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SATELLITE-AIDED SEARCH AND RESCUE — THE COSPAS-SARSAT SYSTEM

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FOREWORD

1. General

1.1 The essence of successful search and rescue lies in the speed with which it can be set up and carried out and the accuracy with which the search area can be defined. This is so because it must be presumed that in each incident there are survivors who need help and whose chances of survival diminish with every passing minute.

1.2 The COSPAS-SARSAT* system, which has been developed by Canada, France, the Union of Soviet Socialist Republics and the United States, introduces space technology to assist in expediting search and rescue and in defining the search area. Experience gained from the COSPAS-SARSAT project has demonstrated significant advantages to be gained by satellite-aided alerting.

1.3 The purpose of this circular is:

a) to acquaint personnel responsible for search and rescue, as well as air traffic services personnel, communications specialists and pilots, with the status of the COSPAS-SARSAT system and how it assists search and rescue; and

b) to inform States which may be interested in taking advantage of the COSPAS-SARSAT system of the points of contact, levels of participation, and likely costs.

Although this circular focuses on aeronautical applications of the COSPAS-SARSAT system, it has broader humanitarian applications which include maritime and terrestrial search and rescue.

1.4 The term "emergency transmitters" when used in this circular is a generic term which encompasses emergency location beacons - aircraft (ELBA), survival radio equipment which emits a distinctive tone, emergency position indicating radio beacons (EPIRB) and emergency locator transmitters (ELT).

2. Background

2.1 At the 23rd Session of the ICAO Assembly in 1980, the Technical Commission took note of a report submitted by the Delegation of Canada on experimental work related to search and rescue satellite-aided tracking (SARSAT). Since that time, the development of the COSPAS-SARSAT system has been monitored and reported on in annual reports of the Council, articles in the ICAO Bulletin and State letters.

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* COSPAS/SARSAT:
COSPAS = Kosmicheskaya Sistyema Poiska Avariynych Sudov (KOSPAS);
SARSAT = Search and Rescue Satellite-Aided Tracking

2.2 In November 1985, the Secretariat prepared a summary report on the COSPAS-SARSAT system. The Air Navigation Commission, after reviewing this report, agreed that:

a) appropriate information concerning COSPAS-SARSAT be prepared in the form of an ICAO circular;

b) States not yet participating in the COSPAS-SARSAT programme be invited to reconsider such participation in accordance with the Council's request of 14 December 1983;

c) all States be invited to take action aimed at reducing the number of false alarms on 121.5/243.0 MHz caused by inadvertent activation of emergency transmitters and eliminating misuse of those frequencies for unauthorized purposes, and to continue their efforts to eliminate unauthorized transmissions in the band 406.0 MHz and 406.1 MHz; and

d) an air navigation study group be established to assist the Secretariat in examining the various aspects relating to the use of the COSPAS-SARSAT system and developing specific proposals for action.

2.3 The decisions in b) and c) above were reflected in State Letter AN 15/12-86/50 dated 7 May 1986 and the air navigation study group mentioned in d) began work in June 1986. This circular is in response to a) above.

TERMS AND ABBREVIATIONS

Aeronautical fixed telecommunication network (AFTN). A world-wide system of aeronautical fixed circuits provided, as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

Air traffic services (ATS). A generic term meaning, variously, flight information service, alerting service, air traffic advisory service, air traffic control service, area control service, approach control service and aerodrome control service.

Ambiguity resolution. The ability of the COSPAS-SARSAT system to correctly determine which of two locations, on each side of the satellite's track, is the true location of an emergency transmitter.

Area control centre (ACC). A unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction.

CCIR. International Radio Consultative Committee.

Coherent. A term used to describe an amplitude-modulated transmission in which a certain minimum amount of transmitted energy is present in the carrier component, thereby facilitating satellite detection of emergency transmitters.

Co-ordinated Universal Time (UTC).

COSPAS: Kosmicheskaya Sistyema Poiska Avariynych Sudov (KOSPAS). The space segment search and rescue packages provided by the Union of Soviet Socialist Republics.

CSSC. COSPAS-SARSAT Steering Committee, which manages the COSPAS-SARSAT system.

D & E. The demonstration and evaluation phase of the COSPAS-SARSAT system.

Detection threshold. The minimum radiated power level which is required in order to provide a location from the COSPAS-SARSAT system.

Emergency code. An optional code which can be set in the 406 MHz emergency transmitter to indicate the nature of the emergency.

Emergency location beacon - aircraft (ELBA).

Emergency locator transmitter (ELT).

Emergency position indicating radio beacon (EPIRB). The maritime equivalent of the ELBA.

Emergency transmitter. A generic term used in this circular to describe the ELBA, ELT, EPIRB or other devices serving a similar purpose which operate on 121.5, 243.0 and/or 406 MHz.

Flight information centre (FIC). A unit established to provide flight information service and alerting service.

Future global maritime distress and safety system (FGMDSS). System developed by the International Maritime Organization.

GHz. Gigahertz.

G-switch. A switch which automatically activates an emergency transmitter when forces are encountered which are beyond those experienced during normal aircraft flight, usually in the direction of flight.

HF. High frequency (3 to 30 MHz).

Hz. Hertz.

IMO. International Maritime Organization.

Incoherent. An amplitude-modulated transmission which is not coherent.

ITU. International Telecommunications Union.

kHz. Kilohertz.

Local user terminal (LUT). A generic term for an Earth station in the COSPAS-SARSAT system which is used to track polar-orbiting satellites carrying search and rescue packages.

Location accuracy. As used in this circular, it is the accuracy to which the COSPAS-SARSAT system can determine the location of an emergency transmitter.

Location ambiguity. Ambiguity which arises in the COSPAS-SARSAT system because two possible correct solutions exist, one on each side of the satellite's track.

Memorandum of Understanding (MOU).

MHz. Megahertz.

Minimum operational performance standards (MOPS).

Mission control centre (MCC). A unit which provides alerting service to RCCs using location information from the COSPAS-SARSAT system.

Multiple access capability. The maximum capacity of the COSPAS-SARSAT system to provide location information for emergency transmitters in simultaneous view of a satellite which carries search and rescue packages.

Orbiting satellites carrying amateur radio (OSCAR).

Rescue co-ordination centre (RCC). A unit responsible for promoting efficient organization of search and rescue service and for co-ordinating the conduct of search and rescue operations within a search and rescue region.

SARSAT: Search and rescue satellite-aided tracking. The space segment search and rescue packages which are provided by Canada, France and the United States.

Search and rescue (SAR).

Search and rescue region (SRR). An area of defined dimensions within which search and rescue service is provided.

Survival radio equipment. A manually activated emergency transmitter which may or may not have a voice capability.

User class. A coded field in 406 MHz emergency transmissions which is used to differentiate between aeronautical, maritime or other types of transmissions.

Very high frequency (VHF). 30 to 300 MHz.

Visibility window. The period during which a satellite carrying search and rescue packages is visible to an LUT.

WARC. World Administrative Radio Conference.

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Chapter 1. BACKGROUND

1.1 CONVENTIONAL ALERTING METHODS

1.1.1 General

1.1.1.1 The success of a search and rescue operation depends, to a large degree, on the prompt receipt by the rescue co-ordination centre (RCC) of information needed for an evaluation of the situation and a decision on the best course of action. Only then can activation of search and rescue facilities be assured, making it possible to:

a) locate, reach, sustain and rescue survivors in the shortest possible time;

b) facilitate self-help by survivors while they are still capable of doing so.

Experience has shown that the chances of survival after an accident decrease significantly during the first 24 hours for injured persons and after the first three days for uninjured persons. Experience has also shown that, because of the shock effect following an accident, uninjured and able-bodied persons are often unable to accomplish simple tasks in a logical manner and thus may hinder, delay or even prevent their own rescue.

1.1.1.2 Although search and rescue organizations have different structures, an RCC usually receives notification that an aircraft is, or is considered to be, in a state of emergency from the flight information centre (FIC) or area control centre (ACC) with which it is associated. Normally, this notification is determined in relation to an aircraft flight plan, transmissions made by the distressed aircraft, reports by other aircraft (visual observations, transmissions from emergency transmitters), loss of radar contact, or from other sources. The state of emergency is indicated by:

1) an uncertainty phase;

2) an alert phase; or

3) a distress phase.

1.1.2 Notification based on flight plan

1.1.2.1 In respect of an aircraft for which a flight plan has been filed, an uncertainty phase is declared when:

a) no communication has been received within 30 minutes after the time it should have been received, or from the time a first unsuccessful attempt was made to establish communications with the aircraft; or

b) the aircraft fails to arrive within 30 minutes of the estimated time of arrival (ETA).

1.1.2.2 When notification is based on the flight plan, the most time-consuming and difficult task is to determine whether or not a distress situation exists. In some cases, aircraft communications capability may be limited to a single radio. Communications searches may be difficult or delayed due to limited hours of operation at destination or alternate aerodromes or other aerodromes en route, or lack of communications facilities in the area in which the aircraft was operating. The alert and distress phases of an emergency are based on positive information, and procedures to be followed are indicated in the Search and Rescue Manual (Doc 7333), Part 2 - Search and Rescue Procedures. It is the process of obtaining the information needed to make the transition from the uncertainty phase to the alert or distress phase which is difficult.

1.1.2.3 For RCCs, the most difficult problems arise with uncontrolled visual flight rules (VFR) flights when no flight plan has been filed, and with aircraft engaged in amphibious operations in areas lacking communications. In such situations, information with regard to the pilot's intentions is limited and communications searches may be prolonged. Delays arising from communications searches may extend into the hours of darkness, further hampering search and rescue operations which rely upon visual sightings of the distressed aircraft, its occupants and/or their distress signals.

1.1.3 Notification by pilot in distress

1.1.3.1 When a pilot transmits information indicating that the operating efficiency of the aircraft has become impaired, reaction by RCCs can be prompt. Difficulties arise in remote areas where very high frequency (VHF) communication is limited and reliance is placed on high frequency (HF) communications. Few general aviation aircraft are equipped with HF communications equipment.

1.1.3.2 Second only to knowing that a distress situation exists, the location of the aircraft is the most important piece of information needed by search and rescue. Shock associated with an emergency may cause the pilot to omit vital information, such as aircraft call sign, intentions or location, from the distress message. Moreover, if a diversion was necessary, the pilot may be uncertain of the aircraft's location.

1.1.4 Notification by emergency transmitter

1.1.4.1 Carriage of emergency transmitters by aircraft is specified in the provisions of Annex 6, Parts I and II. The survival radio equipment and the emergency location beacon - aircraft (ELBA) operate on VHF in accordance with the provisions of Annex 10, Volume I. They may be manually operated by survivors, are not dependent for operation on the aircraft's power supply and are water-resistant. Additionally, the ELBA should be designed and installed so that it operates automatically in the event of a crash and is unlikely to be rendered inoperative by a crash.

1.1.4.2 Emergency transmitters emit a distinctive tone recognizable to overflying aircraft monitoring the emergency frequency. This signal alerts flight crews to the possibility of distress, and to the need to notify the nearest RCC through air traffic services.

1.1.4.3 The principle on which the emergency transmitters work is illustrated in Figure 1. Beneath the track of the overflying aircraft, there is a cone of reception within which signals from an emergency transmitter are received. Not only is the possibility of distress recognized, but its location is known to be within a specific area related to the width (W) of the cone of reception, which is dependent upon the altitude of the overflying aircraft. Normally this width is 100 NM or less. The time needed for search and rescue is thus reduced, especially if the search and rescue aircraft is equipped with homing equipment.

1.1.4.4 One difficulty with notification by emergency transmitter is that it depends upon the presence of, and detection by, overflying aircraft. Another is that the area of coverage is limited by the width of the cone of reception. In Figure 1, the emergency transmitter belonging to aircraft A would be reported because it is within the cone of reception of overflying aircraft. However, the emergency transmitter belonging to aircraft B may go unreported because it is outside the cone of reception of overflying aircraft.

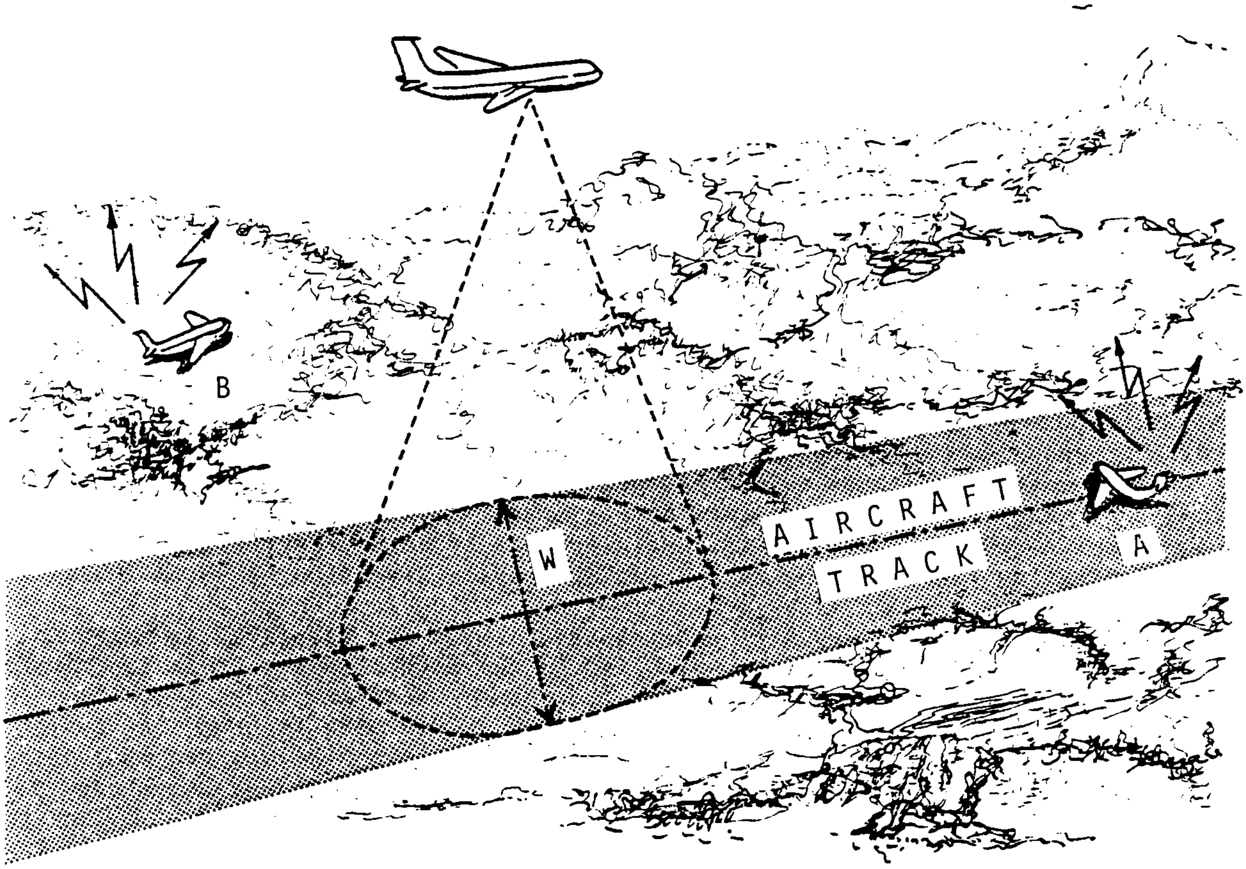


Figure 1. Notification by emergency transmitter

1.2 EVOLUTION OF COSPAS-SARSAT

1.2.1 The emergency transmitter, in various forms, has been in use for 30 years. Although emergency transmitters have improved search and rescue response, the methods of implementation, varieties in the types and qualities of such equipment, cost constraints and operational aspects have combined to produce a situation in which there have been many unintentional activations (false alarms). Also, the essential reliance upon overflying aircraft means that coverage is incomplete and sporadic at best. Search and rescue authorities have therefore looked for improved techniques to receive alerts and to locate distress situations while minimizing problems caused by false alarms.

1.2.2 One such improvement lies in the use of low, polar-orbiting satellites which are able to systematically monitor all parts of the earth. These satellites provide RCCs with a means of distress alerting independent of air routes or air traffic patterns, and have the potential for significantly increasing the accuracy of location information.

1.2.3 In the early 1970s, Canadian authorities experimented with location techniques for low-powered emergency transmitters using the orbiting satellites carrying amateur radio (OSCAR series) which operated at 145 MHz. It was established that by using low, polar-orbiting satellites and measuring the Doppler shift, accurate location estimates could be derived.

1.2.4 As a result, two separate experiments were planned. The first was designed to work with emergency transmitters operating on 121.5 and 243.0 MHz, because of the importance of providing immediate benefit to thousands of users already so equipped. There was uncertainty, however, about the over-all effectiveness of using satellite techniques. Unlike other transmitters used in data collection via satellite, the existing emergency transmitter is uncoded and was not designed for satellite use. A second experiment was therefore planned using an optimized transmitter operating at 406 MHz.

1.2.5 The 406 MHz portion of the radio spectrum has very low signal path losses for earth-to-space communications. Thus, the International Telecommunications Union (ITU) was requested to reserve this frequency for future emergency transmitter applications. The 1979 ITU World Administrative Radio Conference allocated the frequency band of 406 to 406.1 MHz for exclusive use by satellite emergency position-indicating radio beacons in the earth-to-space direction (RR38-10 2997A).

1.2.6 In 1979, a memorandum of understanding (MOU) was signed by agencies in Canada, France and the United States which led to the establishment of an experimental project for exploring the concept of search and rescue satellite-aided tracking (SARSAT). Subsequently, the SARSAT partners signed an MOU with the Union of Soviet Socialist Republics which was engaged in an experimental project with the same objective (COSPAS). In 1980, a COSPAS-SARSAT implementation plan was signed by these four parties.

1.2.7 COSPAS-SARSAT experiments began in June 1982 with the launch by the Union of Soviet Socialist Republics of the first satellite (COSPAS-I) carrying a search and rescue space segment package. A series of technical system performance tests was completed and the demonstration and evaluation (D & E) phase began in February 1983, with the participation of users having national responsibilities for the conduct of search and rescue operations. A second USSR satellite (COSPAS-II) and the first United States satellite (SARSAT-I) carrying search and rescue space segment packages were launched in March 1983. The D & E phase was concluded in late 1984. In addition to the four COSPAS-SARSAT partners, Bulgaria, Denmark, Finland, Norway, Sweden and the United Kingdom participated in the experiments.

Chapter 2. SYSTEM DESCRIPTION

2.1 SYSTEM ORGANIZATION

2.1.1 General

2.1.1.1 The COSPAS-SARSAT system is managed by a Steering Committee consisting of representatives from each of the four COSPAS-SARSAT parties which are funding the search and rescue space segment packages (Canada, France, the Union of Soviet Socialist Republics and the United States). A detailed description of the various levels of participation is provided in Chapter 10 of this circular. In essence, technical and operational search and rescue specialists from the participating States are assigned tasks by the Steering Committee to which they report.

2.1.1.2 The COSPAS-SARSAT system involves the employment of space segment packages on several satellites in low, near-polar orbits for the purpose of receiving transmissions from emergency transmitters, and then relaying these transmissions to a network of dedicated ground stations called local user terminals (LUTs). These ground stations determine the positions of the emergency transmitters and forward the position data to designated mission control centres (MCCs). The MCCs in turn relay the information to the appropriate rescue co-ordination centres (RCCs) for search and rescue action.

2.1.2 Space segment

2.1.2.1 The current COSPAS-SARSAT MOU provides for four polar-orbiting satellites carrying space segment packages (the satellites are not exclusively dedicated to search and rescue). The COSPAS series of satellites monitors signals on the 121.5 and 406 MHz bands. The SARSAT satellites monitor 121.5, 243.0 and 406 MHz signals.

2.1.3 Local user terminals (LUTs)

2.1.3.1 When the search and rescue space segment packages are orbiting the earth, they receive transmissions on 121.5, 243.0 and 406 MHz as indicated above. These signals are then transmitted to the LUTs in the 1.5 GHz band. Because of the motion of the low, polar-orbiting satellites, the signal relayed to the LUTs has a Doppler component. This Doppler component is used to determine the emergency transmitter locations. The resulting locations are forwarded to an MCC.

2.1.4 Mission control centres (MCCs)

2.1.4.1 The functions of the MCC are system control and system co-ordination (data distribution). As part of system control, the MCC receives information needed to track satellites and process satellite data. System control information is provided by the four States according to their space segment responsibilities. The MCC also receives distress incident data from the LUTs and distributes this data to the appropriate RCCs for search and rescue action.

2.1.5 Over-all concept

2.1.5.1 The over-all concept is illustrated in Figure 2. The national LUT or LUTs forward alert data to the national MCC. If the emergency transmitter is transmitting within the national search and rescue region(s), the data is forwarded to the appropriate national RCC. If the emergency transmitter is transmitting outside national search and rescue regions, the data may be forwarded either to another MCC for distribution to its own national RCCs, or to RCCs in other States. The RCC within the appropriate State still has the responsibility for initiating and co-ordinating search and rescue actions.

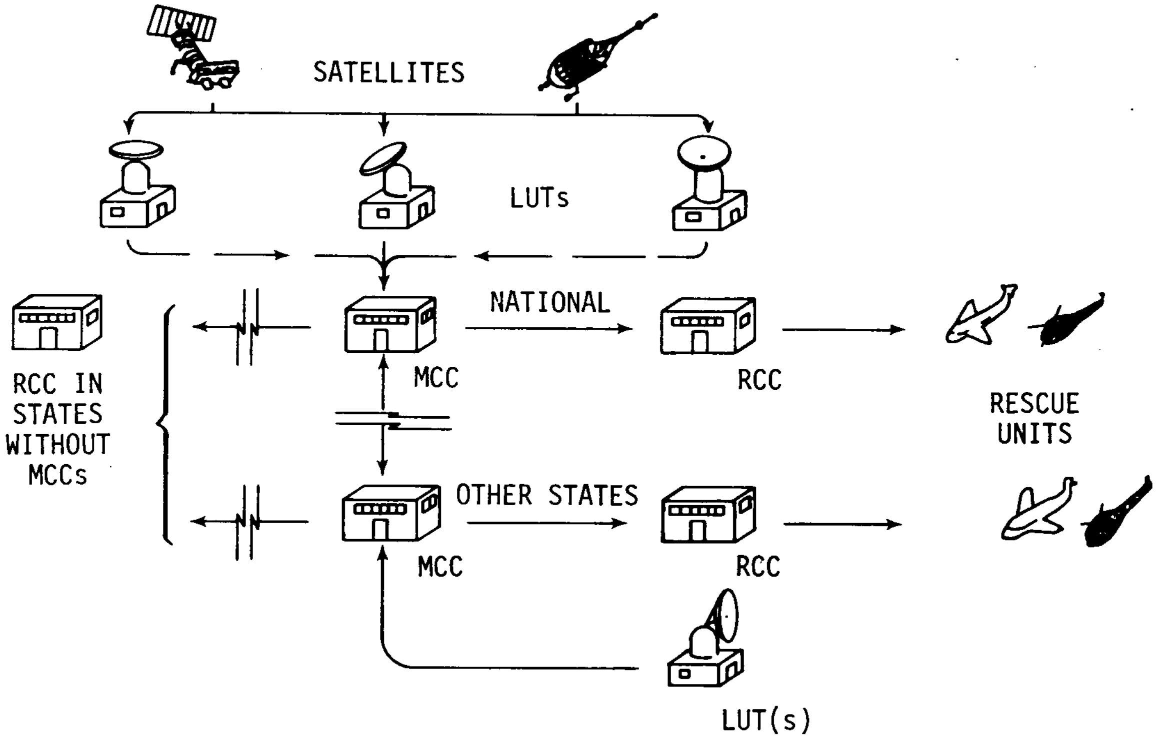


Figure 2. Over-all system concept

2.2 TECHNICAL PRINCIPLES OF OPERATION

2.2.1 Doppler principle

2.2.1.1 As mentioned earlier, the COSPAS-SARSAT system makes use of the Doppler principle. This is illustrated in Figure 3. As the satellite approaches the emergency transmitter (point A), the frequency of the transmitter which is received at the satellite is higher than the transmitted frequency. When the satellite passes overhead or abeam of the emergency transmitter, the received frequency is the same as the transmitted frequency. As the satellite travels away from the emergency transmitter, the received frequency is lower than the transmitted frequency.

2.2.1.2 As a result of the Doppler principle, the signal received at the LUT results in a Doppler curve, as depicted in the illustration. The inflection point in the Doppler curve (point B) indicates when the satellite has passed overhead or abeam of the emergency transmitter. The slope of the Doppler curve is used to determine how far the emergency transmitter is located from the satellite. Since the locations of the LUT and satellite are precisely known, it is possible to determine the location of the emergency transmitter.

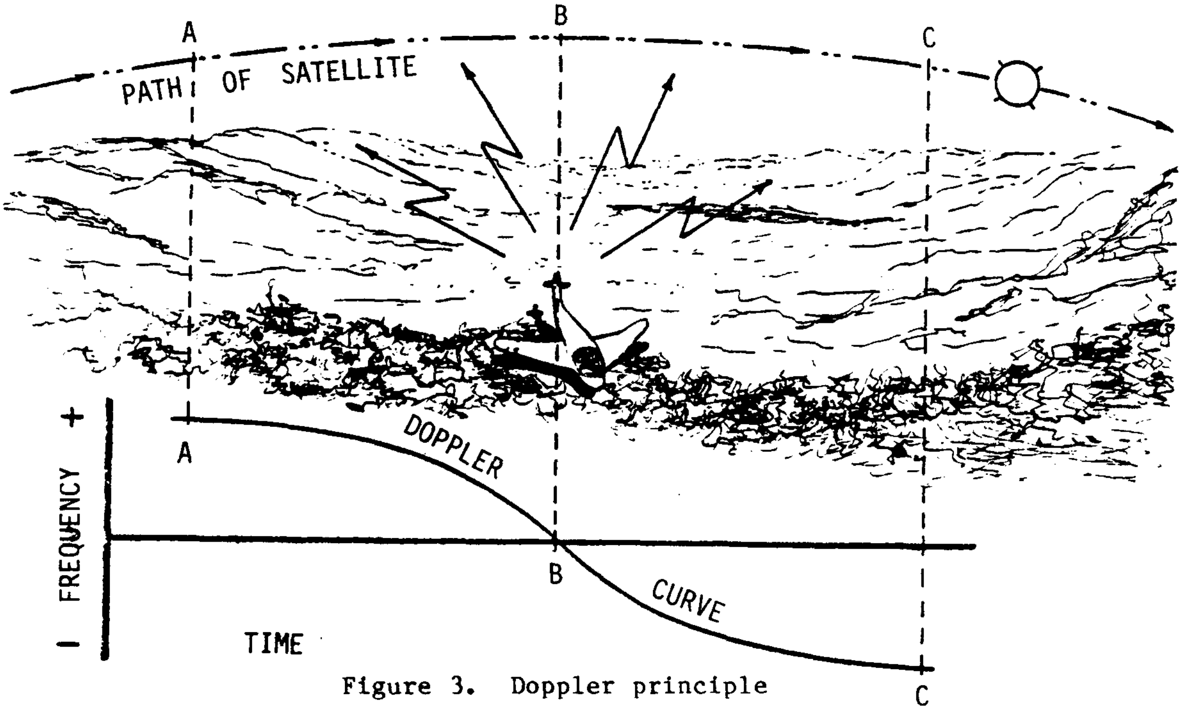


Figure 3. Doppler principle

2.2.2 121.5/243.0 MHz emergency transmitters

2.2.2.1 Emergency transmitters on the frequencies 121.5 and 243.0 MHz normally emit a continuous signal at a minimum power of 75 mW. These transmitters have no unique identification code, thus ruling out simple on-board spacecraft signal processing. The spacecraft is limited to serving as a repeater for the 121.5 and 243.0 MHz signals.

2.2.2.2 For existing emergency transmitters, relay of transmissions via satellite requires line-of-sight visibility between the spacecraft and both the emergency transmitter and the LUT. This concept is known as "visibility window" and is illustrated in Figure 4. As long as the satellite is within the LUT visibility window and is receiving signals from an emergency transmitter, the location of the emergency transmitter can be computed. If the satellite is outside this visibility window (in area 1 or 2), the signals will not be received at the LUT and no locations will result, even though the satellite itself may still be receiving emergency transmitter signals.

2.2.2.3 Figure 5 illustrates the present areas of LUT coverage, in which the LUTs can track the satellites and thus receive emergency transmitter signals on 121.5 and 243.0 MHz. It is also possible, under conditions of mutual visibility, for the satellite to locate the position of an emergency transmitter situated beyond the LUT coverage areas in both easterly and westerly directions. For example, while in line of sight of the LUT, a satellite following the track indicated in the figure could receive an emergency transmission from a location in the mid-Atlantic.

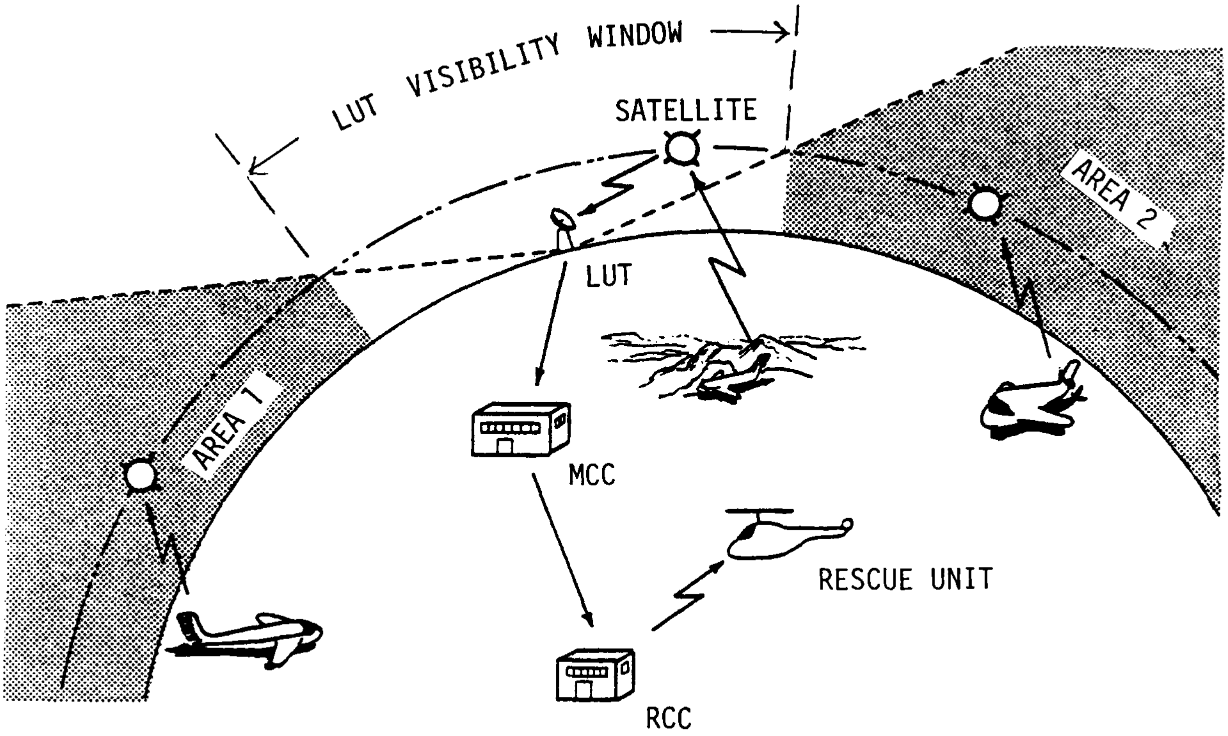
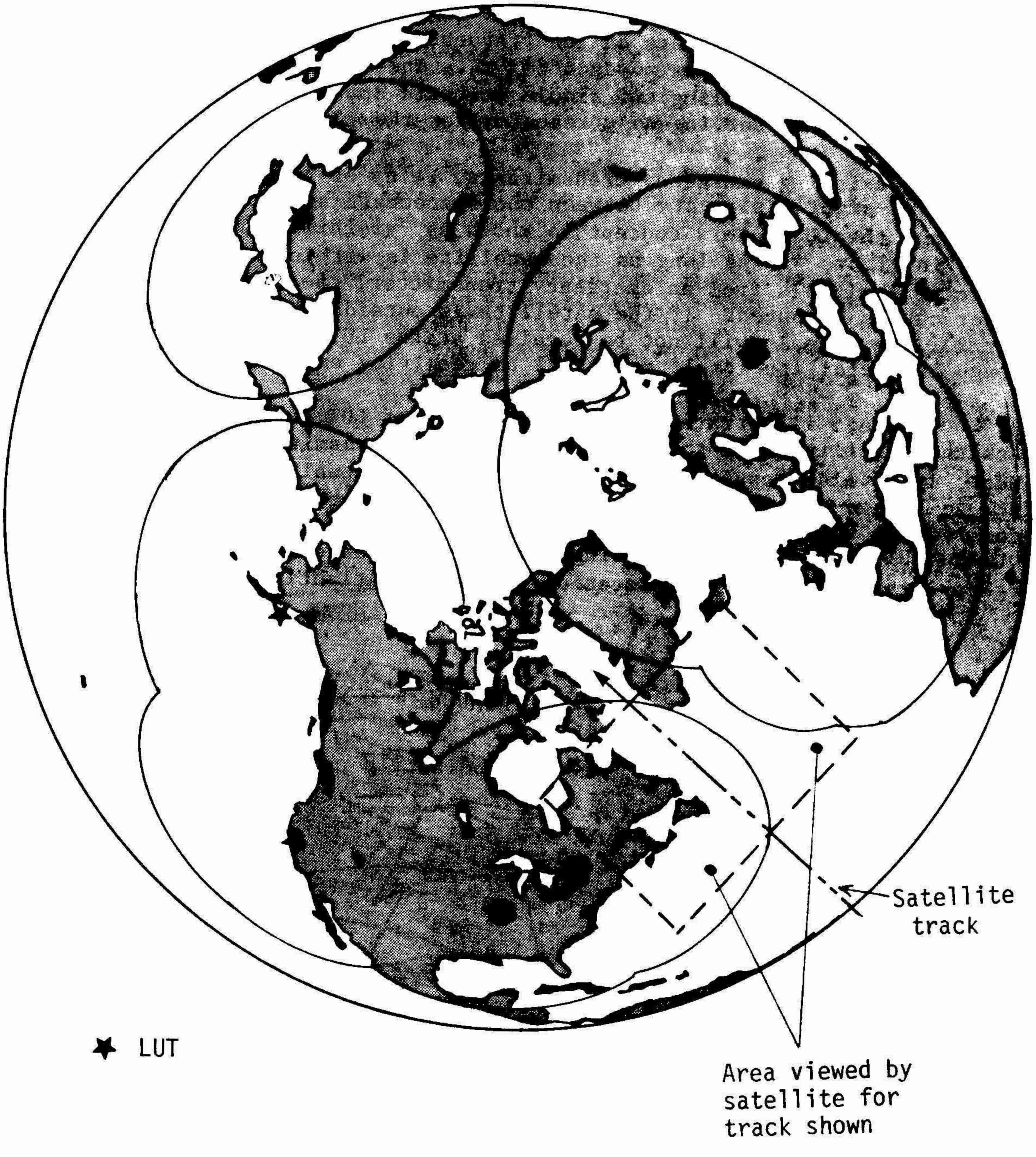


Figure 4. LUT visibility window



Note.- This is the area in which 121.5/243.0 MHz coverage is provided for this particular pass.

Figure 5. Combined LUT-satellite visibility

2.2.3 406 MHz emergency transmitters

2.2.3.1 The 406 MHz beacon designed for use with COSPAS-SARSAT was designed to take advantage of satellite detection systems. It has higher power than current transmitters on 121.5/243.0 MHz (5 W) and improved frequency stability. It also transmits a data message which is used to distinguish one beacon from another. This permits on-board spacecraft processing.

2.2.3.2 The on-board satellite processor makes accurate frequency and time measurements for each signal. This information is then relayed to any LUT which is in line of sight of the satellite. If no LUT is within line of sight of the satellite, the information is stored in spacecraft memory and is broadcast to a ground station when it is in view of the satellite. Full global coverage on 406 MHz is thereby possible with a small number of LUTs.

2.2.3.3 The global capability, illustrated in Figure 6, is possible because data is stored on board the spacecraft. For example, 406 MHz beacons could be transmitting distress signals at locations A and B, where there are no LUTs in view of the satellite. Several minutes later, when the satellite passes within the coverage area of an LUT, the data is broadcast to the LUT and location information for the 406 MHz beacons is obtained.

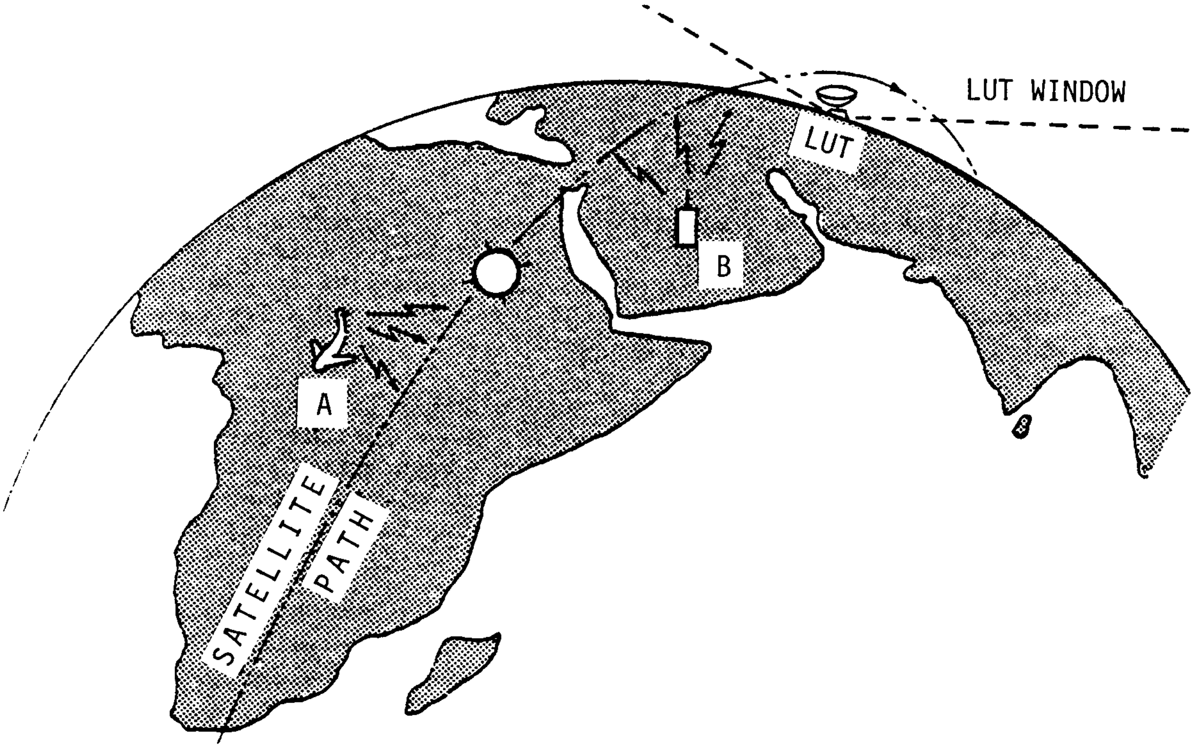


Figure 6. 406 MHz global coverage

2.2.4 Satellite coverage

2.2.4.1 Satellite orbit time in the COSPAS-SARSAT system is approximately 105 minutes. During the interval from one orbit to the next, the earth will have rotated approximately 26 degrees. This is illustrated in Figure 7. On the first orbit (Figure 7 a)), assumed to be at 0000 UTC, the satellite is passing over eastern Australia. On the next orbit (Figure 7 b)), the earth has rotated and western Australia is being viewed. On the next two orbits (Figures 7 c) and 7 d)), areas farther to the west are being viewed.

2.2.4.2 Figure 7 has been used to illustrate the path of one satellite. However, there is more than one satellite circling the earth. Thus, when one State such as Australia leaves the path of the satellite shown in Figure 7, it will soon enter the path of a different satellite (not shown).

2.2.4.3 Low, polar-orbiting satellites have a limited viewing area within which they can receive signals from emergency transmitters. Figure 8 illustrates typical satellite terrestrial viewing areas on 121.5/243.0 MHz. On the first orbit, at 0530 UTC, the satellite passes over eastern South America. On the second orbit, it passes over the central part of the continent. On the third orbit it passes along the western coast.

2.2.4.4 The circles in Figure 8 indicate the area in which the satellite can receive emergency transmitter signals on each orbit. Near the equator, the typical terrestrial viewing area provides only partial overlapping coverage from one pass to the next. However, farther to the south, more overlapping coverage occurs because the satellites are polar-orbiting and their tracks converge in the polar area.

2.3 DATA-HANDLING FUNCTIONS

2.3.1 Functions carried out at an LUT

2.3.1.1 An LUT is basically a signal processor. It receives from the MCC data which are needed to track the satellites and to process satellite data. It receives the downlink signals from the satellite and uses this information to compute emergency transmitter locations. The resulting location information is a latitude and longitude computation which is then passed on to the MCC.

2.3.1.2 Depending upon the LUT design, various other items of information of interest in search and rescue are also computed. These include estimated accuracy of the calculated position, frequency of the emergency transmitter, signal strength, and type of signal. Within some LUTs, audio monitors are also provided to confirm whether or not the received signal has the modulation characteristics of an emergency transmitter.

2.3.2 Functions carried out at an MCC

2.3.2.1 An MCC serves as a national point of contact for data exchange. This function mainly involves transfer of system control data which are needed at the LUTs, but may also involve location information received from other MCCs.

2.3.2.2 When the emergency transmitter locations are received at the MCC from its associated LUT(s), search and rescue responsibility must be determined so that the alert data can be forwarded to the responsible RCC. This is the prime function of the MCC, whether the data originates domestically or internationally.

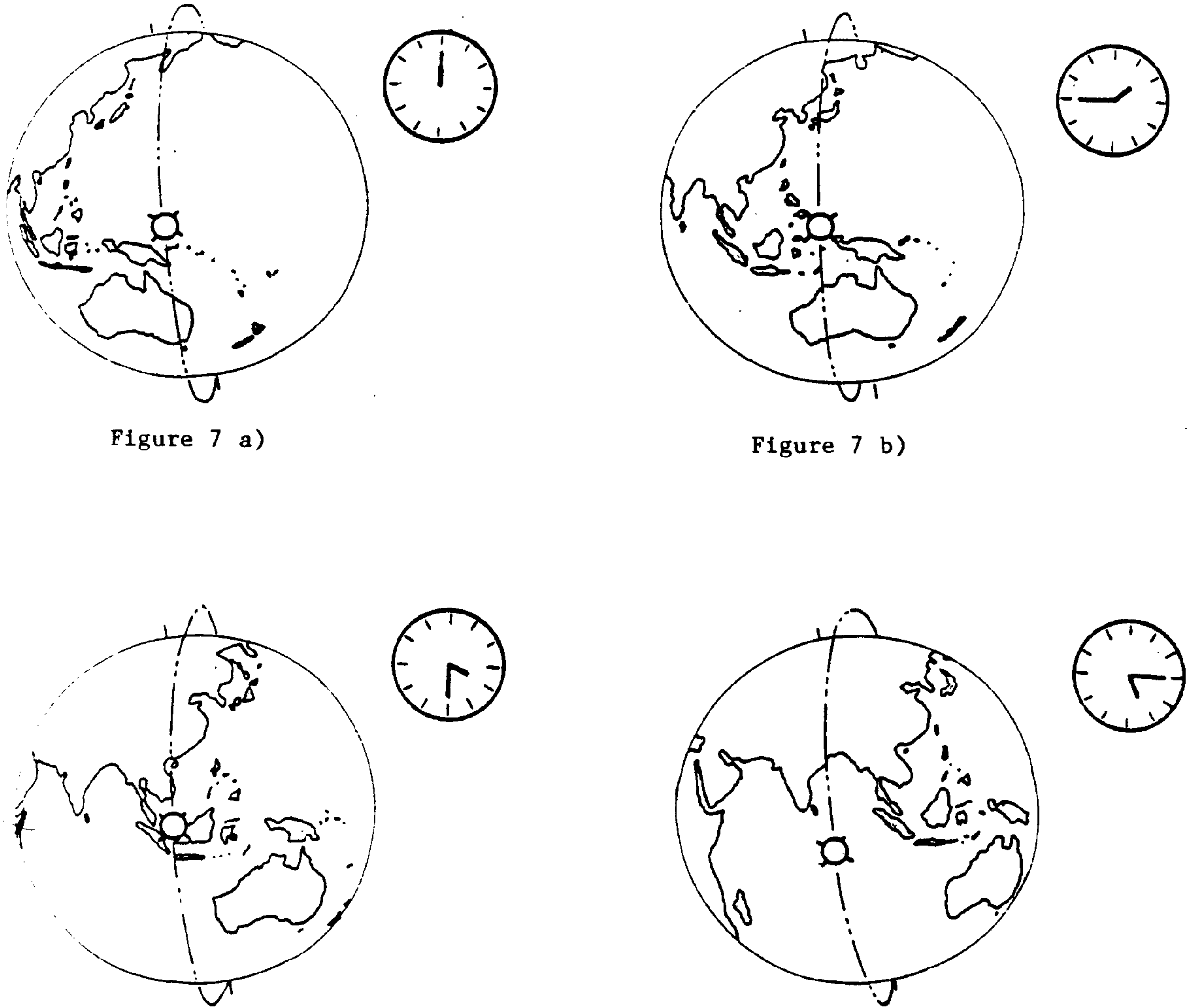


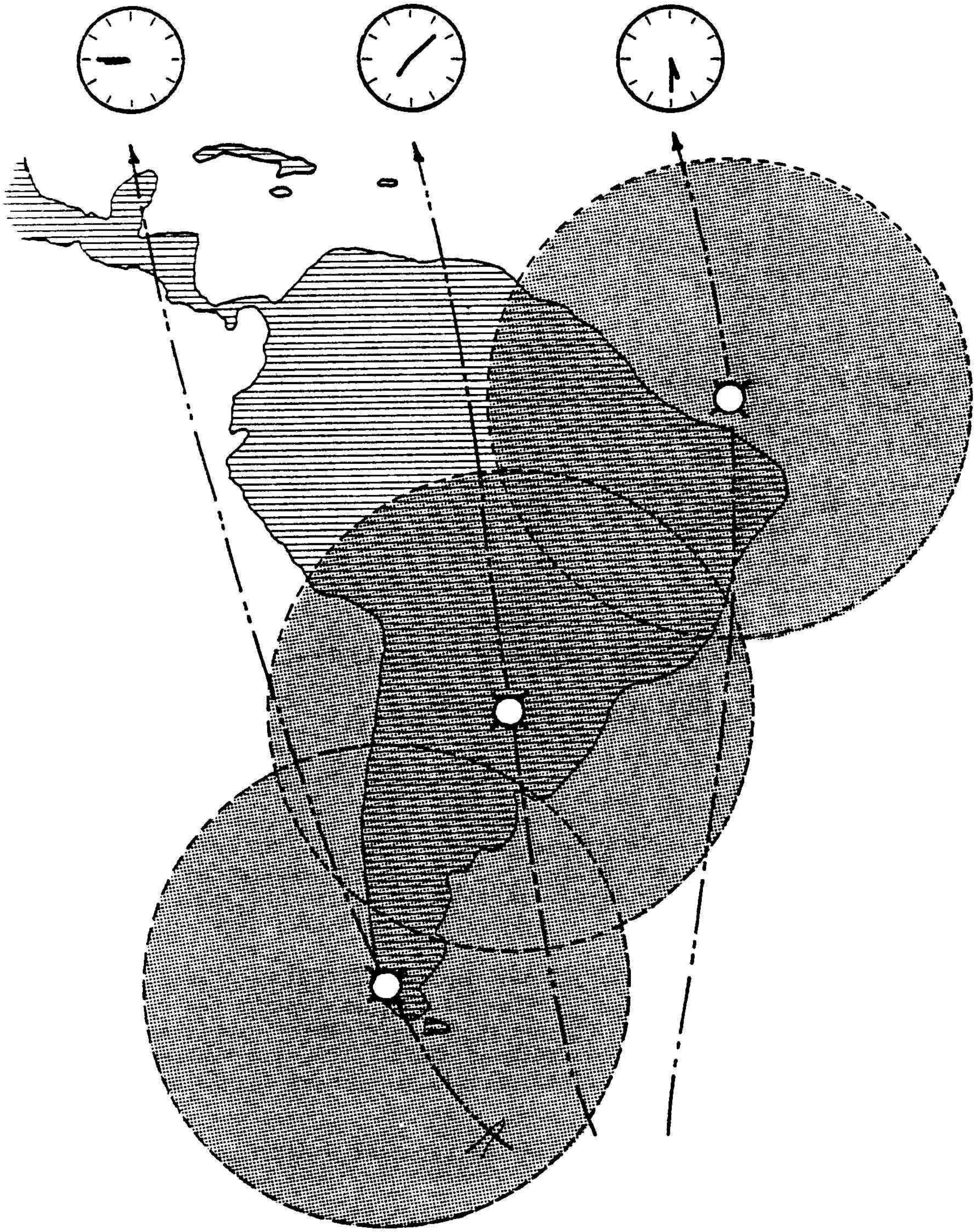
Figure 7 a)

Figure 7 b)

Figure 7 c)

Figure 7 d)

Figure 7. Satellite position for successive orbits



Note.- Circles represent 121.5/243.0 MHz coverage. On 406 MHz it is approximately 50 per cent greater.

Figure 8. Satellite viewing areas on successive orbits

2.3.2.3 The COSPAS-SARSAT system does not assume any search and rescue responsibility other than alerting RCCs. Some Contracting States have integrated the MCC function with a national RCC. Other States, which are participating in the COSPAS-SARSAT system but which do not have an MCC, have established a single national search and rescue point of contact to which MCCs can send COSPAS-SARSAT emergency transmitter locations.

2.3.3 Functions carried out at RCCs

2.3.3.1 Basically, there is no change in the functions carried out by RCCs. The COSPAS-SARSAT system is simply an additional, independent source of alert information for the RCC. However, some educational programmes may need to be implemented and procedures reviewed in order that the satellite data can be used effectively.

Chapter 3. SYSTEM PERFORMANCE

3.1 OVERVIEW OF TESTS

3.1.1 The first search and rescue space segment package was placed in orbit in June 1982 when COSPAS-I was launched. The months which followed were used to verify space and ground segment performance. An official demonstration and evaluation phase began on 1 February 1983 and was concluded in mid-1984. During this phase, a number of technical, operational, and environmental tests were conducted by the participating States. Data were also collected on actual distress cases which occurred during the demonstration and evaluation phase.

3.1.2 Controlled environmental tests involved personnel from search and rescue organizations. These tests were selected to evaluate system performance when the emergency transmitter is operated under varying conditions of temperature, terrain, vegetation cover and sea.

3.2 TECHNICAL TESTS

3.2.1 Technical tests involved measurement of spacecraft and LUT performance for various emergency transmitter signals. All four space segment packages which were used during the demonstration and evaluation phase met or exceeded the nominal performance requirements established prior to satellite manufacture and launch. Other tests measured detection probability and thresholds, location accuracy, and multiple access capacity using technically controlled signals.

3.2.2 Technical tests demonstrated that:

a) over-all system performance for COSPAS-SARSAT either meets or exceeds all original design goals using controlled test signals; and

b) for 121.5/243.0 emergency transmitters, medium-term frequency stability or drift (15 minutes) is the most significant characteristic which will degrade detection probability and location accuracy.

There was no significant difference between 121.5 and 243.0 MHz emergency transmitters, except that the minimum power level needed for satellite detection is higher on 243.0 MHz. An emergency transmitter signal is considered to be coherent if the signal has a distinct carrier component which can be tracked by the LUT; otherwise, the signal is considered incoherent. The results of these tests are summarized in Table 1.

3.3 CONTROLLED ENVIRONMENTAL TESTS

3.3.1 Environmental tests have been carried out in mountains, valleys, at sea, in forests, and under climatic conditions which ranged from desert to thunderstorms to blizzards. Temperatures ranged from -40 to +55°C. Many of the tests were conducted by search and rescue units. A brief summary of the results is given in Table 2.

Table 1. Technical tests for 121.5, 243.0 and 406 MHz signals

	121.5/243.0 MHz		
	coherent	incoherent	406 MHz
Location probability	.95	.80	0.98
Detection threshold			
121.5 MHz	0.5 mW	3 mW	(Note 1)
243.0 MHz	5 mW	30 mW	
Location accuracy	20 km (68%)		3.0 km (90%)
Ambiguity resolution	75%		95%
Multiple access capacity	10+		70 (Note 2)

Note 1.- The performance for 406 MHz varied due to the presence of continuous or intermittent interference in some parts of the world.

Note 2.- The system was designed to be capable of processing 90 beacons which were simultaneously in view of the satellite. It has been tested with 70 beacons.

Table 2. Environmental tests

	121.5/243.0 MHz	406 MHz
Location probability (Note 1)		
Ambiguity resolution	73%	89%
Mean location error	17.2 km	5.8 km

Note 1. See the notes to Table 1. No differentiation was made between coherent and incoherent signals. These tests used standard, commercially available units of both types.

3.4 "REAL WORLD" RESULTS

3.4.1 During the demontration and evaluation phase, a number of "real world" incidents occurred for which data were collected. These included both distress incidents and non-distress incidents (false alarms). Distress incidents, where the COSPAS-SARSAT system was used, involved both aviation and marine cases. Non-distress incidents included emissions from emergency transmitters which were located in burning garbage dumps or stored in closets in private residences.

3.4.2 Over 600 operational incidents (121.5/243.0) were documented during the demonstration and evaluation phase which involved over 5 000 satellite-reported detections. Location accuracy, based on the number of incidents which were within the system design specification of 20 km, ranged from 61 to 79 per cent. The median location error ranged from 12.6 to 14.1 km.

3.4.3 Non-distress incidents dominated "real world" operational results. and were generally caused by the inadvertent activation of an emergency transmitter. The results of a study conducted by one State show some of the reasons why these incidents occur (Table 3). The most frequent occurrence was in parked aircraft where no reason can be attributed. In these cases, the emergency transmitter had been left in the armed position, and the G-switch activated the emergency transmitter. It is known that the G-switch in current emergency transmitters may be too sensitive, and it is therefore suspected that the emergency transmitter may have been triggered by wind gusts, propeller blasts, or other external forces which jarred the aircraft.

3.4.4 In spite of the large numbers of non-distress incidents, the system has proved its worth in actual distress cases. During the demonstration and evaluation period of approximately 18 months in 1983-1984, there were 194 aviation and marine distress incidents world-wide in which an emergency transmitter was activated, involving 527 people, 473 of whom were rescued. In all these cases, the COSPAS-SARSAT system provided the RCCs with timely location information. In 106 of these cases, information provided by COSPAS-SARSAT was the first source of alert information received at the RCC. In several cases, it was the only source of alert.

Table 3. Reasons for non-distress incidents

		Examples
Maintenance	15%	installation, removal, overhaul
Parked aircraft	39%	unattended
Bad landing/minor accidents	11%	
Poor operating practices	8%	human error
Non-air/marine environment	8%	ATS transmitters
Weather	6%	strong winds overturn parked aircraft
Other reasons	13%	corrosion

Chapter 4. CURRENT STATUS

4.1 SPACE SEGMENT

4.1.1 In view of the successful demonstration of the system, the COSPAS-SARSAT parties concluded a new memorandum of understanding in October 1984 to continue to operate and to provide search and rescue services until at least 1990. The COSPAS-SARSAT system will consist of four satellites; two provided by the Union of Soviet Socialist Republics and two provided by the SARSAT countries. The decision to extend the COSPAS-SARSAT service will provide continuity of service in the period of transition to a future global operational satellite-aided search and rescue system.

4.1.2 The SARSAT parties will continue to provide service at 121.5, 243.0 and 406 MHz on the National Oceanic and Atmospheric Administration (NOAA) series of weather satellites. The USSR will provide service at 121.5 and 406 MHz on the COSPAS series of satellites. A summary of the current space segment status is given in Table 4. Three COSPAS and three SARSAT space segment packages are either under construction or planned for construction by 1988.

4.1.3 Although there are some differences between the COSPAS and SARSAT space segments, interoperability exists. With the COSPAS spacecraft, the 406 MHz global data are stored in memory and broadcast to the LUTs. With the SARSAT spacecraft, the 406 MHz data are stored on tape and then distributed via NOAA ground stations and the United States MCC. However, beginning with SARSAT 04, the data will be handled in a manner similar to that of COSPAS.

Table 4. Space segment status

Satellite	Launch date	Status
COSPAS 01	June 1982	Some 406 MHz limitations
COSPAS 02	March 1983	Operational
SARSAT 01	March 1983	Shutdown in December 1985
COSPAS 03	June 1984	Operational
SARSAT 02	December 1984	Operational
SARSAT 03	September 1986	Operational
COSPAS 04	--	Launch in late 1986

4.2 GROUND SEGMENT

4.2.1 There are at present ten operational LUTs in the COSPAS-SARSAT ground system. Their locations and status are summarized in Table 5. In addition, NASA operates an LUT at the Goddard Space Flight Centre which at times is used operationally. The following enhancements to the LUTs are currently under way:

a) Canada is building three new LUTs to be operational in 1987 at Edmonton, Churchill and Goose Bay;

b) an LUT is under construction for Brazil and will be operated near São Paulo in 1987;

c) the USSR will be adding an LUT in Novosibirsk which is expected to be operational in 1987; and

d) the LUT in the United Kingdom will be upgraded to process 121.5 and 243.0 MHz data in 1987.

Table 5. LUT location and operational status

	Frequency and Status		
Location	121.5	243.0	406
Archangelsk, USSR	(0)*	-	0
Kodiac, Alaska, U.S.A.	0	0	0
Lasham, United Kingdom	-	-	0
Moscow, USSR	0	-	0
Ottawa, Canada	0	0	0
San Francisco, U.S.A.	0	0	0
Scott AFB, U.S.A.	0	0	0
Tromso, Norway	0	0	0
Toulouse, France	0	0	0
Vladivostok, USSR	0	-	0

*(1986)

4.3 MISSION CONTROL CENTRES

4.3.1 There are at present six operational mission control centres in service. They are located in Moscow (USSR), Bodø (Norway), Toulouse (France), Plymouth (United Kingdom), Trenton (Canada), and Scott Air Force Base (United States). Their capabilities are summarized in Appendix A. MCCs in the United States, United Kingdom, Norway and Canada are co-located with existing RCCs. For participating States which do not operate LUTs, a national search and rescue point of contact is established to receive COSPAS-SARSAT alert data.

4.4 EMERGENCY TRANSMITTERS

4.4.1 Specifications for survival radio equipment and emergency location beacon - aircraft (ELBA) are contained in Annex 10, Volume I. The provisions specify that the emergency transmitters shall operate on 121.5 MHz and 243.0 MHz. The following requirements apply to ELBAs:

a) the frequency tolerance shall not exceed ± 0.005 per cent;

b) the emission from a beacon under normal conditions and attitudes of the antenna shall be vertically polarized and essentially omnidirectional in the horizontal plane;

c) over a period of 48 hours of continuous operations, at an operating temperature of - 20°C the equivalent isotropically radiated peak envelope power shall at no time be less than 75 mW on each frequency;

d) the type of emission shall be A2. Any other type of modulation that meets the requirements in e), f) and g) below may be used, provided that it will not prejudice precise location of the beacon by homing equipment;

e) the carriers shall be amplitude-modulated at a modulation factor of at least 0.85;

f) the modulation applied to the carriers shall have a minimum duty cycle of 33 per cent; and

g) the emission shall have a distinctive audio characteristic achieved by amplitude-modulating the carriers with an audio frequency sweeping downward over a range of not less than 700 Hz within the range 1 600 Hz to 300 Hz and with a sweep repetition of between 2 Hz and 4 Hz.

Commercially available emergency transmitters meeting the above specifications were used in the operational trials carried out during the COSPAS-SARSAT demonstration and evaluation phase. Some problems with current specifications have been noted and will be described further in Chapter 6 of this circular.

4.4.2 406 MHz beacons

4.4.2.1 The 406 MHz beacon specifications are technically more complex than 121.5/243.0 MHz specifications, because the 406 MHz beacon transmits a digital message. It only transmits once every 50 seconds, and the duration of the transmitted signal is 0.5 seconds. The digital message content and interpretation were developed with extensive search and rescue input from COSPAS-SARSAT participants so that the beacon information would be useful to RCCs. A 406 MHz beacon specification (electronics) for emergency position indicating radio beacons (EPIRBs) was accepted in November 1985 by Study Group 8 of the International Radio Consultative Committee (CCIR). It included recommendations for both maritime and aviation use.

4.4.2.2 The 406 MHz beacon specifications were developed primarily for the maritime community. In January 1986, the International Maritime Organization (IMO) voted to use 406 MHz for float-free EPIRBs beginning in 1992. Some States are expected to implement the IMO recommendation in the near future. However, the beacon coding schemes also have provision for coding which may be used by the aviation community.

4.4.2.3 The 406 MHz beacon signal consists of a short carrier followed by:

a) bit and frame synchronization pulses which enable the satellite to identify the signal;

b) 82 bits of data for beacon identification and error-correcting codes;

c) 6 bits containing an emergency code; and

d) an optional 32 bits of additional data, which have been defined for use in maritime beacons to indicate such information as course, heading, speed and/or navigation system information.

Chapter 5. CURRENT OPERATIONS

5.1 INFORMATION AVAILABLE TO RCCs

5.1.1 The information which is available to an RCC will vary depending upon LUT and MCC design. The following minimum information requirements have been identified by RCC personnel from COSPAS-SARSAT States:

a) emergency transmitter location in latitude and longitude. There are two possible locations, one on either side of the satellite's track. A probability factor is also provided for each location (see Appendix B);

b) location time, which is the time that the spacecraft passed overhead or abeam the emergency transmitter. This time is referred to as the time of closest approach or TCA (point B in Figure 3);

c) the frequency of the emergency transmitter, which is expressed to the nearest kHz; and

d) any available information concerning the quality of the signal and an assessment of the accuracy of the location.

For 406 MHz beacons, the class of user, country of owner or registration, identification information, and auxiliary homing signal information would be available. Optional information such as the nature of the emergency may also be available.

5.1.2 Message formats

5.1.2.1 The COSPAS-SARSAT participants have agreed upon a standard format for messages used to send data to RCCs. Examples of this message format are presented in Appendix B together with an explanation of the terms used. Depending upon the design of the LUT and MCC, additional information such as signal strength may be made available to RCCs.

5.2 COMMUNICATIONS

5.2.1 Rapid, reliable communications to RCCs are vital. Telex is the prime method of communications amongst MCCs and between MCCs and RCCs. Some MCCs have access to the aeronautical fixed telecommunication network (AFTN), while other links include dedicated circuits. Data communications, such as DATAPAC, are being studied and will soon be implemented for portions of the ground segment. These enhancements will improve over-all system reliability and minimize alert message delivery times.

5.3 OPERATIONAL POINTS OF CONTACT

5.3.1 Appendix A gives a list of operational points of contact for the COSPAS-SARSAT MCCs which could be used by RCCs requesting search and rescue information. It includes telephone numbers, telex and AFTN addresses, and mailing addresses. All MCCs operate 24 hours per day, seven days a week, and it should therefore always be possible to reach the nearest MCC if required.

Chapter 6. 121.5/243.0 MHZ EMERGENCY TRANSMITTERS

6.1 ADVANTAGES

6.1.1 The 121.5/243.0 MHz emergency transmitter is widely used at present by over 200 000 general aviation aircraft. It is simple and relatively low in cost, and many States have regulations making carriage of these emergency transmitters compulsory. Even though these transmitters were not designed for satellite detection, they have worked reasonably well with the COSPAS-SARSAT system.

6.1.2 For several years, 121.5 MHz has been a designated aeronautical distress frequency, and many search and rescue aircraft are now fitted with homing equipment on this frequency. Commercial air transport aircraft are equipped with radios to permit in-flight monitoring of this frequency, and some have equipment dedicated to this purpose. The ability of overflying aircraft to monitor and report transmissions on 121.5 MHz will likely continue to be needed, because many regions of the world may not have LUTs to provide location information.

6.2 DISADVANTAGES

6.2.1 One disadvantage of 121.5 MHz is that it is used primarily for voice distress and urgency traffic. Because it is not dedicated to emergency transmitter use, weaker emergency transmitter signals may be masked by other transmissions. The LUTs are frequently able to detect these emergency transmitters through normal voice transmissions; however, extensive voice transmissions, or any transmitter which is transmitting continuously, can have an adverse impact on satellite detection. For example, a transmitter which is inadvertently transmitting continuously on 121.5 MHz can affect the detection of emergency transmitter signals as far away as 2 000 NM from the source of the inadvertent transmission.

6.2.2 Satellite detection of transmissions on 121.5 MHz is affected by both poor medium-term frequency stability (the amount that the transmitted frequency changes (drifts) over a 15-minute period) and the lack of a coherent carrier component in the emergency transmitter (see paragraph 3.2.2). These units transmit continuously, and there is a very limited capacity for satellite detection (approximately 10 to 20 emergency transmitters transmitting simultaneously within range of the satellite). Overly sensitive G-switches and lack of identification information contribute to a high percentage of false alarms which causes excessive workloads at an RCC and can affect response to a genuine distress.

6.2.3 LUT signal processing results in two possible locations for each 121.5/243.0 MHz emergency transmitter, one on each side of the satellite's track. This ambiguity can be resolved if the transmitter exhibits good frequency stability, because the Doppler signal is not symmetrical due to the earth's rotation. Unfortunately, existing emergency transmitters exhibit poor medium-term frequency stability, and the ambiguity resolution (determining which location is correct or more probable) is also poor.

6.2.4 Location ambiguity sometimes causes delays in search and rescue response until the RCCs have resolved it. Ambiguity can be resolved if the LUT location can be correlated with an overdue report or an emergency transmitter report from an overflying aircraft. Ambiguity is also resolved when another satellite pass has been processed. Ambiguity resolution reported in Chapter 3 refers to the A location being more correct than the B location (see Appendix B). The A location is more often the correct location because this solution is closer to the theoretical Doppler curve. However, current probability factors computed by the LUTs for each location are normally only in the order of 50 per cent because of poor frequency stability.

6.2.5 Emergency transmitter survivability is also a recognized problem. Operational experience indicates that emergency transmitter survivability in an aircraft crash appears to be in the order of 45 to 60 per cent. In fact, aircraft occupants seem to be surviving aircraft crashes better than do emergency transmitters. The problem appears to be related partly to emergency transmitter design and partly to emergency transmitter installation in the aircraft. Efforts are being made to improve survivability (see Chapter 9).

6.2.6 The use of satellites in conjunction with existing emergency transmitters requires that both the LUT and the emergency transmitter be in line of sight with the satellite at the same time. Therefore, if the COSPAS-SARSAT system is to be used for alerting based on existing emergency transmitters, LUT coverage of the various SRRs must be provided by individual States or groups of States.

Chapter 7. 406 MHz EMERGENCY TRANSMITTERS

7.1 ADVANTAGES

7.1.1 406 MHz beacons are specifically designed for satellite use. They will provide better location accuracy and ambiguity resolution because of more rigid specifications for frequency stability; substantially greater capacity for simultaneous signals is possible because of the short transmission period. Although the transmitted power is higher, the short duty cycle results in approximately the same battery power requirements as are needed by existing emergency transmitters. The frequency spectrum is exclusively allocated for emergency transmitters and is expected to be relatively free from interference once existing sources of interference have been eliminated.

7.1.2 The digital code contained in the 406 MHz beacon transmission can provide RCCs with important information concerning the identity of the aircraft or vessel. False alarms can be quickly resolved by communications checks, using the identification information transmitted by the beacon. More important, the identification can help the RCC to determine that a distress situation exists, particularly if the emergency code option has been implemented.

7.1.3 Another important advantage of 406 MHz is that the system would provide complete global coverage without an extensive network of LUTs. States could obtain search and rescue information via arrangements with a COSPAS-SARSAT MCC rather than investing in their own LUT. Most of the northern hemisphere is covered by existing LUTs, and data from anywhere in the world would normally be available at one of the associated MCCs within one hour after it is received by the satellite.

7.1.4 Because each 406 MHz beacon would have a unique identification code, signals could also be relayed through a satellite placed in geosynchronous orbit. This would give an instant alerting capability. The optional data field in 406 MHz beacons could be used to provide position information to RCCs. A separate experiment is under way to evaluate this possibility.

7.2 DISADVANTAGES

7.2.1 Design complexity and tighter technical standards mean that the 406 MHz beacons may cost more to manufacture than existing emergency transmitters. Although efforts are under way in COSPAS-SARSAT States to reduce production costs, the final product is still likely to be more expensive than existing emergency transmitters.

7.2.2 The 406 MHz global data would be broadcast by the spacecraft to all LUTs, and would therefore be available to all MCCs. Considerable redundancy would exist which is advantageous for search and rescue; however, it would also pose new operational problems. If all MCCs were to forward this information to the appropriate RCC in the area where the beacon is located, there is a risk that the receiving RCC would become overloaded with redundant data. COSPAS-SARSAT and national search and rescue authorities are developing methods to ensure that beacon locations are delivered quickly without overloading RCCs.

7.2.3 At the MCC level, the responsible search and rescue authorities or RCCs to whom the location data should be transmitted are not always known with certainty. Whereas SRR procedures are well defined for the aviation community, this is not always the case for the maritime community. The COSPAS-SARSAT parties have an operational plan for the delivery of 406 MHz global mode data; however, in order to ensure efficient delivery of COSPAS-SARSAT data, States are encouraged to provide the COSPAS-SARSAT parties with current information on the appropriate points of contact.

7.2.4 Since 121.5 MHz has been a recognized distress frequency for many years, search and rescue aircraft are normally equipped with a homing capability on this frequency. Because the 406 MHz signal is a short duration signal, special homing equipment would be needed. So far, only one State has developed this capability. Monitoring of 406 MHz would therefore depend entirely on the COSPAS-SARSAT system.

Chapter 8. REGULATORY AND INSTITUTIONAL ASPECTS

8.1 INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)

8.1.1 In December 1985, the ICAO Air Navigation Commission, having reviewed a Secretariat report on the COSPAS-SARSAT system, considered it timely to begin a study within ICAO of the future potential of improved aircraft emergency beacons transmitting on 121.5 and 406 MHz and, if the need were confirmed, to study implementation aspects of a new generation of beacons. It noted that efforts to improve the performance of emergency transmitters on 121.5 and 243 MHz were under way and that many of the improvements envisaged would be applicable also to beacons on 406 MHz. It recognized that the current provisions of Annex 10 would need to be reviewed in the light of these developments. Moreover, in view of the benefits to be derived from satellite-aided detection and location of emergency transmissions, it was considered timely to review the existing requirements in Annex 6 for the carriage of emergency transmitters on board aircraft.

8.1.2 The Commission considered that the these aspects, as well as all other aspects relating to the use of the COSPAS-SARSAT system, merited detailed examination by a group of specialists. Accordingly, an air navigation study group was established and began its work in June 1986. The terms of reference of the study group are to examine the technical, operational and institutional aspects relating to the use of the COSPAS-SARSAT system and to develop specific proposals for action by the Air Navigation Commission, having due regard to cost-effectiveness. The work programme of the group includes the development of proposals for amendment of relevant ICAO regulatory documents and the <u>Search and Rescue Manual</u> (Doc 7333).

8.1.3 The results of the Air Navigation Commission's deliberations were brought to the attention of States by State letter AN 15/12-86/50 dated 7 May 1986. The letter encouraged participation by States in the COSPAS-SARSAT system. It also urged States to take those measures that might be necessary to eliminate misuse of the emergency frequency 121.5 MHz and unauthorized use of the frequency 406 MHz, which are causing interference with the COSPAS-SARSAT system.

8.1.4 The longer-term aspects of emergency aircraft location are also within the terms of reference of ICAO's Special Committee on Future Air Navigation Systems (FANS), which will take account of the work of the air navigation study groups.

8.2 OTHER INTERNATIONAL ORGANIZATIONS

8.2.1 International Telecommunications Union (ITU)

8.2.1.1 The 1979 General World Administrative Radio Conference (G-WARC) provided that:

a) the frequency band 406.0 to 406.1 MHz is to be used exclusively by satellite emergency position indicating radio beacons (EPIRBs) in the earth-to-space direction; and

b) the use of bands 1544-1545 MHz (space-to-earth) and 1645.5-1646.5 MHz (earth-to-space) by the mobile-satellite service be limited to distress and safety operations.

Provisions adopted by the 1983 WARC for Mobile Services (WARC-MOB-83) indicate that the use of the 1544-1545 MHz band includes feeder links of satellites needed to relay the emissions of satellite EPIRBs to earth stations, as well as narrowband (space-to-earth) links from space stations to mobile stations.

8.2.1.2 The COSPAS-SARSAT parties have provided system information to the International Radio Consultative Committee (CCIR). A summary description and a listing of the system performance capabilities are provided in CCIR Reports 761 and 919 respectively. The 406 MHz satellite EPIRB characteristics are given in CCIR Recommendation AH/8.

8.2.1.3 There are at present several proposals to share the 1.5 GHz band which is now being used extensively by COSPAS-SARSAT. The next generation of geostationary operational environmental satellites (GOES) will downlink unprocessed 406 data at 1544.8 MHz. As an operational complement to the use of satellite EPIRBs, a shore-to-ship alerting channel using receive-only ship earth stations was proposed (CCIR Report 921). Another proposal provides for the transfer of data between COSPAS-SARSAT and the INMARSAT spacecraft in the 1.6 GHz distress band; this proposal would result in a 55-minute reduction in the mean forwarding time of distress signals. Sharing of the 1.5 and 1.6 GHz spectrum will be discussed at WARC-87 (Mobile Services). The situation should be monitored to ensure that it does not cause any problems with COSPAS-SARSAT operations.

8.2.2 International Maritime Organization (IMO)

8.2.2.1 The Maritime Safety Committee at its fifty-second session (January-February 1986) decided that the 406 MHz frequency should be used and the carriage of float-free satellite EPIRBs operating in the COSPAS-SARSAT system should be mandatory in the future global maritime distress and safety system (FGMDSS).

8.2.2.2 The Sub-Committee on Safety of Navigation at its thirty-second session (March 1986) agreed that there was a need to prepare detailed procedures for routing information derived from the COSPAS-SARSAT system. This includes principles of SAR data distribution to countries with and without COSPAS-SARSAT earth stations, content and format of messages to be sent to an RCC, EPIRB/ELT registration methods and the availability of any national or international register.

8.2.2.3 The Sub-Committee on Radio Communications, at its thirty-first session (April 1986) agreed to draft performance standards for float-free satellite EPIRBs operating through a polar-orbiting satellite system on 406 MHz and submitted them to the fifty-third session (September 1986) of the Maritime Safety Committee for approval. It also agreed to a text of the draft requirements for equipment to be carried as part of the FGMDSS which, among other things, include 406 MHz EPIRBs.

8.3 FUTURE MANAGEMENT OF THE COSPAS-SARSAT SYSTEM

8.3.1 The current MOU signed by the COSPAS-SARSAT parties provides for the continuation of the satellite-aided search and rescue services and will remain in effect until the parties agree to a replacement international framework or until 31 December 1990, whichever comes first. Discussions are now under way for the post-1990 period. Meanwhile, space segment packages which will provide service beyond this date are under manufacture.

Chapter 9. FUTURE OPERATIONAL CONSIDERATIONS

9.1 IMPROVEMENTS TO 121.5/243.0 MHz EMERGENCY TRANSMITTERS

9.1.1 In 1983, revised minimum operational performance standards (MOPS) for emergency locator transmitters were proposed by the Radio Technical Committee for Aeronautics (RTCA/DO-183). RTCA has an advisory role to the Federal Aviation Administration in the United States. Some of the major changes include improved transmitter modulation characteristics to improve satellite detection, improved crashworthiness, revised crash activation sensor specification, and a monitor capability to indicate when the emergency locator transmitter has been activated. Experience gained from the COSPAS-SARSAT project may result in some additional changes. The issue is still under review and no firm date has been set for the new standards to take effect.

9.1.2 Improvement of medium-term frequency stability (drift) in the emergency transmitter will result in better location accuracy and better ambiguity resolution. The provision of a standard beacon identification code, which can be decoded by the LUTs, would enable existing emergency transmitters to offer some of the benefits of the 406 system.

9.1.3 Because of the continuous carrier of 121.5/243.0 MHz emergency transmitters, the number of simultaneous beacons which can be processed is limited to about 10 to 20. The capacity of the system could be increased if some form of carrier burst technique, such as the 406 MHz system, is used. LUT processing could also be simplified if an identification code were provided.

9.2 POTENTIAL FUTURE SYSTEMS

9.2.1 In the longer term, consideration must also be given to potential alternatives to the emergency transmitter. Satellite techniques can be used to provide better communications. One could also use techniques such as space-based surveillance radar systems to detect distress situations and to locate distressed aircraft. Although the emergency transmitter will play an important role for many years, the alternatives must be evaluated against the cost and benefits of shorter-term changes to the emergency transmitter.

9.2.2 If the carriage of 406 MHz emergency transmitters is required by regulation, the need for regulations requiring aircraft to have a capability to monitor this frequency must also be considered. Although the COSPAS-SARSAT parties have developed specifications for 406 MHz beacons which include provisions for aviation use, these specifications will need to be reviewed by regulatory bodies.

Chapter 10. GENERAL INFORMATION

10.1 LEVELS OF PARTICIPATION

10.1.1 In response to a request from IMO, the COSPAS-SARSAT Steering Committee (CSSC), at a meeting in July 1985, confirmed that COSPAS-SARSAT is not a commercial service and is open to participation by all countries. The CSSC has further stated that it does not intend to charge the owners of emergency transmitters for the use of the COSPAS-SARSAT system.

10.1.2 Basically, there are three levels of participation. The CSSC consists of those States which are funding the space segment packages and which manage the COSPAS-SARSAT programme. The next level of participation involves those States which operate an MCC which controls one or more LUTs. These States participate in working groups appointed by the CSSC whose activities relate to the COSPAS-SARSAT ground segment. The third level of participation involves those States which do not fit into either of the two above categories. Participation by such States will vary depending upon national interests and may include, for example, participation in special tests of emergency transmitters with the aim of improving the over-all effectiveness of the system. More information is to be released by the CSSC in the form of a publication entitled "Introduction to the COSPAS-SARSAT System". This guide will include technical details of the COSPAS-SARSAT system and a list of more detailed publications which are available to participants.

10.2 COST CONSIDERATIONS FOR PARTICIPANTS

10.2.1 The major benefits of satellite-aided detection are that the probability of detection of emergency transmissions is increased and the time required to detect and search for survivors of aircraft incidents is significantly decreased. In one State, the total number of hours flown on aircraft search operations has dropped significantly even though the number of distress cases has been increasing. The savings were sufficient to more than offset the cost of the ground system.

10.2.1 One of the advantages of 406 MHz beacons is that emergency transmitter locations can be obtained from COSPAS-SARSAT without having to build an LUT. However, location information for the present generation of emergency transmitters is only available to those countries which operate or own their own LUT or are within the LUT coverage area of another country and have an arrangement to receive the data.

10.2.2 The cost of an LUT will depend upon the availability of existing equipment, such as earth station antennas which can be modified to track COSPAS-SARSAT, and options included in the LUT design. The cost of an LUT will range from U.S.$540 000 to $2 000 000, depending upon these options (these figures do not include on-site training, spare parts, etc.). Options could include processors limited to only one frequency band, size of antenna, or remote control of the LUT. The antenna is a significant cost item and its size will depend on how large an area is to be monitored.

10.2.3 At present, States operate their LUTs separately from their MCC. These functions could be combined, however, particularly when only one LUT is needed. A fully equipped LUT, which combines both the LUT and MCC functions and which will meet the needs of most States, is expected to be available for approximately U.S.$1 000 000. Recurring annual maintenance costs will range upwards from U.S.$35 000 per annum, excluding the cost of personnel to operate the equipment.

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Appendix A. POINTS OF CONTACT

States wishing more information on COSPAS-SARSAT, such as the Guide for New Participants, or the answer to specific questions regarding participation, etc., may obtain this information from any of the addresses indicated in State Letter AN 15/12-86/50 of 7 May 1986, or by corresponding directly with CSSC members at one of the following addresses:

CANADA

Mr. J.R.F. Hodgson
National SAR Secretariat
7th Floor, Berger Building
100 Metcalfe Street
Ottawa, Ontario
CANADA K1A 0K2

FRANCE

Mr. D. Levesque
Centre National d'Etudes Spatiales (CNES)
2 Place Maurice-Quentin
75039 Paris CEDEX 01
FRANCE

UNION OF SOVIET SOCIALIST REPUBLICS

Mr. Y. Zurabov
Vice-President
V/O Morsviazsputnik
7/9 Shebashevskiy Per
Moscow 125315
UNION OF SOVIET SOCIALIST REPUBLICS

UNITED STATES

Mr. J.T. Bailey
Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data and Information Service (NESDIS)
Federal Building 4
Washington, D.C. 20233
UNITED STATES

The COSPAS-SARSAT operations plan provides for alert information to be delivered either directly or through search and rescue channels according to national policy and/or COSPAS/SARSAT agreements. For operational SAR information, information about areas covered, etc. RCCs may use the following MCCs as operational points of contact:

MCC	Telex	AFTN	Telephone	Mail
CMC	411469 COPA SU	-	926-1374 (095)	1/4, Zhdanova Str. Moscow 103759 UNION OF SOVIET SOCIALIST REPUBLICS
CMCC	-	CYTRYX	(613) 392-2811 Ext. 3872	CFB Trenton Astra, Ontario CANADA KOK 1B0
FMCC	530 682	LFIAZS	61254382	SARSAT-COSPAS FMCC Centre Spatiale de Toulouse Avenue Edouard Belin 31055 Toulouse CEDEX FRANCE
NMCC	64295 RCCN	ENBOYC	4781221267	Hovedredningssentralen Nord Norge BODO Lufthavn 8000 BODO NORWAY
UKMCC	45677	-	563777 (0752) Ext. 2152	UKMCC RCC Plymouth Mount Wisc Richmond Walk Plymouth, Devon Pl1 4JH UNITED KINGDOM
USMCC	270639	-	(618) 256-6141	HQ ARRS/USMCC BLDG P-4 Scott AFB, IL 62225 UNITED STATES

Appendix **B.** **MCC TO RCC ALERT MESSAGES**

The following is an example of a 121.5 MHz ELBA message which would be sent from an MCC to an RCC:

```
 1.  COSPAS/SARSAT ALERT C01
 2.  MSG NO 00321 REF NO 00000
 3.  DETECTION TIME 07 MAY 86 2016 UTC
 4.  DETECTION FREQUENCY 121.503 MHZ
 5.  COUNTRY UNKNOWN
 6.  USER CLASS UNKNOWN/IDENTIFICATION UNKNOWN
 7.  EMERGENCY CODE NIL
 8.  LOCATIONS A LAT 45 32.8N/LONG 028 55.3W PROB 51
               B LAT 43 21.7N/LONG 073 46.8W PROB 49
 9.  NEXT PASS A 2045 UTC
               B 2203 UTC
10.  REMARKS:  TECHNICAL QUALITY GOOD
```

The following is an example of a 406 MHz message which could be used for aviation:

```
 1.  COSPAS/SARSAT ALERT S02
 2.  MESSAGE 00456 REF NO 00435
 3.  DETECTION TIME 11 MAY 86 2231 UTC
 4.  DETECTION FREQUENCY 406.025 MHZ
 5.  COUNTRY FRANCE
 6.  USER CLASS AVIATION/IDENTIFICATION F-ABCD
 7.  EMERGENCY CODE MEDICAL HELP
 8.  LOCATIONS A LAT 43 55.2N/LONG 001 48.7E PROB 96
               B LAT 39 03.2N/LONG 085 21.3E PROB 07
 9.  NEXT PASS UNKNOWN
               B 0018 UTC
10.  REMARKS:  A.  HOMING SIGNAL 121.5 MHZ ACTIVATION MANUAL
               B.  BEACON CODED POSITION 43 48N 001 43E
               C.  NIL
               D.  CESSNA 712, RED WITH WHITE TRIM
```

The above formats show the text of the message only. Message heading, address, origin and ending header will vary depending upon the communications method used to transmit the message (AFTN, telex, other). Each line number is included in the actual message as shown.

A line-by-line decoding follows:

1. This is the message title and includes the space segment package which was the source of information. 'C' indicates COSPAS and 'S' indicates SARSAT. The number identifies the specific satellite.

2. Message number refers to the current message. Reference number is the message number of the first message which reported this location. '00000' means it is the first message which was sent.

3. Detection time is day, month, year and hours/minutes UTC. The month is indicated by the first three letters of the English spelling. The time is the time at which the satellite passed overhead or abeam the ELBA.

4. Detection frequency is expressed to the nearest kHz.

5. Country applies to the code used in the 406 MHz beacon.

6. User class applies to 406 MHz. It will be MARITIME, AVIATION, or SERIAL. If it is SERIAL, the subclass will also be included (AVIATION, MARITIME, SURVIVAL, or PERSONAL). The identification code is determined by the user class; in this case it is the aircraft registration markings. More specific information is contained in the 406 MHz beacon specification and in the user's guide available from the COSPAS-SARSAT partners.

7. Emergency code applies to 406 MHz and is further described in the 406 MHz beacon specification.

8. This line contains the two possible locations for the emergency transmitter as determined by the receiving LUT. 'PROB' is the probability computed by the LUT to indicate confidence in each location.

9. If the time (UTC) at which the receiving LUT will next view each of the locations is known, it will be indicated in this line.

10. Other information of interest to RCCs will be included in this line. For 121.5/243.0 MHz, technical quality may be included as an indication of solution accuracy. The COSPAS-SARSAT partners are working on standard interpretations of accuracy. For 406 MHz, the following information may be added:

    A. Auxiliary homing signal if it is also included in the 406 MHz beacon, and method of activation (manual or automatic).

    B. Other coded information which may be included in the 406 MHz beacon (optional long format message).

    C. Other coded information (MARITIME beacons).

    D. Any pertinent remarks which are available at the MCC and may be of interest to RCCs.

In addition to alerting RCCs, the 406 MHz message may also be used in the above format to advise the State of the owner or registration of the beacon (line 5) that one of its ELBAs has been detected and to whom location information is being sent. This is an optional service provided by the COSPAS-SARSAT system to States which have made specific arrangements with the COSPAS-SARSAT partners for this service. It does not replace normal RCC responsibility to inform the aircraft operator and the State of registry in accordance with Annex 12. If the alert message is being used for this purpose, it will be specifically indicated under line 10 D.

- END -

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for world-wide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

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