CGMS XXIX
USA-WP-19
Agenda Item: H.2
To be discussed in Plenary

COSPAS-SARSAT
SEARCH AND RESCUE
SYSTEM OVERVIEW
AND PERFORMANCE

Summary and Purpose of Document

To provide the Coordinating Group for Meteorological Satellites (CGMS) members information regarding the operation and performance of the Cospas-Sarsat system

Action Requested: None

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SYSTEM DESCRIPTION

Operational since 1982, Cosmicheskaya Sistyema Poiska Avariynich Sudov - Search and Rescue Satellite-Aided Tracking (Cospas-Sarsat) is an international, humanitarian search and rescue (SAR) system that uses satellites to detect and locate emergency beacons carried by ships, aircraft or individuals. The system consists of a network of satellites, local users terminals (LUTs), mission control centers (MCCs) and rescue coordination centers (RCCs). Three Russian Cospas spacecrafts, five U.S. Sarsat low earth orbiting (LEO) weather satellites, two U.S.geostationary (GEO) satellites and one Indian GEO spacecraft form the space segment of the Sarsat system.

As illustrated in Figure 1, a typical SAR event would be initiated by the activation of an aircraft Emergency Locator Transmitter (ELT), maritime Emergency Position Indicating Radio Beacon (EPIRB), or Personal Locator Beacon (PLB). The signal is detected by the receiver on the spacecraft and transmitted to a satellite ground station, or LUT, where the appropriate MCC and/or RCC is alerted.

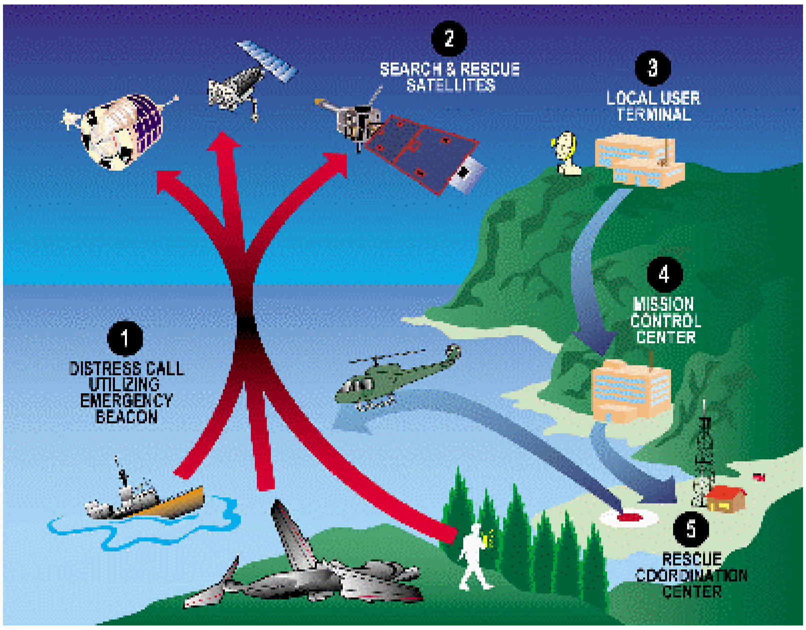

Figure 1. SARSAT System Overview

The Sarsat system contains two types of coverage modes: local and global. Local coverage mode provides coverage to areas where the satellite footprint is in view of the LUT and the distress beacon. The global coverage mode provides full earth coverage by storing data in the spacecraft and continually transmitting the stored for up to 48 hrs.

ELTs, EPIRBs and PLBs are available for transmission on 121.5 MHz, 243 MHz or 406 MHz signals. The 406 MHz signals are encoded with the type of platform, country of origin, and vessel/aircraft identification. The data-carrying signal is biphase-L encoded and phase modulated on 1544.5 MHz carrier downlink frequency. These characteristics allow the receiver to easily distinguish between the actual signal and interfering signals. The 121.5 MHz and 243 MHz distress beacons, however, transmit a CW signal that cannot be distinguished from interfering signals and hence, creates numerous non-distress alerts (false alarms). In addition, 121.5 MHz and 243 MHz beacons are suitable for only the LEO satellite system. These two facts have led to the international recommendation to eliminate Cospas-Sarsat use of the 121.5 MHz and 234 MHz by February 1, 2009. Therefore, this document will be limited to 406 MHz subsystem operation and performance.

SPACE SEGMENT

The space segment consists of:

- low earth orbit and geostationary spacecraft;
- a 121.5 MHz Search and Rescue Repeater (SARR) unit on Cospas satellites, a 121.5, 243 and 406 MHz SARR unit on Sarsat satellites and a 406 MHz SARR on the GEO satellites designed for retransmission of distress signals; and
- a 406 MHz Search and Rescue Processor (SARP) and memory unit on Cospas and Sarsat LEO spacecraft designed to receive, process and store signals received on 406 MHz for retransmission in the local and the global coverage mode.

Satellites

Both LEO and GEO spacecraft are utilized in the Cospas-Sarsat system.

LEO Spacecraft

Russia and the U.S. operate two different types of LEO search and rescue (LEOSAR) satellites. The Russian satellites maintain a near polar orbit at an altitude of 987 to 1022 kilometers with a period of 105 minutes +/- 30 seconds and an inclination of 83 degrees[1]. The U.S. spacecraft are in a near polar sun-synchronous orbit at an altitude of 833 to 870 kilometers with period of 102 minutes +/- 3 seconds and an inclination of around 98.75 degrees[2]. Each satellite is in a different orbital plane and its local coverage is shown in Figure 2.

GEO Spacecraft

GEO search and rescue (GEOSAR) instruments are currently operational on two U.S. and one Indian spacecraft. The coverage area of the U.S. 406 MHz Geostationary Operational Environmental Satellites (GOES) spacecraft and the Indian Insat-2B is shown in Figure 3. The U.S. GOES spacecraft are located at 75^{0} W (GOES E/8) and 135^{0} W (GOES W/10). Presently, only GOES 8 and GOES 10 are used for SAR.

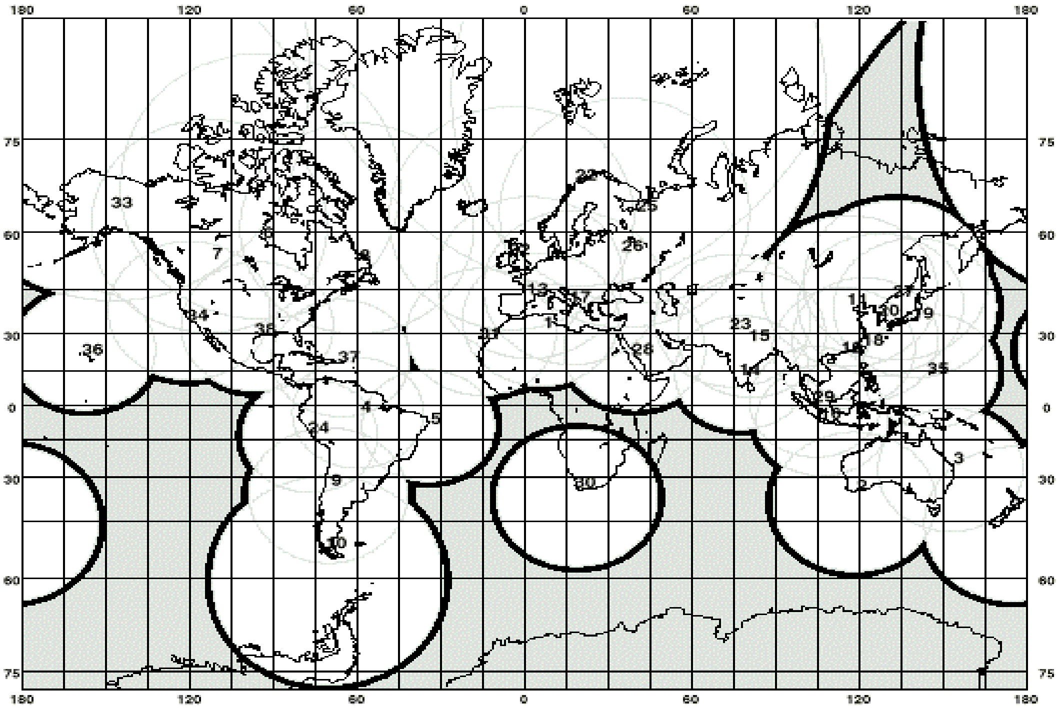

Figure 2: LEO Local Coverage

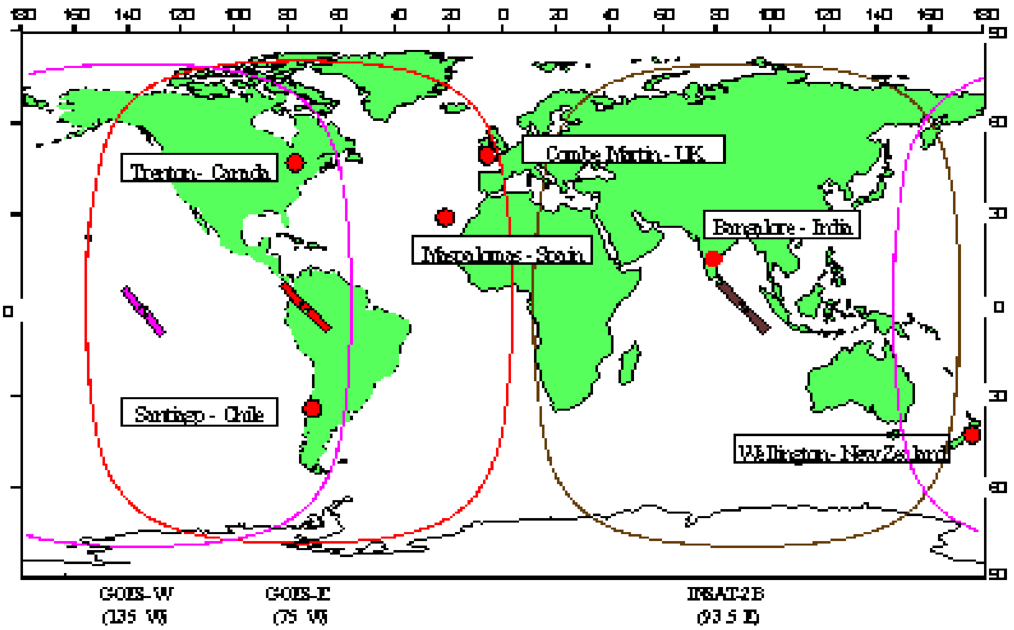

Figure 3: GEO Coverage

Search and Rescue Processor (SARP) and Memory Unit

SARPs are located aboard Cospas and Sarsat LEO spacecraft. The SARPs' functions are to demodulate digital messages received from 406 MHz beacons, measure the received frequency, and time-tag the measurement. All data downlinked from the spacecraft is biphase L encoded and phase modulated onto a 1544.5 MHz carrier. Frames are transmitted at 2400 bits per second in the processed data mode and simultaneously stored in memory.

In addition, the SARP, after storing received data into its memory unit, continually retransmits this information for a period of 24 to 48 hours, giving the satellites a global beacon detection capability. The on-board memory is dumped in the same format and at the same bit rate as local mode data. LUTs thus receive the stored beacon messages acquired during previous orbits. If a beacon signal is received during the stored memory dump, the dump is interrupted so that the signal can be processed and the resultant message interleaved with the stored data.

Search and Rescue Repeater Unit (SARR)

There are two main types of 406 MHz repeaters in the SAR system. The first type is located on the LEO spacecraft and a functional diagram of the Sarsat SARR is represented in Figure 4. The Sarsat SARR receives signals transmitted by activated distress beacons operating at frequencies of 121.5, 243, or 406 MHz and within view of the spacecraft. After amplification and frequency conversion, the signals are retransmitted on the 1544.5 MHz downlink.

The second type of 406 MHz repeater is located on the GOES spacecraft and is depicted in Figure 5. This is configurable and offers command selectable band pass filters (BPF) and power amplifiers (PA). The BPF can be configured for narrow band (20 kHz) or wide band (80 kHz) mode, and the PA can be configured for fixed (linear) gain or Automatic Gain Control (AGC) mode maintains a constant power level to the input of the receiver. Consequently, there are 4 different modes of operations the SARR can perform. These modes are contained in Table 1. Presently, testing is being conducted to determine the optimal operating mode for this SARR.

Table 1: SARR Operating Modes

Mode	Center Frequency (MHz)	Receiver 3 dB Bandwidth (kHz)
Narrow Band with ALC	406.025	20
Narrow Band Fixed Gain	406.025	20
Wide Band with ALC	406.050	80
Wide Band with Fixed Gain	406.050	80

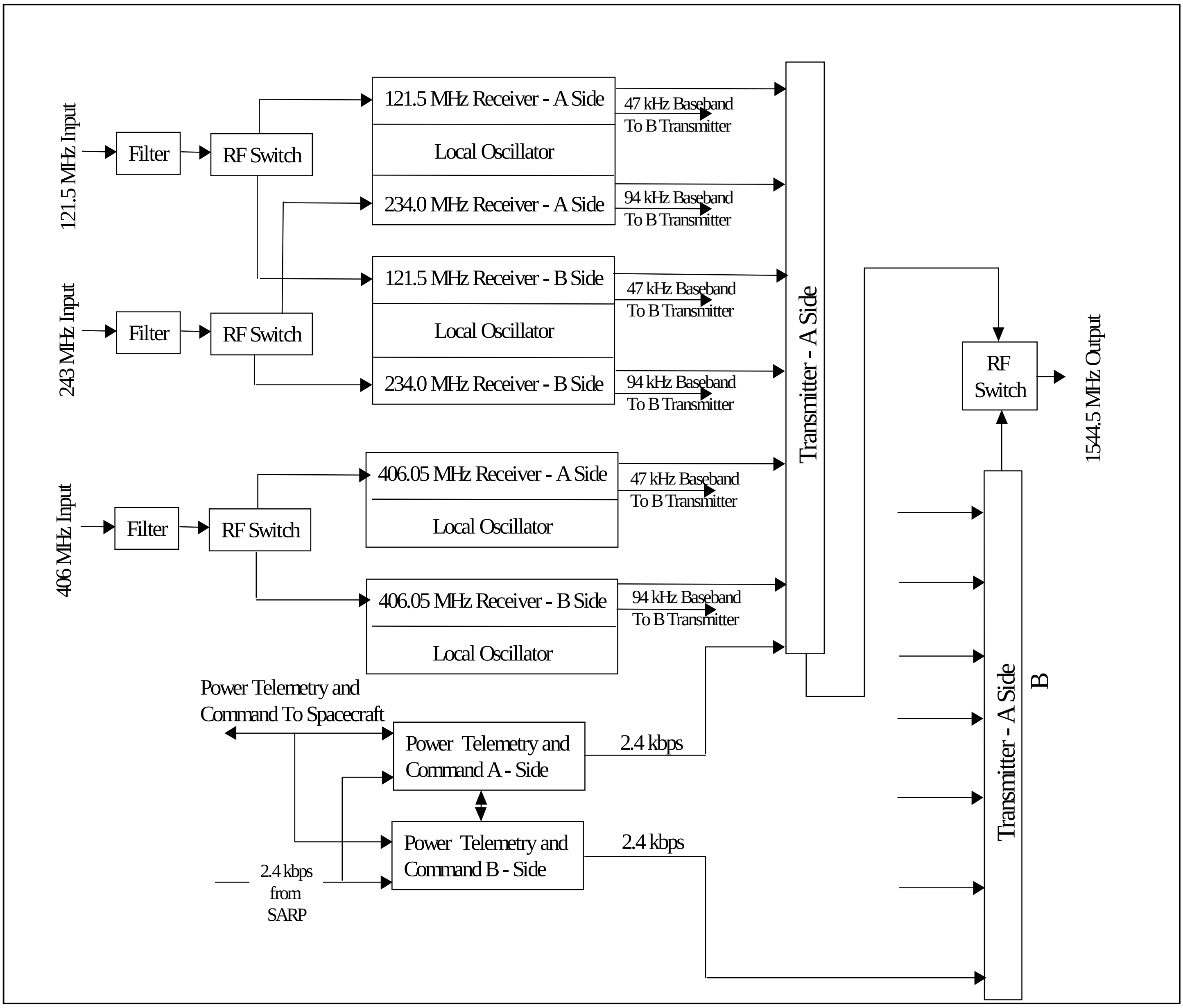

Figure 4: Sarsat LEO Search and Rescue Repeater Functional Diagram

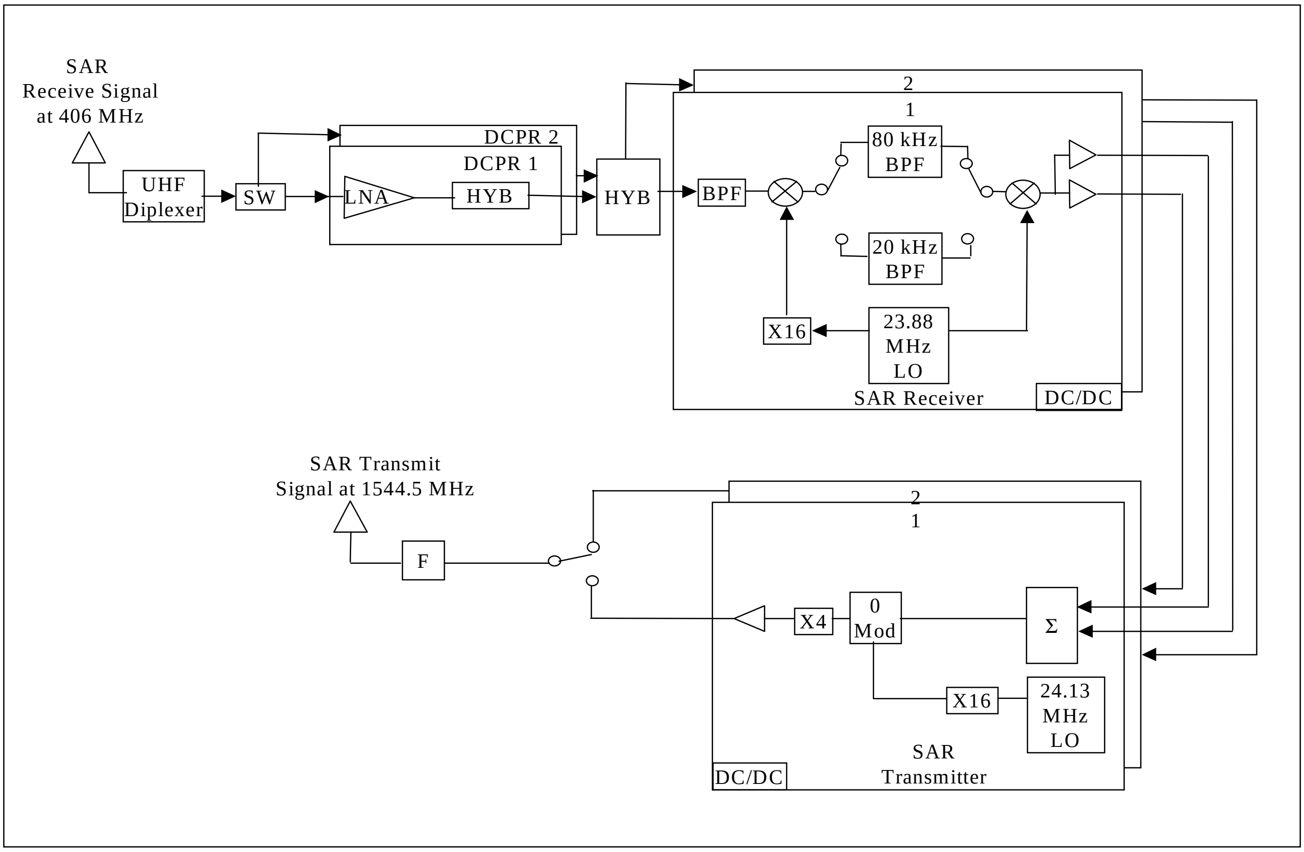

Figure 5: GOES Search and Rescue Repeater Functional Diagram

GROUND SEGMENT

The LEOLUT and GEOLUT are the two types of Cospas-Sarsat LUTs designed to operate with the LEO and GEO SAR systems respectively. The LEOLUT computes location solutions from LEO spacecraft based on its Doppler shifts of the emergency beacon signal. The Doppler shift is a beacon signal’s frequency change caused by the motion of the spacecraft relative to the beacon. These changes in measured frequency allow the LUT to calculate a real and image solution. Subsequent passes eliminate the image solution and reduce search radius.

The U.S. operates and maintains fourteen Cospas-Sarsat LEOLUTs at seven different sites. Each U.S. LUT site is capable of tracking and processing data from two LEO spacecraft simultaneously. In figure 6, the dots represent operational LUT sites worldwide.

The GEOLUT receives and processes distress alerts signals almost as soon as the beacon is activated. There are no Doppler shifts associated with this system. The GEOLUT relies only on the data contained in the transmitted signal. In addition to beacon identification data, some 406 MHz beacon signals are encoded with position data derived from internal or external satellite navigation system, such as the U.S. Global Positioning System (GPS) or the Russian Global Navigational Satellite System (GLONASS). Both types of LUTs interface with the MCCs.

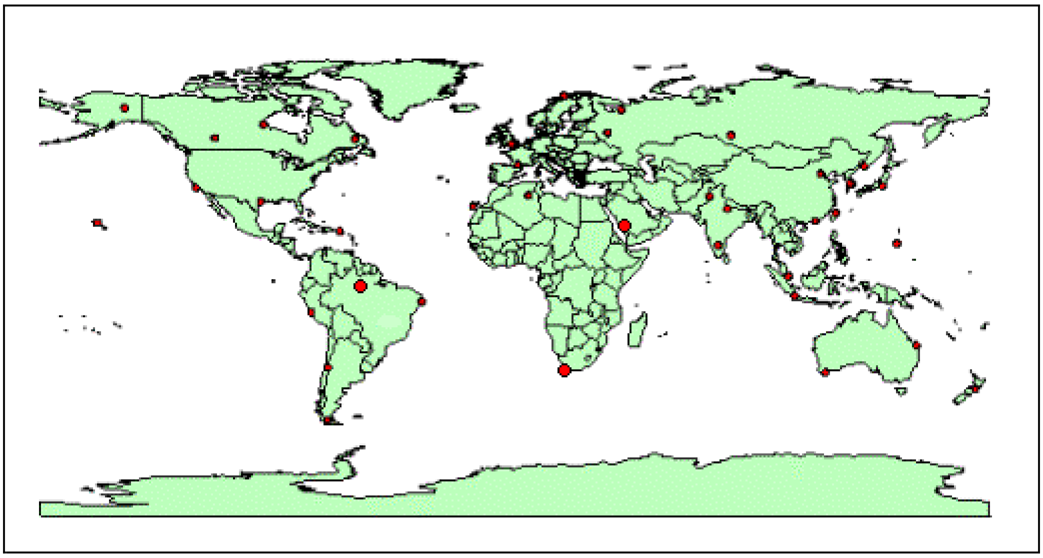

Figure 6: Operational LUT Sites

SYSTEM PERFORMANCE

SAR Events

As of June 11, 2001, 12,801 persons worldwide have been rescued and 4,214 of those rescues were within the United States. Figure 7 summarizes the number of persons saved and the number of SAR events since the start of the program (September 1982) to December 31, 2000.

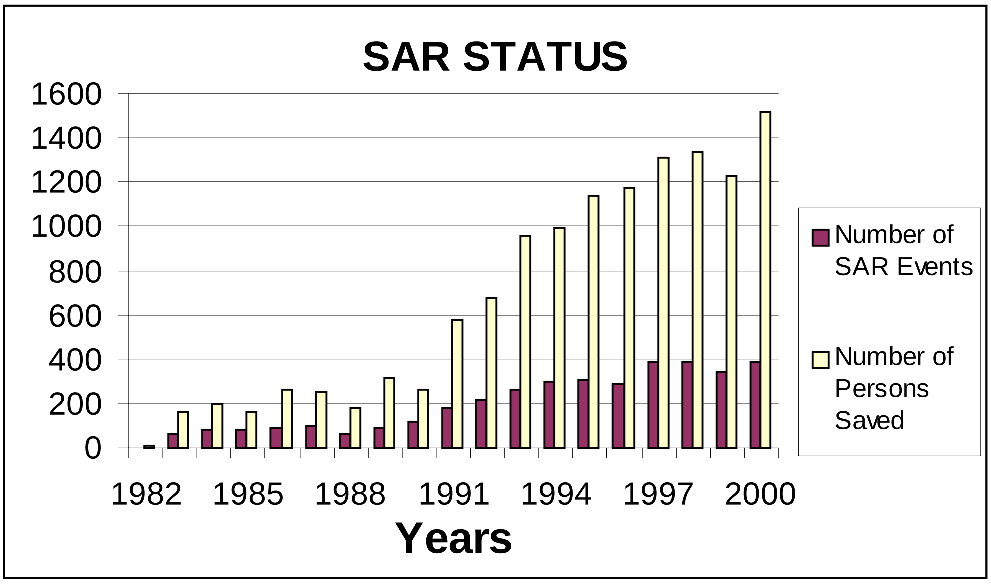

Figure 7: SAR Yearly Status

Spacecraft Status

The status of the spacecraft as of July 25, 2001 is listed in Tables 2 and 3 and the Table Legend is also listed below.

Table 2: Cospas-Sarsat LEOSAR Status

Spacecraft	Payload	SARR			SARP	
		121.5 MHz	243 MHz	406 MHz	Global	Local
Sarsat-3	NOAA-10	F	F	F	NO	NO
Sarsat-4	NOAA-11	F	F	NO	F	F
Sarsat-6	NOAA-14	F	F	F	NO	NO
Sarsat-7	NOAA-15	F	L	F	F	F
Sarsat-8	NOAA-16	F	F	F	F	F
Cospas-6	Nadezda-3	NO	NA	NA	NO	NO
Cospas-8	Nadezda-5	NO	NA	NA	NO	NO
Cospas-9	Nadezda-6	F	NA	NA	F	F

Table 3: GEOSAR Status

Satellite	Operational Status	Gain Control	BPF Mode
GOES-East/ GOES 8	F	Fixed	Narrowband
GOES-West/ GOES 10	F	AGC	Wideband
INSAT	L	TBD	TBD

Table Legend

AGC Automatic Gain Control
F Fully Operational
L Limited Operations
NA Not Applicable
NO Not Operational
TBD To Be Determined

System Testing

In order to preserve the integrity and ensure operability of the SAR system, system testing and monitoring are continually being performed. Two such tests were recently performed on the SARR instrumentation aboard the GOES spacecraft in an attempt to determine its optimal SARR operating mode (see Table 1). These tests are briefly discussed below.

AGC vs. Fixed Gain Mode

The first test was conducted to determine the effectiveness of the SARR AGC mode on GOES 10 as compared to the fixed gain mode on GOES 8. One beacon was radiated from an omni directional antenna located at the USMCC in Suitland, Maryland, and the signal was attenuated in 3 dB steps every 24 hours. The attenuation levels ranged from 0 dB to 15 dB and the daily throughput was collected and analyzed. GOES 8 (fixed mode) has a .6 dB path loss advantage over GOES 10. However, GOES 10 outperformed GOES 8 by a significant margin for weaker signals (see Figure 8). In addition, it was noted that the data set was small, and the daily performance of the spacecraft due to interference, unusual levels of activity or solar activity can vary considerably. For detailed information about this evaluation, refer to JC-15/Origin: USA, “GEO Performance: AGC vs. Fixed Gain Mode,” Cospas-Sarsat Joint Committee, Fifteenth Meeting, June 2, 2001.

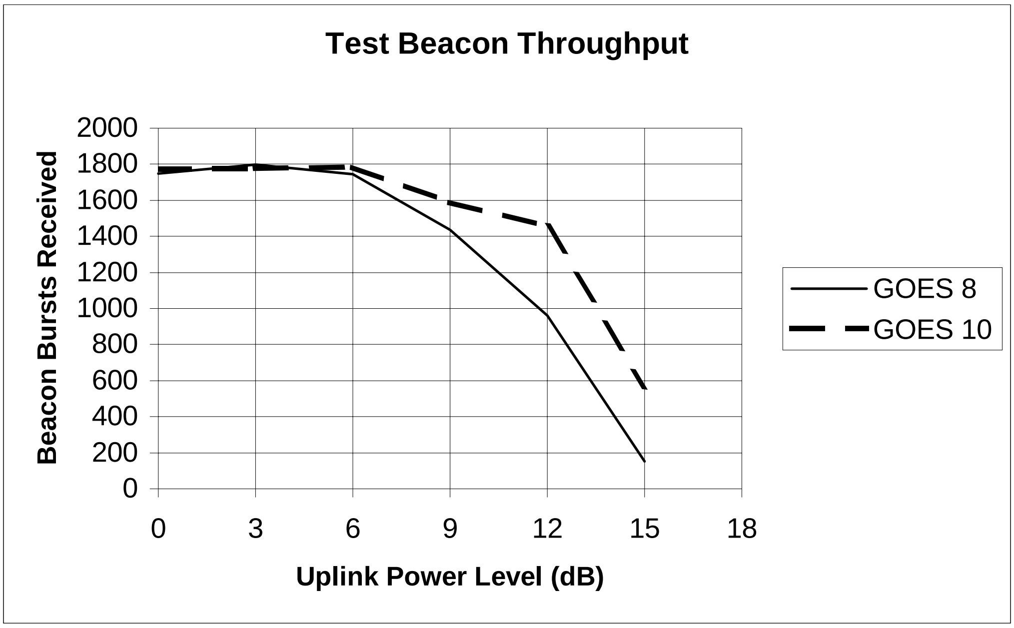

Figure 8: AGC vs. Fixed Gain Mode

<u>Narrowband vs. Wideband Mode</u>

Testing is currently being conducted to determine the performance differences between the GOES SARR BPF narrowband and wideband modes. GOES 8 is configured for the narrowband mode and GOES 10 is configured for the wideband mode. The narrowband mode should be less susceptible to harmful interference due to its narrower bandwidth. Two months of raw data have been collected and processed from GOES 8 while it was operating in an AGC wideband mode and two months while operating in an AGC narrowband mode. Cursory evaluations of the data reveal little difference in performance between the two satellites. However, GOES 8 is subjected to more interference and activity in its footprint than GOES 10. Testing will continue and a more detailed analysis performed and formally documented.

Interference Monitoring

A recent addition to the U.S. Sarsat program is the Automatic Interference Monitoring System (AIMS) for reporting 406 MHz interference. The AIMS was activated May 2001 in the USMCC located at Suitland, MD. AIMS automatically tracks 406 MHz interference sites, generates a report, and sends it to the U.S. Federal Communication Commission. Reports are automatically generated when the interferer is visible for 8 passes within a 72-hour period and the search radius is less than 12 km. The search radius is a statistical analysis performed by the AIMS computer that will give a 95% probability that the interferer will be located into a given radius around a composite solution.

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[1] C/S T.003 p.2-6
[2] Ibid