Cospas-Sarsat Secretariat in the document “Cospas-Sarsat System Data”. This information can also be obtained from the Cospas-Sarsat Web site at the following address:

www.cospas-sarsat.org

- END OF SECTION 5 -

6. COSPAS-SARSAT ALERT DATA DISTRIBUTION

6.1 The Cospas-Sarsat Data Distribution Plan

Cospas-Sarsat alert data generated by LEOLUTs, both in the local mode of operation and in the global mode of operation, or by GEOLUTs have to be distributed to the appropriate RCC, according to the position of the distress. Due to the high degree of redundancy in the Cospas-Sarsat Ground Segment (each operational LEOLUT is capable of providing essentially the same data in the global mode of operation, likewise each operational GEOLUT pointing to a geostationary satellite provides the same alert data), such distribution must be co-ordinated and redundant data filtered out of the ground communication network.

Each LUT is linked to an associated MCC and alert messages are forwarded to the appropriate RCC through the MCC communication network, in accordance with the procedures described in the Cospas-Sarsat Data Distribution Plan (C/S A.001).

6.2 Cospas-Sarsat MCC Service Areas

Each Cospas-Sarsat MCC is responsible for distributing all alert data for distresses located in its Service Area. An MCC Service Area includes aeronautical and maritime Search and Rescue Regions (SRRs) in which the MCC's national authorities facilitate or provide SAR services, and include in addition such regions of other countries with which the MCC's national authorities have appropriate agreements for the provision of Cospas-Sarsat alert data.

MCCs' Service Areas are established following co-ordination among Cospas-Sarsat Ground Segment Providers (i.e. LUT-MCC Operators), through the Cospas-Sarsat Joint Committee, taking into account:

- geographical location and common SRR boundaries
- communication capabilities
- existing national SAR arrangements and existing bilateral operational agreements.

Agreed MCC Service Areas are described in the Cospas-Sarsat Data Distribution Plan. When a Cospas-Sarsat beacon transmission is located outside the Service Area of the MCC which receives the alert, the alert message is either forwarded to the MCC serving the area where the distress has been located, or is filtered out if the alert data has already been received through another LUT/MCC.

To further improve the distribution of operational information amongst a growing number of Cospas-Sarsat MCCs, MCC service areas have been regrouped in a small number of Data Distribution Regions (DDRs) and one MCC in each region, acting as a node in the communication network, has been requested to take responsibility for the exchange of data between the DDRs. Figure 6.1 illustrates the flow of alert messages in the Cospas-Sarsat MCC network.

6.3 SAR Points of Contact (SPOCs)

Each MCC distributes Cospas-Sarsat alert data to its national RCCs and to designated SAR Points of Contact (SPOCs) in the countries which are included in its Service Area. A SPOC is generally a national RCC that can accept or assume responsibility for the transfer of all Cospas-Sarsat alert data on distresses located within its national area of responsibility for SAR, defined as its Search and Rescue Region.

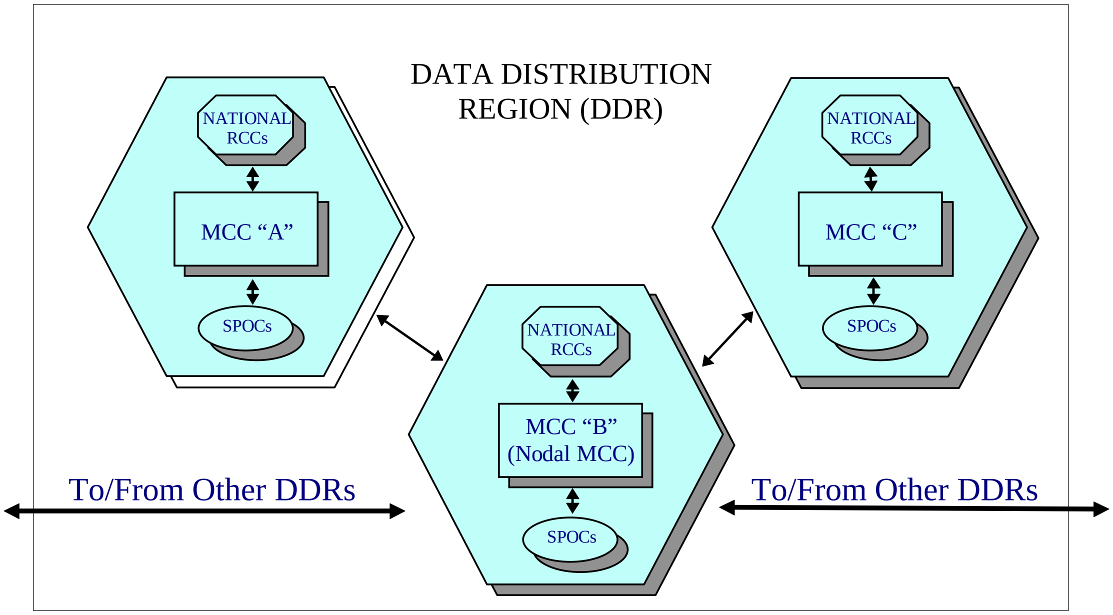

Figure 6.1: Simplified Flow Diagram of Cospas-Sarsat Operational Information

6.4 Message Formats

Cospas-Sarsat alert messages are exchanged among MCCs according to standardised message formats while messages between MCCs and their national LUTs and RCCs are formatted to satisfy national requirements. The detailed structure of messages for distribution of alert data and system information are described in document C/S A.002 "Cospas-Sarsat Mission Control Centres Standard Interface Description (SID)".

6.5 Communication Links

The Cospas-Sarsat SID formats have been defined to allow for the transmission of alert messages on any communication system as agreed between MCCs and between a Cospas-Sarsat MCC and its associated RCCs or SPOCs. Alert messages in SID formats can be routed and processed by MCCs either automatically or manually.

In addition to telephone (voice and/or facsimile) communications, all Cospas-Sarsat MCCs are required to have access to at least two international networks for transmitting alert messages in order to provide maximum availability and adequate flexibility for the exchange of alert data. MCCs transmit alert data to other MCCs, SPOCs or RCCs using the following systems:

- international telex
- Automatic Fixed Telecommunication Network (AFTN) of Civil Aviation
- packet data networks (X.25)

AFTN addresses, telex numbers, telephone or facsimile numbers are given in the Cospas-Sarsat Data Distribution Plan (C/S A.001). Prior co-ordination may be necessary between the MCC operator and SPOCs in its Service Area to agree on communication systems and interfaces to be used.

In order to ensure that Cospas-Sarsat alert and location data is distributed efficiently, IMO and ICAO have invited each of their Member governments to designate a national SPOC and to provide the required information on available communication links (telephone, international telex, AFTN or X.25), either to IMO, ICAO, or the Cospas-Sarsat Secretariat.

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7. COSPAS-SARSAT TYPE APPROVAL AND COMMISSIONING PROCEDURES

7.1 Scope

Since the Cospas-Sarsat System is open to countries and/or agencies other than the original Parties, it is vital that all systems and equipment be compatible and consistent with Cospas-Sarsat performance requirements. Therefore, MCCs, LUTs and beacons to be operated in the system must undergo commissioning or type approval.

It is the manufacturer's responsibility to obtain type approval of its 406 MHz beacons and to comply with specific national regulations. For LUTs and MCCs, the agency intending to implement the station is responsible for testing and commissioning.

7.2 Cospas-Sarsat Type Approval of 406 MHz Beacons

7.2.1 General

Type approval of 406 MHz beacons is a national responsibility. However, to assist administrations, Cospas-Sarsat has developed a type approval procedure. A Cospas-Sarsat Type Approval Certificate is delivered by the Cospas-Sarsat Secretariat to manufacturers whose beacons have been successfully tested, according to the Cospas-Sarsat procedure, at Cospas-Sarsat approved laboratories. The Cospas-Sarsat type approval procedure covers only the transmission characteristics of the beacons.

The purpose of the Cospas-Sarsat type approval is to ensure that:

- beacons, when activated, will not degrade nominal system performance;
- beacon transmissions will be compatible with satellite on-board equipment; and
- the content of coded information transmitted by the beacons will be compatible with LUT processing.

Successful completion of Cospas-Sarsat certification testing does not relieve the manufacturer from the obligation to obtain national type acceptance and/or relevant authorisations from national administrations.

Cospas-Sarsat type approval procedures to be followed by the manufacturer are detailed in section 7.2.3. National regulations may include requirements concerning beacon packaging, installation and operation which are not included in the Cospas-Sarsat specification (e.g. homing frequencies, automatic release mechanism).

7.2.2 Reference Documents

Reference documents for the development, manufacturing and testing of 406 MHz distress beacons are:

- ITU-R Recommendation 633-1, Transmission characteristics of a satellite emergency position-indicating radiobeacon (satellite EPIRB) system operating through a low polar-orbiting satellite system in the 406 MHz band.
- Cospas-Sarsat document C/S T.001 "Specification for Cospas-Sarsat 406 MHz Distress Beacons".
- Cospas-Sarsat document C/S T.007 "Cospas-Sarsat 406 MHz Distress Beacons Type Approval Standard".
- Cospas-Sarsat document C/S G.005 "Guidelines on Beacon Coding, Registration, and Type Approval".
- Relevant national specifications and requirements based on IMO performance standards for 406 MHz EPIRBs or ICAO standards for 406 MHz ELTs.

7.2.3 Cospas-Sarsat Type Approval Testing

Cospas-Sarsat type approval testing may be performed at 406 MHz beacon test facilities which have been accepted by the Cospas-Sarsat Council. A list of accepted test facilities is available from the Cospas-Sarsat Secretariat. The requirements for a test facility to become a Cospas-Sarsat accepted facility for type approval testing are defined in the document C/S T.008 “Cospas-Sarsat Acceptance of 406 MHz Beacon Type Approval Facilities”.

Manufacturers seeking Cospas-Sarsat type approval of 406 MHz beacons should contact the Cospas-Sarsat Secretariat for further details concerning the type approval procedures described in the document C/S T.007.

The cost of type approval testing will be borne by the manufacturers.

7.2.4 Cospas-Sarsat Type Approval Decision

After review of the test results and approval by the Cospas-Sarsat Council, a Cospas-Sarsat type approval certificate will be issued by the Cospas-Sarsat Secretariat. The Council reserves the right to revoke the certificate should it be demonstrated that production models do not meet Cospas-Sarsat specifications.

7.3 Commissioning of LUTs and MCCs

Minimum technical and operational requirements for LUTs and MCCs to be used in the Cospas-Sarsat System and the commissioning procedures are contained in the following documents:

C/S T.002 "Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines"
C/S T.005 "Cospas-Sarsat LEOLUT Commissioning Standard"
C/S T.009 “Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines”
C/S T.010 “Cospas-Sarsat GEOLUT Commissioning Standard”
C/S A.005 "Cospas-Sarsat MCC Performance Specification and Design Guidelines"
C/S A.006 "Cospas-Sarsat MCC Commissioning Standard"

Prior to integration of a new LUT or MCC into the Cospas-Sarsat System, the applicable commissioning report, submitted by the applicant, is reviewed by the Joint Committee. When all requirements for operation have been adequately demonstrated by the new component, the Cospas-Sarsat Council approves its entry into the System.

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8. PROGRAMME MANAGEMENT

8.1 Background

The Cospas-Sarsat Programme was established in 1979 by the US National Aeronautics and Space Administration (NASA), the Canadian Department of Communications (DOC), the French Centre National d'Etudes Spatiales (CNES) and the Ministry of Merchant Marine (MORFLOT) of the former USSR.

Initially, the objective of these agencies was to demonstrate that polar orbiting satellites could effectively assist search and rescue operations by providing alert and location data to responsible administrations.

Following the success of the Demonstration and Evaluation Phase, the Parties to the 1979 Memorandum of Understanding (MOU) decided to continue the endeavour and a new MOU was signed in 1984 between MORFLOT, CNES, the US National Oceanic and Atmospheric Administration (NOAA) and the Canadian Department of National Defence (DND). The change of US and Canadian signatories reflected the transition to the operational phase of the Programme and in 1985, the satellite system was declared operational by the Cospas-Sarsat Steering Committee (CSSC). The Parties to the MOU also agreed to establish the Programme on an inter-governmental basis in order to address IMO's and ICAO's desire to assure the long-term continuity of the System.

8.2 The International Cospas-Sarsat Programme Agreement

The International Cospas-Sarsat Programme Agreement between Canada, France, the former USSR and the USA was signed in Paris on 1 July 1988 and entered into force on 30 August 1988. The Agreement is open for accession by other States wishing to provide space segment capabilities. It also allows for the use of the System by all States on a long-term non-discriminatory basis.

The International Cospas-Sarsat Programme Agreement establishes a Council and a Secretariat. The Council oversees the implementation of the Agreement and co-ordinates the activities of the Parties. The Secretariat, the permanent administrative organ of the Programme, takes direction from the Council and assists the Council in the implementation of its functions. The Council has established a subsidiary organ, the Cospas-Sarsat Joint Committee, which comprises an Operations Working Group (OWG) and a Technical Working Group (TWG).

States non-Party to the International Cospas-Sarsat Programme Agreement can participate in the System by notifying one of the Depositaries of the Agreement (the Secretary-General of IMO or the Secretary General of ICAO) of their association with the Programme either as Ground Segment Providers or as User-States. Ground Segment Providers and User-States are full members of the Cospas-Sarsat Joint Committee. Other interested Administrations may be invited to attend meetings convened from time to time by the Cospas-Sarsat Council.

- END OF SECTION 8 -

ANNEX
TO THE INTRODUCTION
TO THE COSPAS-SARSAT SYSTEM

ANNEX A

Acronyms Used in this Document

AFTN	Aeronautical Fixed Telecommunication Network
Beacon	All types of distress radiobeacons used in the Cospas-Sarsat System operating at 406 MHz
bps	Bits per second
CNES	Centre National d'Etudes Spatiales (France)
Cospas	(Cosmicheskaya Sistyema Poiska Avariynich Sudov) Space System for the Search of Vessels in Distress
CSC	Cospas-Sarsat Council
dB	Decibel
DDR	Data Distribution Region
DND	Department of National Defence (Canada)
ELT	Emergency Locator Transmitter (aeronautical distress beacons)
EPIRB	Emergency Position Indicating Radio Beacon (maritime distress beacon)
GEO	Geostationary Earth Orbit
GEOLUT	Ground receiving station in the GEOSAR system
GEOSAR	GEO satellite system for SAR
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
ITU	International Telecommunications Union
LEO	Low-altitude Earth Orbit
LEOLUT	Ground receiving station in the LEOSAR system
LEOSAR	LEO satellite system for SAR
LUT	Local User Terminal (Cospas-Sarsat ground receiving station)
MCC	Cospas-Sarsat Mission Control Centre
MHz	Megahertz (Radio Frequency)
MORFLOT	Ministry of Merchant Marine (former USSR ministry)
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration (USA)
NSS	National Search and Rescue Secretariat (Canada)
PLB	Personal Locator Beacon (distress beacon for personal use)

RCC	Rescue Co-ordination Centre
RF	Radio Frequency
SAR	Search and Rescue
SARP	Search and Rescue Processor (406 MHz processor of the LEOSAR system)
SARR	Search and Rescue Repeater (406 MHz repeater of the LEOSAR system)
Sarsat	Search and Rescue Satellite-Aided Tracking
SPOC	SAR Point of Contact
SRR	Search and Rescue Region

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