

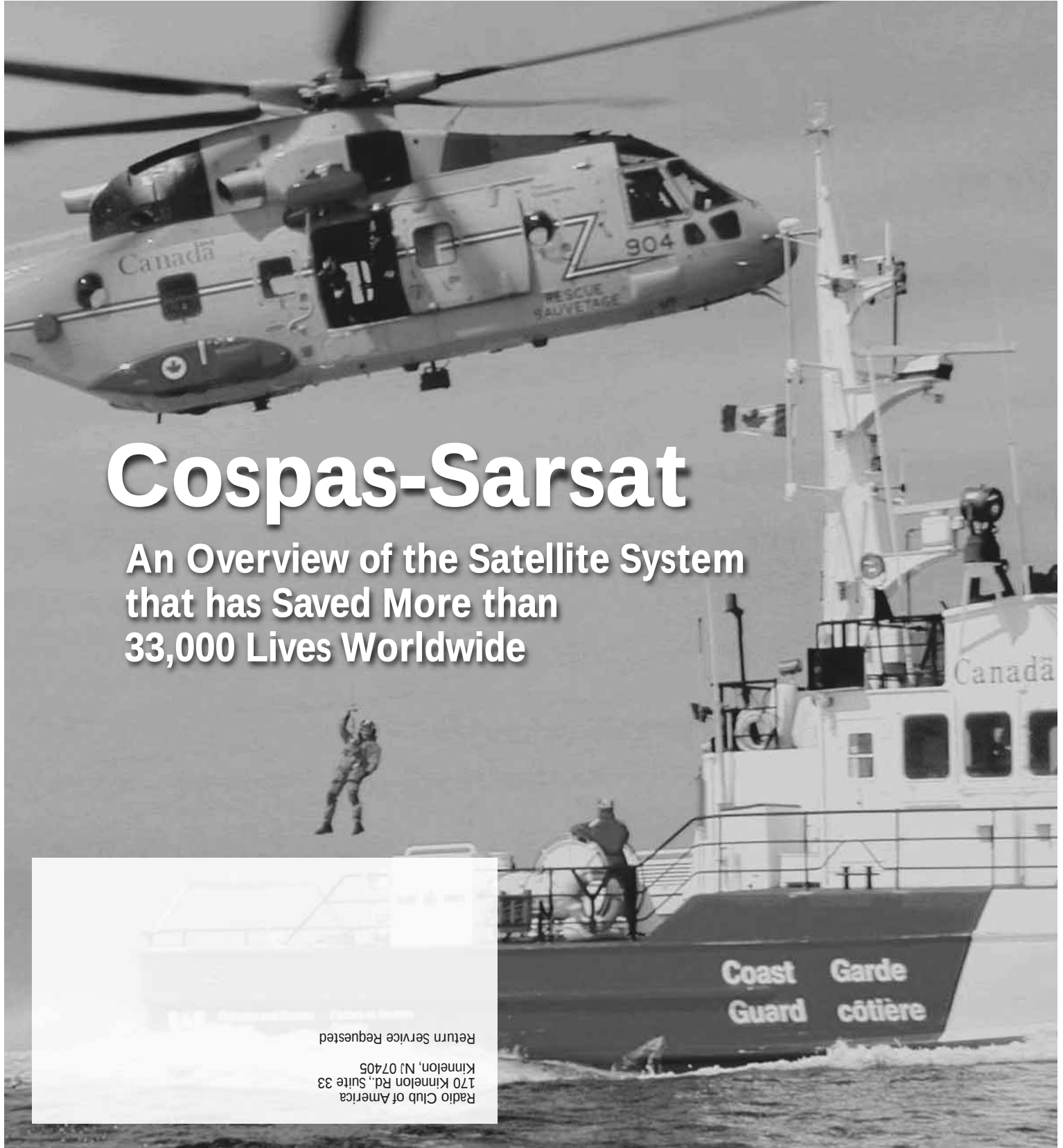
SPRING 2013 PROCEEDINGS of



THE RADIO CLUB OF AMERICA, INC.

Founded 1909, New York, U.S.A.

Honoring the Past, Committed to the Future



Cospas-Sarsat

An Overview of the Satellite System
that has Saved More than
33,000 Lives Worldwide

Return Service Requested
Radio Club of America
170 Kinnelon Rd., Suite 33
Kinnelon, NJ 07405

The Radio Club of America, Inc.

Honoring the Past, Committed to the Future

The Proceedings - Spring 2013

Volume 85, Number 1

Headquarters Office: 170 Kinnelon Road, Suite 33, Kinnelon, NJ 07405
Tel: 973-283-0626 or email Patricia S. Koziol at pat@radioclubofamerica.org
Website: www.radioclubofamerica.org

PRESIDENT	Bruce McIntyre
EXECUTIVE VICE-PRESIDENT	Sandra L. Black
VICE-PRESIDENT	Timothy J. Duffy
VICE-PRESIDENT/COUNSEL	Robert Famiglio, Esq.
VICE-PRESIDENT/CO-COUNSEL	Alan Tilles, Esq.
TREASURER	Ronald J. Jakubowski
SECRETARY	Margaret Lyons P.E.
EXECUTIVE SECRETARY	Patricia S. Koziol
DIRECTORS	David P. Bart John S. Belrose, Ph. D. John E. Dettra, Jr. V.G. Duvall, Jr., P.E. William "Bill" Endres John Facella, P.E. Carroll L. Hollingsworth Craig M. Jorgensen Harlin McEwen Carole J. Perry Andrew Seybold Robert P. Walsh Marilyn Ward Larry Weber
EXECUTIVE COMMITTEE	John Dettra VG Duvall William "Bill" Endres John Facella Craig M. Jorgensen June P. Poppele Anthony Sabino, Jr. Andrew Seybold Tom Thornton (includes all officers)
STAFF	Patricia S. Koziol, Executive Secretary
PRESIDENTS EMERITI	Vivian A. Carr Stan Reubenstein Philip M. Casciano Anthony Sabino, Jr. Mercy S. Contreras Steven L. Aldinger John E. Brennan Raymond C. Trott, P.E. Gaetano J. Amoscato Mal Gurian Renville H. McMann, Jr.
COMMITTEE CHAIRPERSONS	Awards: Sandra L. Black Fellows: V.V. Thomas Thornton Banquets & Meetings: Open Constitution & By-Laws: Robert Famiglio, Esq., Alan Tilles Continuing Education: Richard P. Biby, P.E.

A Call for Renewal	4
A note from the president of the Radio Club of America	
Honoring the Past, Committed to the Future.....	6
A note from the technical editor	
Overview of the Cospas-Sarsat Satellite System for Search and Rescue	8
By James V. King, M.Eng., P.Eng. Cospas-Sarsat, which started as an experiment by four countries in the 1970s, soon became an international satellite system for search and rescue. The system has been credited with saving over 33,000 lives worldwide.	
The 2012 Radio Club of America Awards and Banquet Panoramic Photo.....	14
2102 RCA Awards Banquet Keynote	18
By David Sumner, K1ZZ, chief executive officer and secretary of the American Radio Relay League (ARRL), the national association for amateur radio	
Centennial of the Proceedings of the IEEE	21
By David and Julia Bart IEEE celebrates centennial with Classic Papers from the past 100 years.	
Wireless and Steam Museum.....	24
By Robert W. and Nancy A. Merriam An historic field trip in Rhode Island	
Business and Professional Directory.....	28
News and Notes	30
Membership Information	www.radioclubofamerica.org

Technical Editor: **John S. "Jack" Belrose**, Ph.D, VE2CV
811-1081 Ambleside Dr., Ottawa, ON K2B 8C8, Canada
Tel: 613-721-7587; Email: john_belrose@ieee.org
Editorial Director: Paulla A. Nelson-Shira
7108 S. Alton Way, Building H, Centennial, CO 80112
Tel: 303-792-2390, ext. 112; Email: pnelson-shira@rrmediagroup.com
For Advertising Information Contact: **Patricia S. Koziol**
Tel: 973-283-0626; Email: pat@radioclubofamerica.org
Production: RadioResource Media Group

Pictured on cover: Search and rescue cover photo courtesy of the Canadian Department of National Defence.

Youth Activities: Carole Perry
Finance: V. G. Duvall
Good & Welfare: June P. Poppele
Historical: David P. Bart
Keeping RCA Vibrant: John Facella
Long-Range Planning: Philip M. Casciano
Marketing: Open
Membership: Craig Jorgensen
Museums & Archives: David P. Bart

Nominations & Elections: Anthony Sabino, Jr.
Publications: Paulla A. Nelson-Shira
Regional Conferences: Carroll L. Hollingsworth, Sr.
Scholarship Fund: John E. Dettra, Jr.
Website: Bruce McIntyre
Technical Symposium: John Facella
Aerogram Editor: Patricia S. Koziol
Keeping RCA Vibrant: John Facella

Overview of the Cospas-Sarsat Satellite System for Search and Rescue

Cospas-Sarsat, which started as an experiment by four countries in the 1970s, soon became an international satellite system for search and rescue. The system is now operated by more than 40 countries around the world and has been credited with saving over 33,000 lives worldwide since it began operating in 1982.

By James V. King, M.Eng., P.Eng.

In the 1960s, light aircraft and some 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 or Emergency Position Indicating Radiobeacons (EPIRBs) on ships, emitted a low-power signal that could be picked up by a receiver in a nearby aircraft or by an air traffic control tower in the vicinity.



121.5 MHz emergency locator transmitters were installed on small aircraft.

By the mid-1970s, more than 250,000 distress beacons were in service in various parts of the world, and lives of aviators and mariners were being saved thanks to these transmitters, but the service could be improved now that it was the space age.

A New Satellite System

To improve the reception of such distress signals in remote areas, a satellite system was first proposed in January 1971, in a Canadian study entitled "Locating People in High Latitudes"

[1]. It assessed various possible satellite orbits, coverage areas, and satellite waiting times and predicted that a satellite system could do the job. About that time, the space agencies in France (CNES) and USA (NASA) were starting to use satellites for tracking animals and scientific buoys, so a satellite system for relaying distress signals could also be feasible.

In addition, in the early 1970s, crashes of small planes in remote regions of northern Canada and Alaska led to extensive, and sometimes unsuccessful, searches for survivors, including a high-profile case involving two U.S. congressmen in October 1972. Subsequently, small planes were mandated to carry emergency beacons.

In 1976, satellite proof-of-concept tests were carried out at the Communications Research Centre in Canada (CRC) using



Detection of an experimental beacon signal is relayed via the OSCAR-6 satellite in 1976.

modified distress beacons to transmit signals through an amateur radio satellite called OSCAR-6, which relayed the signals to a prototype ground receiving station.

A senior Canadian military search and rescue (SAR) official witnessed this successful demonstration and supported further development. Agencies in those three countries then set up a

joint experiment called Search And Rescue Satellite-Aided Tracking (SARSAT), and began developing space and ground segment equipment.

In 1979, the former USSR (Russia) joined the experiment and agreed to develop a compatible system called COSPAS (Cosmicheskaya Sistyema Poiska Avarinyich Sudov in Russian), meaning a space system to search for vessels in distress.

These four countries established the Cospas-Sarsat system that began initial testing and preliminary operations when the first satellite was launched in 1982. Within weeks of turning on that first satellite, the system helped SAR forces save several lives in real distress events.

Following the successful testing of the initial experimental



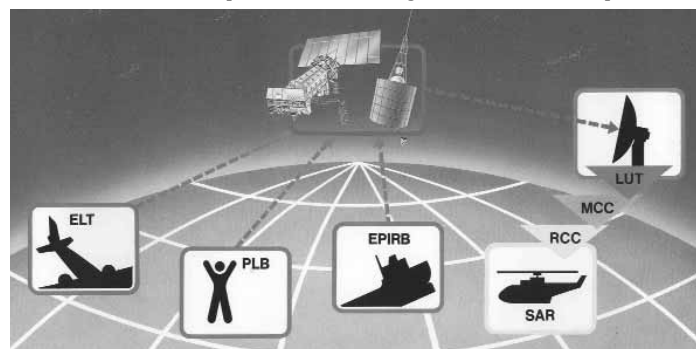
Current Cospas-Sarsat logo

credited with helping save more than 33,000 lives worldwide during its first 30 years of operations, and that number continues to grow daily.

System Concept

Distress beacons can be activated manually by the user in an emergency situation, or automatically on impact or immersion in water, depending on the type of beacon. Distress signals get relayed by satellites to ground tracking stations that compute the distress location and send the alert to a mission control centre and then on to the SAR forces. The system comprises a number of satellites in different orbits and several dozen ground stations operating on six continents.

Basic Cospas-Sarsat System Concept



ELT	Emergency locator transmitter
EPIRB	Emergency position-indication radio beacon
PLB	Personal locator beacon
LUT	Local user terminal
MCC	Mission control center
RCC	Rescue coordination center
SAR	Search and rescue



Initial Cospas-Sarsat logo of the four founding countries

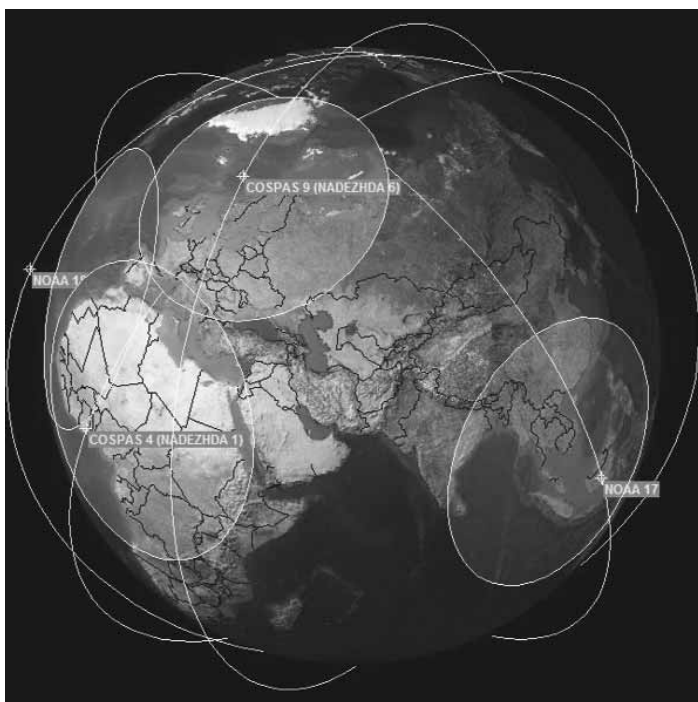
system [2, 3], an institutional structure [4, 5] was put in place to manage a more formal, operational system for many years to



Tests of a maritime beacon through a satellite are conducted.

Courtesy of CRC

come. Today, more than 40 countries contribute and actively participate in operating the system and managing the international program, under the auspices of the United Nations specialized agencies ICAO and IMO for civil aviation and maritime matters. Cospas-Sarsat operates on a non-discriminatory basis and is free of charge for the end-user in distress. The system was



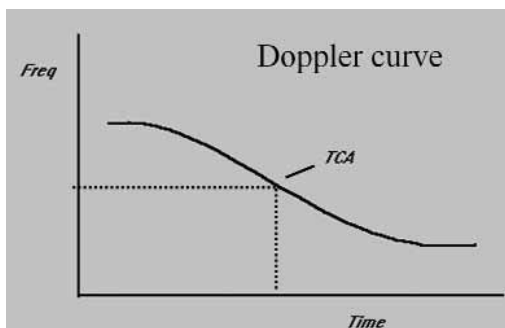
This image shows the orbital planes and moving footprints of four LEO satellites.

LEOSAR System

A satellite in low Earth orbit (LEO) can circle the earth around the poles in a fixed plane while the Earth rotates underneath it, enabling a single satellite to eventually view the entire Earth's surface within several hours. Having more satellites in different planes reduces this waiting time, so the nominal Cospas-Sarsat constellation is four LEO satellites at about 850 to 1,000 km altitude, providing a typical waiting time of less than one hour at mid-latitudes.

Satellites at that low altitude must move quickly over the Earth (about 7 km per second) just to stay in orbit. This movement causes a shift in the radio frequency, called the Doppler effect, due to the relative motion between the satellite in space and the distress beacon on Earth. This principle is used to compute the locations of the distress beacons. The Doppler curve has an inflection point when the satellite passes nearest to the beacon, called time of closest approach (TCA).

However, the Doppler effect always generates pairs of predicted locations, one on



Doppler frequency shift versus time

each side of the satellite sub-track, resulting in an ambiguity, because one is the real location and the other a mirror image. The ground stations analyze this pair and try to assess which is the most likely, based on the skewing of the Doppler curve because of the rotation of the Earth. Both possible locations are always forwarded to the SAR authorities, with a calculated probability for each.

A New Distress Beacon

In addition to providing distress alerting via satellite for 121.5 MHz distress beacons, Cospas-Sarsat also developed a new type of distress beacon in the 1980s, which transmitted a digital signal at 406 MHz containing a unique identification code. This provided information about the type of user and allowed a more precise location of the distress to be computed. 406 MHz beacons still transmit a low-power 121.5 MHz homing signal so SAR forces can locate the beacon with existing homing equipment once they are in the vicinity.

406 MHz beacons transmit a 5-watt, half-second burst approximately every 50 seconds, meaning it is on for only 1 per-



Various types of 406 MHz distress beacons

Courtesy of Cospas-Sarsat

cent of the time, thereby allowing many other beacons to transmit in the same channel. There is an option in 406 MHz beacons to also transmit the beacon location as part of the distress signal, and if the beacon has a built in GNSS re-

ceiver, it can update its position periodically when the beacon is moving or drifting at sea. This feature is now common in many of the newer 406 MHz beacons.

The satellites instantly relay distress signals to ground stations and the 406 MHz signals are also stored in the satellite's memory and continually replayed to all ground stations, thereby providing global coverage. [6, 7] To be most effective, 406 MHz beacons must be properly registered with relevant administrations so SAR authorities can obtain supplementary data and emergency contact information when a beacon gets activated.

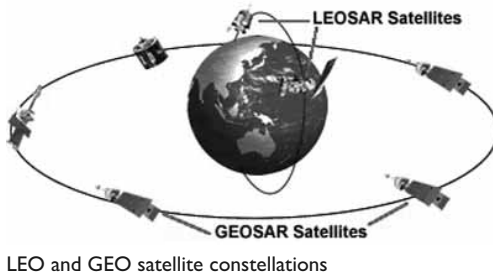
The number of 406 MHz beacons in service grew rapidly, and since the 406 MHz system provided far superior performance and fewer false alarms, satellite detection of 121.5 MHz signals was finally terminated in 2009, after more than 25 years

of service. Most users transitioned to 406 MHz beacons, and now over 1 million are in service around the world.

GEOSAR System

Because of the inherent time delay waiting for a LEO satellite to come into view, Cospas-Sarsat added geostationary-Earth-orbit (GEO) satellites to its constellation to enhance the detection of 406 MHz alerts. Geostationary satellites, at an altitude of 36,000 km, remain at a fixed position in the sky, constantly viewing a huge area of the Earth [8]. They can immediately relay 406 MHz distress alerts, along with the identification codes, thereby eliminating the waiting time of the LEO system.

However, since there is virtually no relative motion between the geostationary satellite and the distress beacon, there is no Doppler shift, so the system cannot automatically compute the location of the distress beacon, unless it is encoded in the beacon message. Another limitation of GEOSAR is that the beacon

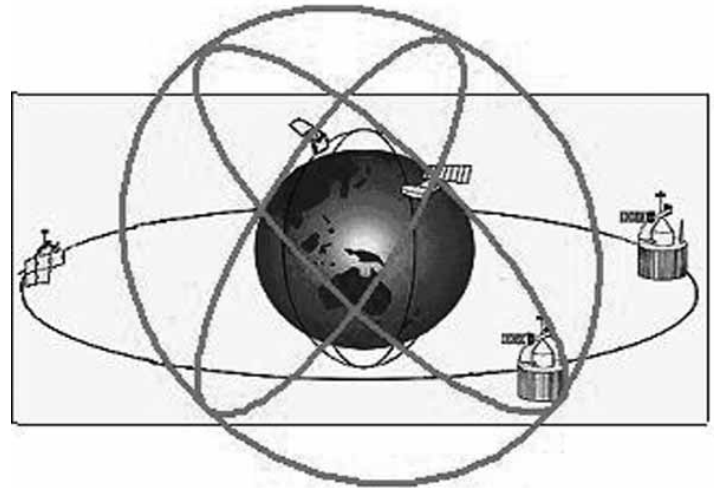


signal requires a direct line of sight to one of the satellites. There are some distress situations where this line of sight is impossible, such as in polar regions or when a plane crashes on the wrong side of a mountain or in a deep valley or when a maritime beacon is blocked by the ship superstructure.

Future MEOSAR System

A 1997 Canadian "Follow-on SAR System (FOSS)" Study [9] investigated possible methods to improve satellite SAR service. It showed that satellite SAR could be significantly improved by putting SAR payloads on navigation satellites, such as GPS, in medium Earth orbit (MEO) at some 20,000 km altitude. This concept was further pursued by Canada's Cospas-Sarsat partners, France, Russia and the USA, who deemed it would be feasible.

It was agreed that the 406 MHz systems on LEOSAR and GEOSAR should be complemented by this new MEOSAR system, so this is now being developed and implemented. It will comprise 406 MHz repeaters on many future global navigation satellite systems (GNSS), including GPS, GLONASS and Galileo, and a new network of ground stations called

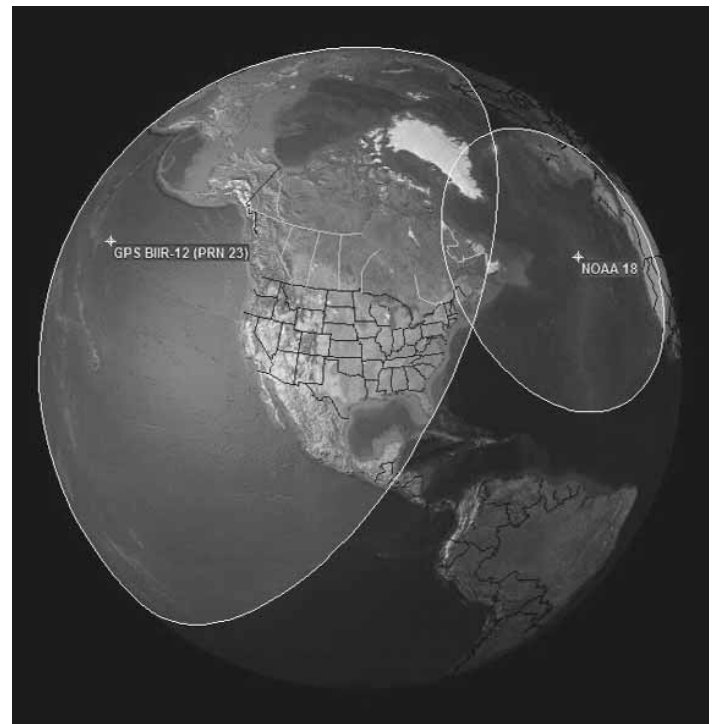


A medium-Earth-orbit (MEO) satellite constellation is between LEO and GEO.

MEOLUTs. Galileo is also planning to provide a satellite return link to the distress beacon to acknowledge receipt of the distress alert.

At that altitude, a MEOSAR satellite has a footprint much larger than a LEOSAR, and almost as large as GEOSAR, and it slowly moves around the world, providing long periods of coverage. Having multiple MEOSAR satellites in orbit provides continuous, global coverage, thereby overcoming the time delay of LEOSAR and the non-polar coverage of GEOSAR.

These MEO constellations provide multiple viewing angles to the satellites, thus minimizing blockage by local terrain,

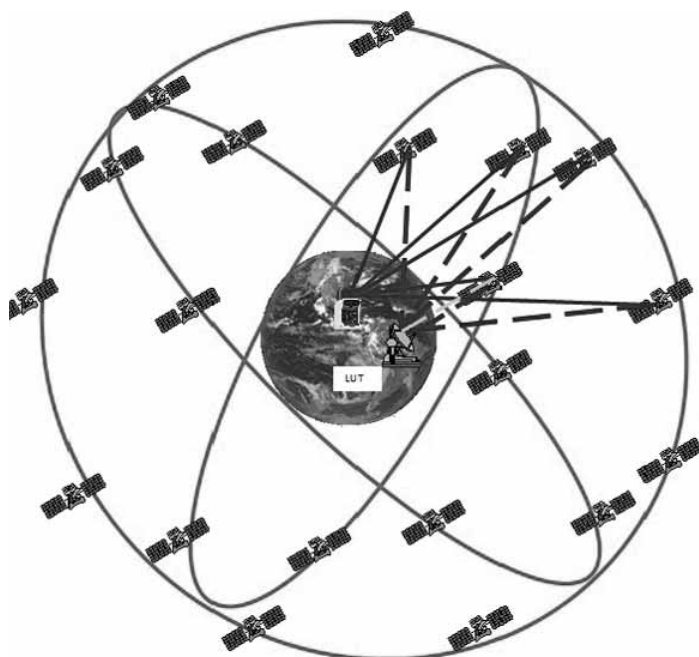


A MEO footprint (left) is much larger than a LEO footprint (right) and moves much slower.

meaning MEOSAR can quickly detect and locate 406 MHz beacons activated almost anywhere in the world.

Principle of Operation of MEOSAR System

In simple terms, the MEOSAR system is just the reverse of a satellite navigation system based on ranging or triangulation. The user in distress activates a transmitter, rather than a receiver, and its signal travels “backwards” via the navigation satellites (i.e. through the SAR repeaters) to MEOLUTs. Each burst transmitted from a distress beacon gets relayed via multiple navigation satellites simultaneously, each located in a different part of the sky, so the burst arrives at the ground station at



Beacon signals are relayed simultaneously by multiple MEO satellites to a MEOLUT.

slightly different times via each path, due to the different signal path lengths, and at slightly different frequencies, due to the Doppler shift of the satellites in orbit.

These small time differences of arrival (TDOA) are accurately measured by the MEOLUT. Since the MEOLUT knows its own fixed location, and the location of each of the navigation satellites since they broadcast that, it can quickly determine the location of the beacon. Because the MEOSAR satellites are all slowly moving in different directions across the sky, they also impart a small Doppler shift on the radio signal. This shift is slightly different through each satellite, so the MEOLUT also detects this frequency difference of arrival (FDOA), which it

can also use to help compute the beacon location.

These techniques allow a beacon to be detected and located on a single burst within a few seconds, without having to wait for a LEO satellite to come into view, and then waiting for a Doppler curve to be produced from multiple bursts, taking several more minutes.

The MEOSAR system will offer many benefits, including:

- Continuous, global coverage
- Multiple signal paths so more reliable reception of distress signals
- Almost instantaneous detection and location of distress beacons
- Ability to track moving distress beacons on a life raft or in an aircraft even before it crashes

Although the MEOSAR system is gradually being implemented over several years, there is now a partial system in place, but it does not yet provide global coverage or 24-hour-a-day service. But that is sufficient for engineers and SAR authorities worldwide to start testing elements of the system, so a three-year demonstration and evaluation phase of the MEOSAR system is now under way.

With these new features soon becoming available, it is desirable to improve 406 MHz distress beacons so they can provide even more useful information to SAR forces for planning and



Typical SAR resources at work

carrying out a rescue mission. Therefore, specifications for second-generation 406 MHz distress beacons are now being developed and tested so new types of beacons can eventually be put on the market in the next few years.

It is expected that an operational MEOSAR system will be in

place before the end of this decade, thereby ensuring that SAR forces and 406 MHz beacon users will continue to have an optimum distress alerting and locating service for worldwide operations for many years to come. Additional information about Cospas-Sarsat can be obtained from the website at

www.cospas-sarsat.org



Jim King is a consultant at Ovik Inc. in Ottawa, Canada. He is involved in developing and testing the next generation satellite system for search and rescue, known as MEOSAR. He has over 30 years' experience on satellites systems for search and rescue, maritime and asset tracking, and broadband satellite communications.

Mr. King was previously the director of Major Satellite Communications Programs at Communications Research Centre Canada (CRC), and prior to that had worked at Inmarsat in London, England for 10 years. Early in his career, Jim worked on military navigation and communication systems for the Canadian Defence Department, and in the 1980s worked at CRC designing, building and testing a new satellite system for search and rescue, called Cospas-Sarsat.

He has attended more than 100 international Cospas-Sarsat meetings over 30 years, and chaired several of them. He has written and submitted more than 200 papers to those meetings, has given several seminars and training courses on Cospas-Sarsat and MEOSAR, and has also written many papers on other satellite systems.

Mr. King has a Bachelor of Engineering (1971, U of Sask) and Master of Engineering (1986, U of Ottawa), specializing in satellite communications, and has an aircraft private pilot's licence. He is a member of the Professional Engineers of Ontario (PEO), and the Ontario Society of Professional Engineers (OSPE) and was a Canadian delegate at international meetings of Cospas-Sarsat, the European Space Agency and the United Nations.

References

[1] Stevinson, H.T., and Baker, D.A. (1971). *Locating People in High Latitudes*. Laboratory Technical Report LTR-FR-32 and -32A, National Aeronautical Establishment, National Research Council of Canada, January and October 1971, Ottawa, Canada.

[2] Werstiuk, H.L. (1983). *Cospas-Sarsat System Overview*. Paper No. 83071, Proceedings of the 1983 International Electrical, Electronics Conference and Exhibition -IEEC&E '83 (pp.168-171), IEEE Catalogue No. 83CH1955-4, September 1983, Toronto, Canada.

[3] King, J.V., Hayes, E.J., & Jutras, G.J. (1983). *Results of Cospas-Sarsat System Performance Testing*. Paper No. 83074, Proceedings of the 1983 International Electrical, Electronics Conference and Exhibition-IEEC&E '83 (pp-180-183), IEEE Catalogue No. 83CH1955-4, September 1983, Toronto, Canada.

[4] McGunigal, T.E., McKinnon, D.J., Brachet, G., Zurabov, Y., (1984). *Cospas/Sarsat- An Overview*, Presented at the International Symposium on Satellite Aided Search and Rescue, April 1984, Toulouse, France.

[5] Levesque, D., Hodgkins, K., Drover, P., (1984). *The development of an institutional structure for the future global satellite system for search and rescue*, Presented at the International Symposium on Satellite Aided Search and Rescue, April 1984, Toulouse, France.

[6] Goudy, Ph., King, J., Kissel, F. (1984). *Sarsat 406 MHz System Technical Evaluation*, Presented at the International Symposium on Satellite Aided Search and Rescue, April 1984, Toulouse, France.

[7] Rogalski, V., Krupen, V. (1984). *The Cospas System Tests Technical Results*, Presented at the International Symposium on Satellite Aided Search and Rescue, April 1984, Toulouse, France.

[8] Keightley, R.J. (1987), *Simulation of the Canadian GOES Signal Processor*. IEEE Transactions on Aerospace and Electronic Systems – Vol. AES-23, No. 3, (pp361-370). May 1987.

[9] Renner, R.C., (1997), *Follow-On SAR System (FOSS) Final Report*, document CAL-RP-0890-10016, CAL Corporation, submitted to DND/NSS, March 1997, Ottawa, Canada.