How soon will rescue know I am in trouble

And where to find me?

The Cospas-Sarsat System includes two types of satellites:

Satellites in low-altitude Earth orbit (LEO) which form the LEOSAR System

Satellites in geostationary Earth orbit (GEO) which form the GEOSAR System

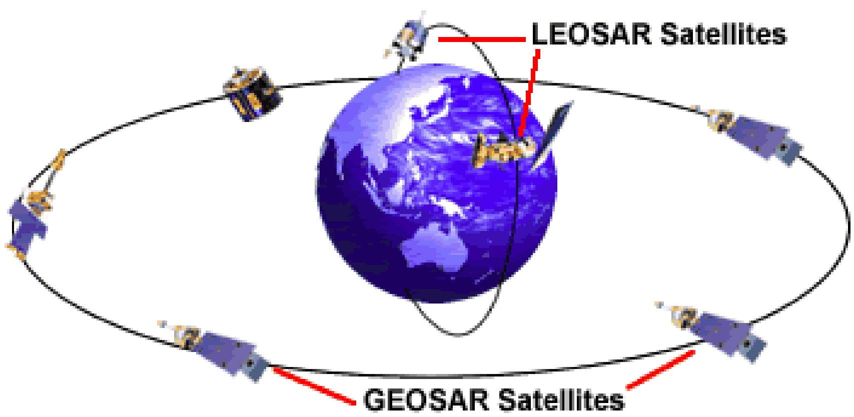

Figure 1

The GEOSAR and LEOSAR system capabilities are complementary. For example the GEOSAR system can provide almost immediate alerting in the footprint of the GEOSAR satellite, whereas the LEOSAR system:

- provides coverage of the polar regions (which are beyond the coverage of geostationary satellites);

- can calculate the location of distress events using Doppler processing techniques; and
- is less susceptible to obstructions which may block a beacon signal in a given direction because the satellite is continuously moving with respect to the beacon.

LEOSAR and GEOSAR Capabilities

LEOSAR	**GEOSAR**
Beacon identification information and location information provided Global coverage, but *not instantaneous*	Beacon identification provided, and location information available if encoded in beacon message (location protocol beacon) Near instantaneous alerting in the GEOSAR coverage area

Table 1

Local User Terminals (LUTs)

- There are two types of LUTs in the Cospas-Sarsat System, those which are designed to operate with the LEOSAR satellite constellation are referred to as LEOLUTs,

- and those which operate with the GEOSAR satellite constellation are referred to as GEOLUTs.

- LEOLUT and GEOLUT provide the SAR community with reliable alert and location data, without restriction on use and distribution. The Cospas-Sarsat Parties providing the space segment supply LEOLUT and GEOLUT operators with System data required to operate their LUTs.

Cospas-Sarsat Mission Control Centres (MCCs)

MCCs have been set up in most 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 Rescue Coordination Centers (RCCs) or National SAR Points of Contact (SPOCs).

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. 406 MHz beacons alert data comprise the beacon location and 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 coordination 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

The Cospas-Sarsat Geostationary Search and Rescue (GEOSAR) System

The GEOSAR system consists of 406 MHz repeaters carried on board various geostationary satellites, and the associated ground facilities called GEOLUTs which process the satellite signal.

GEOSAR Satellite Coverage

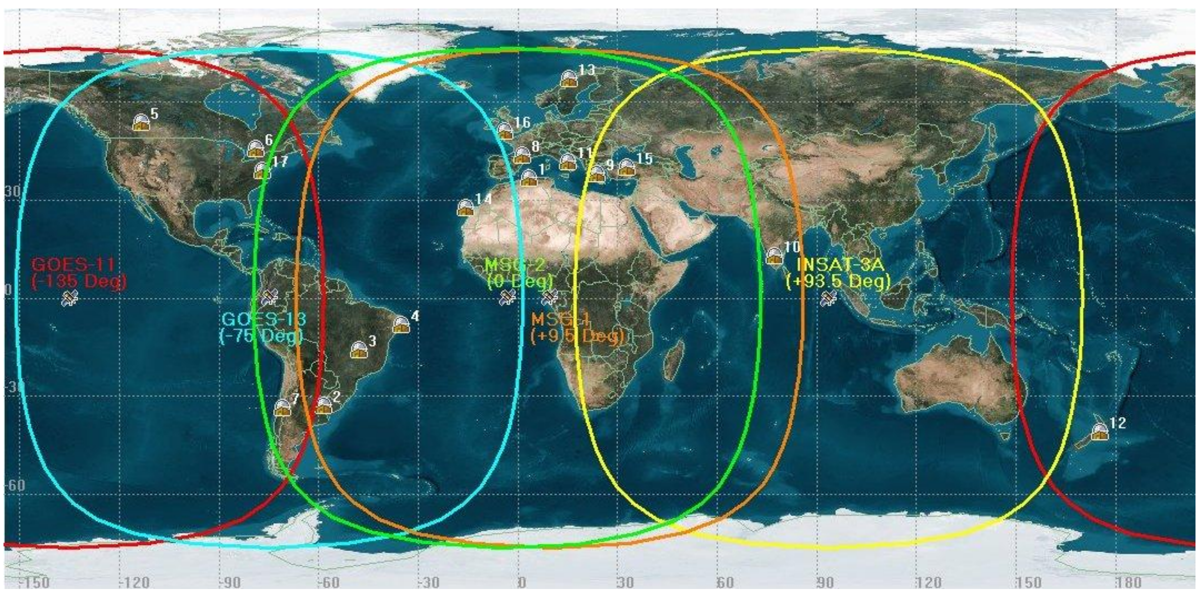

Figure 2

As a GEOSAR satellite remains fixed relative to the Earth, there is no Doppler effect on the received frequency and Doppler radio location positioning techniques cannot be used to locate distress beacons. 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, (a location protocol beacon, a beacon with GPS) or,
- derived, *with possible delays*, from the LEOSAR System.

The Cospas-Sarsat Low-altitude Earth Orbit (LEOSAR) System for Search and Rescue

The detection and location of 406 MHz distress beacon signals can be greatly facilitated by global monitoring based on low-altitude spacecraft in near-polar orbits. Complete, yet non continuous coverage of the Earth is achieved using simple emergency beacons operating on 406 MHz to signal a distress. The coverage is not continuous because polar orbiting satellites can only view a portion of the Earth at any given time (see Figure 3). Consequently the System cannot produce distress alerts until the satellite is in a position where it can "see" the distress beacon. However, since the satellite onboard 406 MHz processor includes a memory module, the satellite is able to store distress beacon information and rebroadcast it when the satellite comes within view of a LUT, thereby providing global coverage.

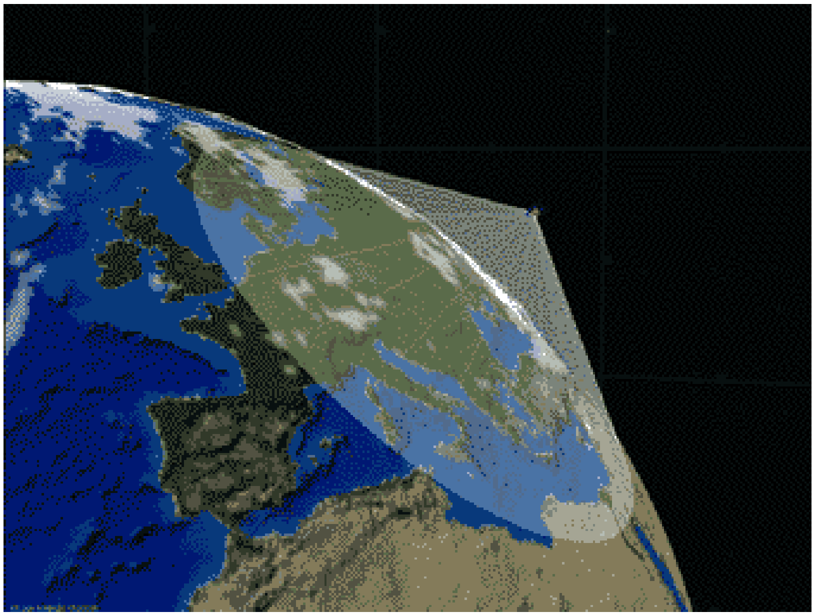

Figure 3

A single satellite, circling the Earth around the poles, eventually views the entire Earth surface. The "orbital plane", or path of the satellite, remains fixed, while the Earth rotates underneath it. At most, it takes only one half rotation of the Earth (i.e. 12 hours) for any location to pass under the orbital plane. With a second satellite, having an orbital plane at right angles to the first, only one quarter of a rotation is required, or 6 hours maximum. Similarly, as more satellites orbit the Earth in different planes, the waiting time is further reduced. The Cospas-Sarsat System design constellation is four satellites which provide a *typical waiting time of less than one hour at mid-latitudes.* Near the Equator the waiting time can be up to 102 minutes.

The LEOSAR system calculates the location of distress events using Doppler processing techniques. Doppler processing is based upon the principle that the frequency of the distress beacon, as "heard" by the satellite instrument, is affected by the relative velocity of the satellite with respect to the beacon. By monitoring the change of the beacon frequency of the received beacon signal and knowing the exact position of the satellite, the LUT is able to calculate the location of the beacon. The Cospas-Sarsat System calculates the location of distress beacons using Doppler processing techniques. Simply stated the Doppler Effect is a term used to describe the phenomena that the frequency of a signal "as heard" by a receiving device is affected by the magnitude of the relative velocity between the transmitter and the receiver. If the distance between the transmitter and the receiver is reducing, the frequency as heard by the receiver is raised by the Doppler Effect. If the distance is increasing, the Doppler Effect reduces the frequency as heard by the receiver. If there is no relative velocity, the frequency heard by the receiver is exactly the transmitted frequency.

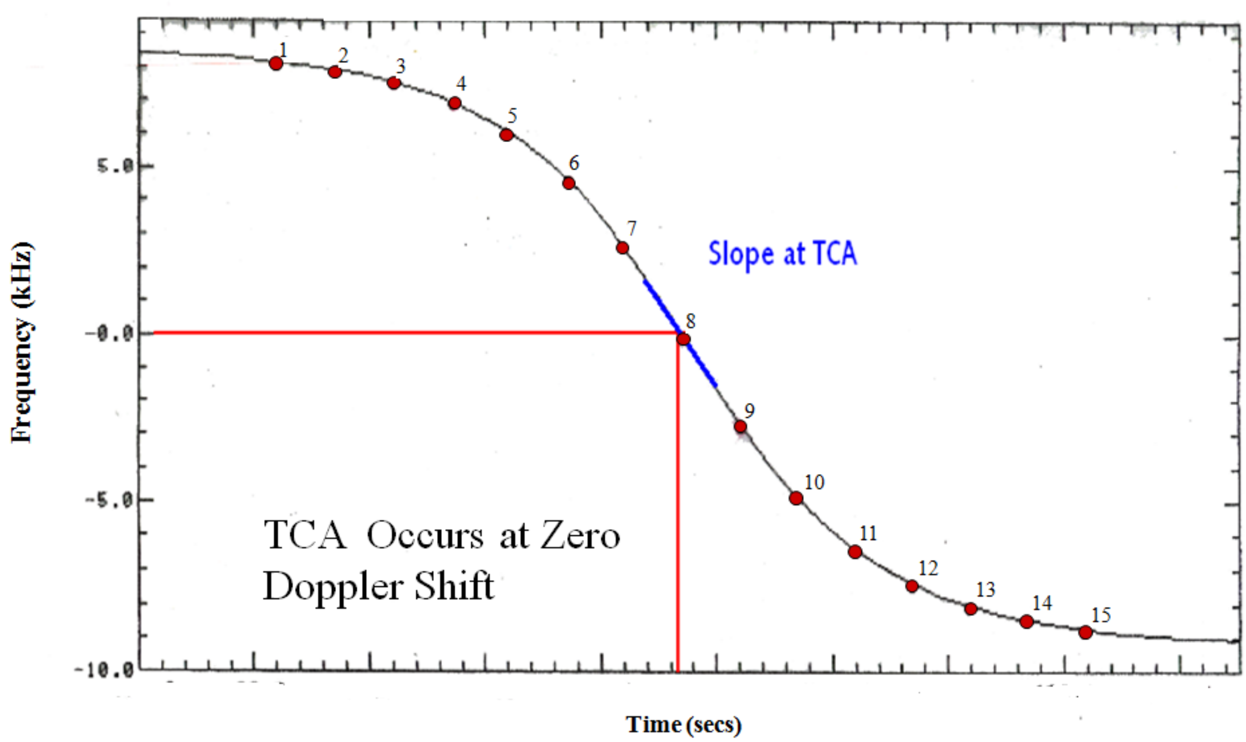

Figure 4

The frequency time plot, Figure 4, is representative of a signal heard by a LEO satellite passing over a stationary transmitter on the surface of the Earth. The inflection point (point on a curve at which the arc changes from convex to concave or vice versa) of the curve represents the point in time where the satellite was closest to the transmitter (TCA - Time of Closest Approach). The slope of the curve at TCA determines the distance of the transmitter from the satellite track.

Using this information, and by knowing where the satellite was at all times during the pass, it is possible to plot two lines which represent the distance from the satellite track where the transmitter could have been (Figure 5). Then knowing the time of closest approach of the satellite, it is a simple matter of drawing a perpendicular line from the point on the satellite track at TCA to the lines representing the distance between the transmitter and the satellite track. Where these lines intersect represent *two possible locations* for the transmitter, one being the actual location and the other being its mirror image. The two positions, real and mirror image, can be up to 2,000 miles apart. *A subsequent satellite pass on a different satellite track is necessary to resolve the ambiguity*.

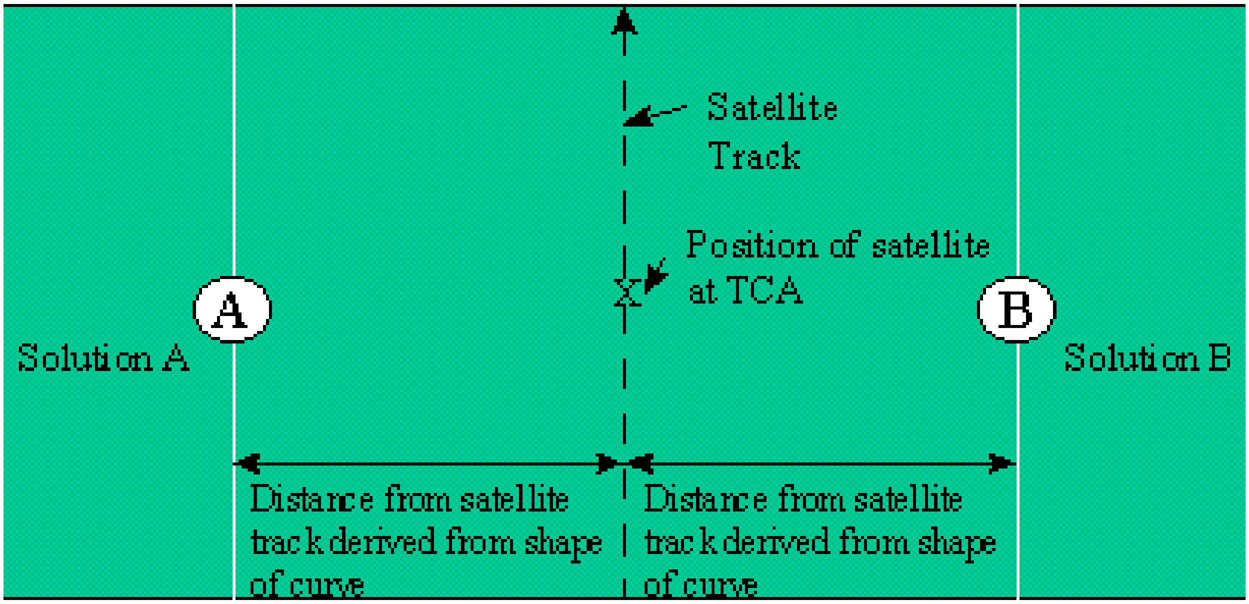

Figure 5

The LEOSAR system requires a satellite passes in which the satellite receives a minimum of 3 complete burst transmissions without interference, and one of the three bursts must be on each side of TCA. It is possible for a LEO to receive 15 transmissions during a single pass. A LEO pass in which 5 or fewer bursts are received are more subject to large location errors. Experience has shown that about 1 in 4 satellite passes will result in a "blown solution" or no position calculation. This can be caused by a low angle between the satellite and the beacon, transmission interference from another source, or blockage of the signal by objects like hills, boat hulls, etc.

Every successful LEO satellite pass generates two positions, the real position and its mirror image. It takes another successful satellite pass to resolve which position is the real position.

How soon will rescue know I am in trouble and where to find me?

Let us take two cases to answer the question.

Case 1: A GPS equipped EPIRB is activated by floating free, in the mid latitudes, and not registered. This is an EPIRB that can calculate and transmit its position; the position data is included in the transmitted signal. These EPIRBS are sometimes called Location Protocol EPIRBs.

Time	Chain of events.
00:00	The beacon floats free and is activated by the water.
00:01	Beacon transmits its first burst; a GEOSAR satellite detects, and transmits the data to its GEOLUT, the LUT forwards the data to the appropriate MCC based on the country coded in beacon HexID. The MCC is unable to forward due to lack of position or identifying information on ownership.
00:02	Beacon transmits second burst with position based on GPS acquired data. GEOSAR detects and forward the signal to LUT, which forwards it to MCC which forward to Coast Guard RCC based on location.
00:03	Coast Guard receives information on unknown (not registered), *located* EPIRB and begins rescue operations.

Case 2: An EPIRB (without GPS) is activated by floating free, in the mid latitudes, and not registered. This is an EPIRB without the ability to determine its own position, so the transmitted data does not include its position and the only way to determine the location is for calculations derived from the satellite data.

Time	Chain of events.
00:00	The beacon floats free and is activated by the water.

00:01 Beacon transmits its first burst; a GEOSAR satellite detects, and transmits the data to its GEOLUT, the LUT forwards the data to the appropriate MCC based on the country coded in beacon HexID. The MCC is unable to forward due to lack of position or identifying information on ownership.

01:00 First LEOSAR pass is successful, with actual position and mirror image location data, an A and a B solution with the A solution as the more probable. The A and the B solution may be several thousand miles apart. The EPIRB information is transmitted to LUT. The LUT forwards the data to the MCC which forwards it to the two different RCCs responsible for the different SAR areas and the appropriate MCC based on the country coded in beacon HexID. Both RCCs will commence call outs and issue a Marine Information Bulletins for the general area of each of the two positions. The RCC with the A solution may launch SAR search assets if it unable to verify the safety of the vessel.

02:00 Second LEOSAR is a "blown solution" and no position calculation is possible. The EPIRB information is transmitted to the LUT and the LUT forward the data to the MCC. The MCC forwards the information that the EPIRB was heard but no position was calculated. The RCCs continue to try to verify the safety of the vessel.

0300 Third LEOSAR pass is successful, with position and mirror image position location data, A and B solutions. EPIRB information is transmitted to LUT. The LUT forwards the data to the MCC. MCC how has enough data to determine which the real position is and eliminate the mirror images. The B solution from the first pass and the A solution from the second pass combine to great a composite position with the ambiguity now resolved. The MCC notifies RCC of position update. Coast Guard receives information on unknown (not registered), *located* EPIRB and begins rescue operations.

Case 2 is an example easily made better with registration and or GPS data. But do not discount Case 2, the Coast Guard deals with cases like this every day. Many beacon signals are never located by the LEOSAR. This can be due to geography, position of the beacon relative the structure of the boat, or occasionally the failure of the beacon to provide a stable and repeated frequency over multiple transmissions.