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NEW DEVELOPMENTS IN THE COSPAS-SARSAT SATELLITE SYSTEM FOR SEARCH AND RESCUE

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ABSTRACT

This paper describes the status and future plans of Cospas-Sarsat, the worldwide satellite system for search and rescue (SAR) that provides the humanitarian service of pinpointing the locations of survivors of distress events on land, sea or air. Since Cospas-Sarsat started operating in 1982, it has been credited with saving many thousands of lives, and today more than a million aviators, mariners and land users are equipped with Cospas-Sarsat distress beacons that could help save their lives in emergency situations anywhere in the world. The satellites, and tracking stations on six continents, provide global detection for user distress signals. These stations receive the satellite-relayed distress signals, compute the locations of the distress events and initiate calls for help to the appropriate rescue authorities. The paper outlines plans to enhance the Cospas-Sarsat system by adding search and rescue payloads to future global navigation satellites, such as GPS, Glonass and Galileo in order to improve its effectiveness well into the 21st century.

BACKGROUND

In the 1960s, light aircraft and some marine vessels started carrying small, battery-operated radio transmitters, operating at the international distress frequency of 121.5 MHz, that could be activated in an emergency distress situation. Such transmitters, called Emergency Locator Transmitters (ELTs) on aircraft, and Emergency Position Indicating Radio Beacons (EPIRBs) on ships, emitted a low-power signal that could be picked up by a receiver in a nearby air traffic control tower or by an aircraft in the vicinity, thus

providing only line-of-sight coverage if one was searching in that location.

By the mid-1970s, more than 250,000 distress beacons were in service in Canada, Europe and the USA. Lives of aviators and mariners were being saved thanks to these transmitters, but there was still room for improvement, particularly as it was now the 'space age'.

A SATELLITE SYSTEM

To improve the detection of distress signals, experiments were successfully conducted in the mid-1970s, and Canada, France and the

USA set up a joint experiment for search and rescue satellite-aided tracking, known as SARSAT. Russia soon joined and developed a compatible system called COSPAS, and the Cospas-Sarsat system was created.

Whereas navigation satellites, such as GPS and Glonass, tell "you" where you are, Cospas-Sarsat tells "someone else" (i.e. search and rescue forces) where you are, even if you don't know where on Earth you are. In a real distress situation, this could well be your only lifeline.

1980s LEOSAR SYSTEM

The original Cospas-Sarsat system of the 1980s comprised a constellation of four satellites in polar, low-Earth-orbit (LEO), dubbed the LEOSAR system (Figure 1), and provided services for 121.5 and 406 MHz beacons ^[1].

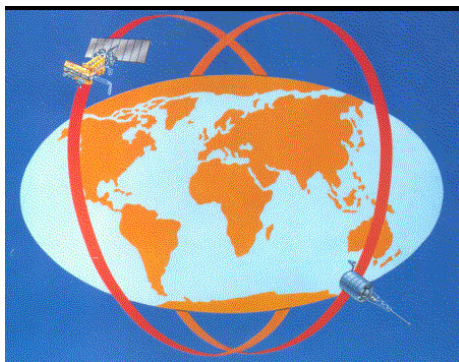


Fig 1: Cospas-Sarsat satellites in polar orbit.

This system worked well, and is still in use today, but has inherent time delays, ranging from minutes to hours, in detecting and relaying distress signals because the low altitude satellites (at about 1000 km) view only a portion of the Earth at any instant as they circle the globe. This LEO system could not be made much better for 121.5 MHz beacons, due to technical limitations of the beacons and that radio channel.

The original satellite system also carried payloads that allowed for the implementation of new digital, distress beacons operating at 406 MHz, which would be far superior to the original analog 121.5 MHz beacons. These new beacons permit the distress location to be automatically computed by the satellite system ten times more accurately (to within 2 km) and the beacon user to be identified, whereas the old 1960s technology beacons gave only an approximate location (to within 20 km) and no user identification, since the 'wow, wow, wow' sound of the signal was similar for all these beacons.

In addition, the 406 MHz system provides global coverage for beacons activated anywhere on Earth, as the beacon signals are stored onboard the satellite and retransmitted to each ground station as the satellite orbits the Earth.

Principle of Operation

LEOSAR Satellite Configuration

Figure 2 shows the path, or "orbital plane", of a low-Earth-orbiting satellite circling the Earth around the poles. The satellite travels in this fixed plane while the earth rotates underneath it, enabling a single satellite to eventually view the entire Earth's surface. At most, it takes only one-half rotation of the Earth (i.e. 12 hours) for any location to pass under the satellite path.

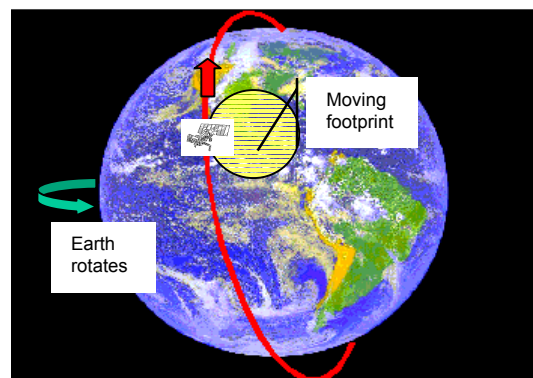


Fig 2: Orbital plane of a LEO polar-orbiting satellite

Having additional satellites in other orbital planes significantly reduces this “waiting time” for a satellite to come into view. The Cospas-Sarsat LEOSAR system provides typical waiting times of less than one hour at mid-latitudes.

Under the International Cospas-Sarsat Program Agreement, Russia builds and launches the Cospas satellites, and the USA carries SAR payloads, built by Canada and France, on their NOAA weather satellites for the Sarsat system.

121.5 MHz Distress Beacons

It is estimated that there are more than 650,000 beacons operating at 121.5 MHz (Figure 3) in use worldwide, primarily aboard aircraft. These beacons transmit signals of only 0.05 to 0.1 Watt, as required by national specifications that were not initially developed for a satellite system.



Fig 3: Typical 121.5 MHz ELTs used in aircraft

406 MHz Distress Beacons

Development of a new generation of beacons transmitting at 406 MHz commenced at the beginning of the Cospas-Sarsat project. The 406 MHz units were designed specifically for satellite detection and Doppler location by having:

- high peak power output and low duty cycle;
- improved radio frequency stability;
- a unique identification code in each beacon;

- digital transmissions that could be stored in a satellite’s memory; and
- spectrum dedicated by the ITU solely for distress beacons.



Fig 4: Various 406 MHz distress beacons

406 MHz beacons, shown in Figure 4, transmit a 5-Watt, half-second burst approximately every 50 seconds. The carrier frequency is phase-modulated with a digital message. The low duty cycle provides a multiple-access capability of more than 90 beacons operating simultaneously in view of a polar orbiting satellite, versus only about 10 for 121.5 MHz beacons.

There are now more than 30 manufacturers of 406 MHz beacons in 12 countries, and many more distributors around the world, with over 100 different models type-approved by Cospas-Sarsat^[2]. The number of 406 MHz beacons in use has increased dramatically from zero in 1985 to 20,000 in 1990 and to about 350,000 today.

LEO Local User Terminals (LEOLUTs)

Cospas-Sarsat LEOLUTs are ground stations which track the satellites, receive the distress beacon signals via the satellites, compute the locations of the distress signals and forward the alert data to Mission Control Centres (MCC). Most LUTs are fully automated; some of which are unattended and installed in remote areas and can be operated remotely from the MCC. The LUT steers a tracking antenna to follow the satellite across the sky,

so each LUT needs to know the satellite orbit data on an ongoing basis.

Today, some 40 LEOLUTs are operating on six continents, as shown in Figure 5.

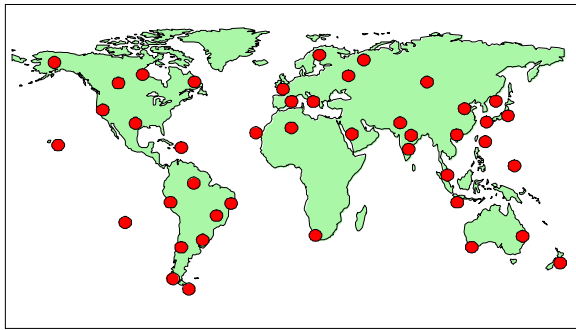


Fig 5: Locations of Cospas-Sarsat LEOLUTs

Distribution of Alert and Location Data

Distress signals from 121.5 MHz beacons are relayed in real-time by a satellite to all LUTs in its footprint at that time, provided the satellite is mutually visible to the beacon and the LUT. Signals from 406 MHz beacons are relayed in a similar manner, and they are also stored in the satellite's memory, along with the time tag and frequency measurement, for later retransmission to each LUT, thereby providing global coverage.

The alert and location data generated by LUTs are automatically forwarded to one of the MCCs in the Cospas-Sarsat network, where they are sorted and routed to the appropriate rescue authorities.

1990s: GEOSAR ENHANCEMENT

In the late 1980s and early 1990s, Cospas-Sarsat also started evaluating the use of geostationary-Earth-orbit (GEO) satellites at 36,000 km altitude as an enhancement to the polar-orbiting system to provide almost immediate alerts, with identification, for 406 MHz beacons.

These initial experiments demonstrated the feasibility of such a concept, called

GEOSAR, and a number of geostationary satellites were then equipped with 406-MHz transponders and new earth stations, known as GEOLUTs, were built. As depicted in Figure 6, two USA weather satellites (GOES-East and West), an Indian satellite (Insat) and Europe's MSG weather satellite now provide this service, and others are planned.

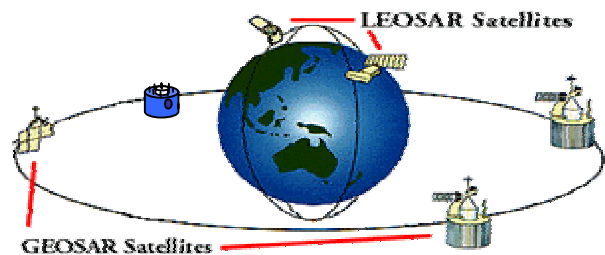


Fig 6: Combined LEO & GEO satellite constellations

Since these satellites appear to be at a fixed position in the sky, there is virtually no relative motion between the satellite and the distress beacon in the GEOSAR system, hence there is no Doppler shift to automatically locate the beacon.

However, the capability exists for 406 MHz beacons to encode location information derived from a satellite navigation receiver, such as GPS, Glonass or the future Galileo system, and to transmit this location data along with the beacon identification code. This feature is included in about ten percent of the 406 MHz beacons in use today, and this number is growing quickly.

Of course, the precise location of such beacons would be known quickly, usually within a few minutes. In some cases it could take longer to derive this position after the beacon is initially turned on from a 'cold start' when the GNSS receiver has no a priori knowledge of where it is.

Even without location data, a rapid distress alert message with the identification code,

coupled with supplementary data obtained from a beacon registration database, is helpful for search and rescue operations.

GEOLUTs are now operating in Argentina, Brazil, Canada, Chile, France, India, New Zealand, Spain and the United Kingdom.

STATUS OF SYSTEM

Currently, some 35 countries are formally participating in Cospas-Sarsat, as shown in Figure 7.



Fig 7: Cospas-Sarsat Participants (shaded areas)

The program is managed by a Council, comprising members of all participating countries, which meets annually, while administrative and coordination activities are carried out by the Cospas-Sarsat Secretariat. A Joint Committee of technical and operational specialists also meets annually to address system enhancements.

Over the years, the Cospas-Sarsat system has been used to help people in all sorts of distress situations around the world, and since 1982 it has assisted in saving 17,000 lives in 4,500 SAR events.

FUTURE

121.5 MHz Phase-out

Little can be done to improve the original 121.5 MHz system, since its limitations (many false alarms, low power beacons, no user identification, poorer location accuracy, limited system capacity, and not global coverage) cannot easily be rectified, but

most of these are overcome by the superior 406 MHz system.

Hence, all new developments are focused only on the 406 MHz system, and Cospas-Sarsat will begin phasing out the 121.5 MHz satellite alerting system in February 2009. A low-power 121.5 MHz signal will continue to be transmitted by 406 MHz beacons for final homing, but these will no longer be relayed and processed by the satellite system. Furthermore, it is anticipated that the use of older, analog 121.5 MHz beacons will diminish in the future as the more sophisticated, digital 406 MHz beacons continue to drop in price and become more commonplace.

New MEOSAR System

Canadian studies in the 1990s showed that having 406 MHz SAR payloads flying on other satellite constellations, such as GPS, could improve the search and rescue service and help save more lives. It was concluded that this could help to take the "search" out of search and rescue.

Therefore, plans are being made to install search and rescue payloads on future Global Navigation Satellite System (GNSS) satellites in medium-Earth-orbit (MEO) at about 20,000 km altitude, including GPS, Glonass and the new Galileo system, as illustrated in Figure 8.

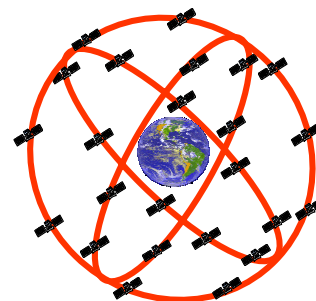


Fig 8: A medium-Earth-orbit (MEO) satellite constellation

Technical parameters for these new SAR payloads have been worked out that permit the satellites to operate in the same frequency band, so any MEOLUT can receive a 406 MHz distress signal via any GNSS SAR-equipped satellite.

A new document, entitled the "MEOSAR Implementation Plan" is being prepared by Cospas-Sarsat to coordinate the development and implementation of the system.

With payloads on a couple of dozen or more MEO satellites, these constellations would improve the 406 MHz distress alerting system by providing continuous, global, real-time coverage. Since 3 or 4 MEOSAR satellites would always be in view from almost anywhere on Earth, this would alleviate the waiting time inherent in the LEO system and the lack of polar coverage in the GEO system.

Future GPS satellites equipped with SAR payloads will be known as the Distress Alerting Satellite System – DASS.

When MEOSAR satellites start being launched towards the end of this decade, they would complement the existing LEOSAR and GEOSAR systems, which will continue for at least the next several years. The MEO system could also provide a satellite link back to the distress beacon, to indicate receipt of the distress alert, so this is being further studied.

Because MEO satellites are about 20 times higher than LEO satellites, they move slower and traverse the sky over a period of several hours, compared to 15 minutes. This slower movement imparts little Doppler frequency shift, so the MEOSAR system would utilize a new technique, described below, to determine the location of the distress beacon, rather than the Doppler method used in the LEOSAR system.

The MEOSAR system would comprise several satellites and a new type of ground

station called a MEOLUT. Since the signal from a beacon would be relayed by several satellites simultaneously, each in a different part of the sky, each path length from the beacon to a satellite to a ground station would be different, as shown in Figure 9.

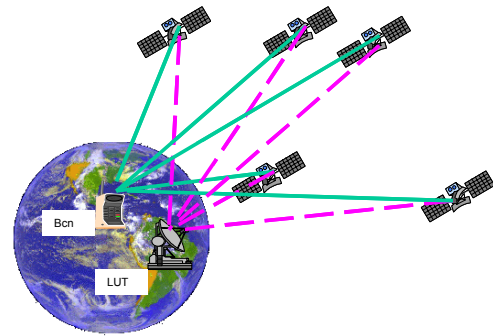


Fig 9: Signal paths via various satellites

As these 'triangles' have sides of different lengths, the beacon signal, traveling at the speed of light, takes a slightly different length of time to reach the ground station. This time difference of arrival (TDOA) is measured by the ground station and used to compute the beacon location, based on simple triangulation, since the position of the ground station and each satellite are accurately known.

An alternative method of computing the beacon location is based on the frequency difference of arrival (FDOA) of the signal. There is a small amount of Doppler shift on the signal from each MEO satellite, which varies as each satellite moves relative to the beacon, and this difference can be measured in the MEOLUT and used to compute the beacon location. With all the minor perturbations in the signal path, the technical challenge will be to measure these time or frequency differences precisely enough to compute an accurate beacon location.

To employ either of these techniques, the ground station needs to receive the signal via at least 3 different paths, preferably 4, so this would require having 3 or 4 tracking antennas, whereas a LEOLUT generally

has only one antenna. If a station does not have the capability to track 3 or 4 satellites simultaneously, it could possibly obtain data for that beacon burst from other ground stations in the region. Interchanging data this way would make a more effective and robust system.

Studies are underway in Canada, Europe and the USA to design and develop prototype ground stations. A few experimental 406 MHz payloads on MEO satellites in orbit today will be used for proof-of-concept demonstrations and for testing and evaluating the performance of new ground stations.

It is anticipated that a beacon could be located by TDOA or FDOA to within 10 km on a single burst, and each successive burst would provide another independent location. By averaging the subsequent cluster of predicted locations, a more accurate location should result, ideally to within just a few kilometres within 5 or 10 minutes, and the homing signal emitted by the beacon would enable the rescue forces to get to the exact spot.

The independent location predictions from the TDOA or FDOA measurements do not depend on the message content and would produce a quick solution.

For a beacon that transmits its position as part of the distress message, a more precise location should be available quickly.

In summary, the benefits of a MEOSAR system would be:

- continuous, global coverage
- multiple viewing angles from beacon to satellites, so more reliable reception
- beacons located quickly
- moving beacon could be tracked
- return link to beacon possible
- more effective use of SAR resources
- better SAR service and more lives saved

CONCLUSION

After more than 20 years of operation, the Cospas-Sarsat system still continues to provide a valuable global service. New satellites are continually being built and launched to replace older satellites, and new features are being added to the 406 MHz system.

With the broad international cooperation that exists in the program today, the Cospas-Sarsat system is expected to continue providing distress alerting and locating service for many more years, and the new developments planned for this decade will improve the system's effectiveness well into the 21st century.

The Cospas-Sarsat system is an excellent long-term example of international cooperation and the peaceful use of outer space for the benefit of humanity.

Acknowledgements

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Additional information about Cospas-Sarsat can be obtained from national administrations and from the web site at www.cospas-sarsat.org

References

- [1] Introduction to the Cospas-Sarsat System, C/S G.003, October, 1999
- [2] Cospas-Sarsat System Data, December, 2003