SUMMARY REPORT
OF THE
406 MHz GEOSTATIONARY SYSTEM
DEMONSTRATION AND EVALUATION

C/S R.009
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COSPAS SARSAT

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of the
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Background

The Cospas-Sarsat Council requested a Demonstration and Evaluation (D&E) to confirm the expected benefits of a geostationary search and rescue (GEOSAR) satellite system. The Council further directed that the D&E should establish the GEOSAR system technical and operational performance characteristics.

The GEOSAR system is composed of geostationary Earth-orbiting satellites and their associated ground processing facilities, that have the capability to detect transmissions from Cospas-Sarsat type approved 406 MHz distress beacons. These satellites orbit at altitudes of 36,000 km at approximately 0° latitude and fixed longitudes, appropriate to the requirements of the space segment provider. Because of the high altitude and fixed orbit position of the geostationary satellites, the geostationary system has the potential to offer several complementary advantages to the low-altitude Earth-orbiting (LEOSAR) system. These advantages include near-instantaneous distress beacon detection and alerting, near-instantaneous beacon locating for beacons capable of calculating and transmitting their location, and continuous monitoring of the 406 MHz frequency band within the satellite footprint.

Goals

The goals of the D&E were to:

- characterise the technical and operational performance of the GEOSAR system;
- evaluate the operational effectiveness of the GEOSAR system and determine the benefits to search and rescue of combined LEOSAR/GEOSAR operations; and
- provide the basis for recommendations to the Cospas-Sarsat Council.

Methodology

A D&E Plan, "Cospas-Sarsat Demonstration and Evaluation Plan for 406 MHz GEOSAR Systems" (C/S R.006, October 1996), was developed to provide the framework for the D&E.

The Plan outlined ten technical and eight operational objectives for which tests were to be undertaken, with guidelines for data collection, reporting and analysis. The technical objectives were developed to address the technical compatibility of the various GEOSAR components and to establish the baseline characteristics of the GEOSAR system. The operational objectives were developed to evaluate the contribution to SAR operations of alert data provided by 406 MHz GEOSAR systems and to provide operational experience in the use of GEOSAR alerts. Data collection and evaluation for the technical and operational objectives generally took place between July 1996 and February 1998.

Participation in the D&E was open to all Cospas-Sarsat Participants. Geostationary satellites equipped with 406 MHz repeaters were available from the USA (the Geostationary Operational Environmental satellites (GOES) of NOAA), and from India (the INSAT-2A geostationary satellite from ISRO). D&E data were collected from experimental ground receiving stations in Canada, Chile, France, India, Spain and the UK. In addition, Australia, Canada, Chile, France, India, Spain, the United Kingdom and the United States contributed data in support of technical and/or operational objectives. The detailed D&E report was reviewed by the Cospas-Sarsat Joint Committee in June 1998 and submitted to the Cospas-Sarsat Council for approval in October 1998.

Results and Discussion

The successful completion of the ten technical objectives was hindered by radio frequency interference from a strong signal emanating from Peru. Because of the interfering signal which affected the two USA satellites providing coverage over the eastern part of the Pacific ocean, the Americas and most of the Atlantic ocean, several of the technical objectives could not be accomplished or completed during the time frame of the D&E. These objectives will be completed at the earliest opportunity. Despite this, the technical objectives of the D&E confirmed that:

- the GEOSAR system could detect transmitting beacons which met Cospas-Sarsat technical specifications when they were in the coverage area of a geostationary satellite;
- the GEOSAR system provided near-instantaneous detection of 406 MHz beacon transmissions;
- beacon transmissions could be detected at elevation angles as low as 0^o and a 4^o elevation angle would provide a conservative estimate of the GEOSAR satellite coverage area where reliable reception of 406 MHz alerts was assured; and
- sufficient technical data had been collected to recommend the incorporation of the GEOSAR system as a complement to the Cospas-Sarsat LEOSAR system.

Results from the eight operational objectives documented the performance and confirmed the effectiveness and benefits of the GEOSAR system. In particular, the D&E indicated that:

- the GEOSAR system provided a useful time advantage over the LEOSAR System. On average, the GEOSAR alert was received 46 minutes before the first corresponding LEOSAR alert; the median time advantage was 21 minutes;
- the GEOSAR system was a good complement to LEOSAR system. More than 85% of 406 MHz alerts within the 0° elevation angle GEOSAR satellite footprints were

detected by the GEOSAR system and valid explanations existed for cases which were not detected; and

- there were many GEOSAR alerts, not detected by the LEOSAR System, that were single burst messages or of very short transmission duration which could be indicative of a large number of inadvertent activations or beacon tests. However, a short duration transmission could also be the only indication of a catastrophic event.

The time advantage provided by the GEOSAR system near-instantaneous alerting was clearly shown to benefit the outcome of SAR events. In particular:

- additional lives and property were determined to have been saved in specific distress cases where a GEOSAR alert was received and used by SAR forces; and

- benefits of the earlier GEOSAR alert and the use of encoded position data were shown in an intercontinental road race, where personal locator beacons, some encoded with one of the new Location Protocols, were used as emergency equipment.

The completeness, accuracy, availability and 24-hour access capability of beacon registration databases were shown to be essential for the above benefits of GEOSAR system to be fully realised. The database information was used to:

- distinguish between real and false alerts and, consequently, was useful in preventing the launch of SAR resources on false alerts; and

- obtain rough location information, enabling SAR personnel to take advantage of the earlier notification provided by GEOSAR, even when encoded position information was not available in the beacon message.

The impact of the GEOSAR system on the Ground Segment of the Cospas-Sarsat System, notably processing anomalies which could result in false alerts, the workload of Cospas-Sarsat Mission Control Centres, and the GEOSAR contribution to the resolution of LEOSAR location ambiguity, were analysed and provided the following results.

- The number of undetected processing anomalies resulting in false alerts transmitted to RCCs was low. All, but three potential false alerts were eliminated through the use of effective screening measures at the MCCs, before transmission to SAR services.

- The volume of GEOSAR alert message processing varied among the Cospas-Sarsat MCCs but was considered to have minimal impact on the MCCs' workload. Furthermore, this additional workload was considered to be fully justified by the benefits of GEOSAR alerts.

- GEOSAR alert data could be used effectively to resolve LEOSAR Doppler location ambiguity, even though manual processes had to be used during the D&E.

Conclusion and Recommendations

The D&E confirmed the complementary nature of the GEOSAR system and the Cospas-Sarsat LEOSAR system. It indicated that incorporation of the GEOSAR system components as a complement to the Cospas-Sarsat LEOSAR system would generate significant benefits and would save additional lives and property. It was also concluded that the benefits would increase when location protocol beacons with the capability to encode the beacon position in the 406 MHz message come into widespread use.

The D&E highlighted the need to inform the 406 MHz beacon user community of the 406 MHz GEOSAR system performance. Greater care in the use of 406 MHz beacons will be required as inadvertent activations (even of short-term duration) would probably be detected by the GEOSAR system and could set off an unnecessary chain of events with a corresponding use of SAR resources.

As the D&E results had confirmed the expected benefits of the GEOSAR satellite system, the Cospas-Sarsat Council, at its Twenty-First Session in October 1998, decided to:

1. adopt the 406 MHz GEOSAR satellite system as an enhancement and complement to the Cospas-Sarsat LEOSAR system;

2. initiate all actions necessary for implementing this enhancement as soon as possible, including the commissioning of the experimental GEOLUTs used during the GEOSAR D&E; and

3. request the Cospas-Sarsat Secretariat to publish and widely distribute the results of the GEOSAR D&E.

In order to ensure the optimal technical and operational performance of the enhanced Cospas-Sarsat System, the Cospas-Sarsat Council further recommended that:

4. responsible administrations should establish and maintain complete, accurate, and up-to-date beacon registration databases, and make the corresponding information available to SAR agencies on a 24-hour a day basis;

5. all manufacturers, administrations and others who develop educational programs and materials, should stress the importance of proper handling, shipping, storage and testing of 406 MHz beacons in view of avoiding false alerts;

6. responsible administrations should review 406 MHz beacon test policies and procedures, and revise them as necessary to avoid possible alerts from test transmissions being forwarded to RCCs as a result of the incorporation of GEOSAR components in the Cospas-Sarsat 406 MHz system.

Benefits of the Geostationary System in Actual Cases

The saving of additional lives is a critical benefit of including a 406 MHz geostationary satellite component within the Cospas-Sarsat System. The following reports of real distress cases clearly highlight this benefit.

- **Hunters at Hall Beach, Northwest Territories, Canada**

On 15 January 1996, two native hunters from Igloolik, set out overland by snowmobile for Repulse Bay with a 406 MHz personal locator beacon (PLB) on loan from the Northwest Territories government. The weather deteriorated the next day, 16 January to a point where their snowmobile froze and they were stranded in a "whiteout". At approximately 15:00 they activated their beacon. At 15:05, the GOES-8 geostationary satellite relayed the signal and at 15:25, it was processed at the Canadian Mission Control Centre (CMCC). The PLB registry was accessed to identify the owner of the beacon as the Northwest Territories government. Within 10 minutes this information was faxed to the RCMP Operational Communication Centre in Yellowknife, which advised the Igloolik RCMP officer (at 15:55) of the PLB alert in the area. The encoded serial number of the PLB identified it as the one requisitioned by the hunters en route to Repulse Bay. At 16:07 the CMCC provided location co-ordinates, which indicated that the hunters were in the Hall Beach area. The Igloolik SAR Committee transferred SAR responsibility to Hall Beach, and by 21:00, the hunters had been found and rescued.

- **Fishing Vessel Incident At Sea, off the California/Oregon Border, United States**

On 1 December 1996, the 40 foot fishing vessel Beach King capsized when hit by a large wave. The vessel was fishing in 20 - 25 foot seas near the California/Oregon border. The crew of three was not able to transmit a mayday call or signal a distress in any way; however, the vessel's 406 MHz EPIRB activated automatically when the vessel capsized. The transmission from the 406 MHz EPIRB was relayed via the GOES-9 satellite to the USMCC and then on to RCC Seattle. RCC Seattle forwarded the information to the Coast Guard Operations Centres in North Bend, Oregon and Humboldt Bay, California. The Operations Centres issued an Urgent Marine Information Broadcast while the RCC called the emergency point of contact listed in the beacon registration database. Upon learning that the Beach King was fishing off the Klamath River, the RCC dispatched a rescue helicopter to search the area. The helicopter located the capsized vessel and hoisted two crew members from the cold (11^{o} Celsius) water. The third crew member was never found. The helicopter transported the crew members to a local hospital where one of the crew required intensive care treatment for hypothermia. Post analysis of the case confirmed that the crew members were not wearing survival suits or flotation devices and would have perished had they remained in the water much longer.

The first notification of distress was an unlocated alert from a geostationary satellite, which arrived at the USMCC 47 minutes before a located alert from a low Earth-orbiting satellite. The Coast Guard was able to investigate the alert (i.e., call the point of contact, check the harbour, make radio call-outs, and launch a helicopter) so that rescue forces could proceed to the vicinity of the distress immediately, even without the located alert data. This resulted in saving the lives of two people.

SUMMARY REPORT ON THE DEMONSTRATION AND EVALUATION OF THE 406 MHz GEOSAR SYSTEM

1. BACKGROUND

The Cospas-Sarsat Council directed that a Demonstration and Evaluation (D&E) of the 406 MHz geostationary satellite systems for search and rescue (GEOSAR) should be performed to confirm the benefits of including geostationary satellites and ground segment elements as a complement to the Cospas-Sarsat 406 MHz low-altitude Earth orbiting satellite system for SAR (LEOSAR), and to establish GEOSAR technical and operational performance characteristics.

1.1 GEOSAR and LEOSAR Systems Description

The 406 MHz GEOSAR system is composed of geostationary Earth-orbiting satellites and their associated ground processing facilities, known as GEOSAR local user terminals (GEOLUTs). The system has the capability to detect transmissions from Cospas-Sarsat type approved 406 MHz distress beacons within its field of view, but cannot provide location information if beacon position data is not included in the transmitted digital message. Geostationary satellites orbit at altitudes of 36,000 km at approximately 0° latitude relative to the Earth, and at fixed longitudes appropriate to the requirements of the space provider. Three geostationary satellites equipped with 406 MHz repeaters (the GOES-8 and GOES-9 satellites, provided by the United States and the INSAT-2A satellite, provided by India) comprised the GEOSAR space segment for the D&E. The GEOSAR satellites footprints are centred over the equator and do not reach the geographic poles.

The Cospas-Sarsat LEOSAR system is an international satellite system designed to assist SAR operations by providing locations of distress beacons operating on 121.5 or 406 MHz. The System is composed of satellites in polar low-altitude Earth-orbit (LEO) and ground receiving stations or ‘local user terminals’ (LEOLUTs). The current LEOSAR System detects transmissions from 121.5 MHz and 406 MHz beacons and, using the Doppler effect resulting from the movement of the satellite relative to a transmitting distress beacon, calculates the position of the distress beacon (referred to as the Doppler location).

1.2 Combined LEO/GEO Operation

Because of the geostationary satellites high altitude and relatively fixed position over the Earth, the GEOSAR system offers several advantages to the LEOSAR System. These advantages include near-instantaneous beacon detection and alerting, near-instantaneous beacon locating for beacons capable of calculating and transmitting their location, and continuous monitoring of the 406 MHz frequency band within the satellite footprint.

With the existing constellation of polar orbiting satellites, the time from activation of a beacon to overflight of the beacon's location and detection by a LEOSAR satellite can be in excess of one hour. This "waiting time" is a function of the available satellite constellation, the location of the beacon, and the available LEOLUTs. The "waiting time" for the LEOSAR System is greatest for a beacon at the equator and shortest for a beacon at the poles.

The LEOSAR and GEOSAR systems are, therefore, complementary in respect of their most effective coverage areas and detection capabilities. With the large number of 406 MHz beacons in use which do not have encoded position information as part of the transmitted message, the GEOSAR system provides for near-instantaneous alerting without location data, whereas the LEOSAR system provides location data but with some inherent system delays.

In conjunction with float, or flight plans, and beacon registration information, a GEOSAR distress alert provided shortly after beacon activation (probably earlier than the first LEOSAR alert), may allow search and rescue (SAR) forces to begin mission planning or initiate a search at an earlier time corresponding to the time advantage provided by the GEOSAR system. If there is no encoded position data available in the beacon, LEOSAR location information, when it becomes available, can be provided to SAR forces to focus their search.

In light of the near-instantaneous alerting capability and the distress alerting time advantage provided by a GEOSAR system, there is a potential for considerable benefit to search and rescue operations if the GEOSAR system can be used as a complement to the Cospas-Sarsat System.

The full benefits of the GEOSAR system are realised when 406 MHz beacons have the capability to encode their position in the emitted digital message. 406 MHz beacons with this capability have been developed and are commercially available. With this type of 'location protocol' beacons the 406 MHz GEOSAR system provides both near-instantaneous alerting and location data to SAR services.

2. D&E PLAN AND SYSTEM CONFIGURATION

2.1 D&E Plan

A detailed plan, "Cospas-Sarsat Demonstration and Evaluation Plan for 406 MHz GEOSAR Systems" (C/S R.006) was developed to:

- ensure that the D&E activities were conducted in a standard manner;
- ensure data would be collected on an agreed basis using compatible formats; and
- establish the process for translating the results into a set of recommendations to be presented to the Cospas-Sarsat Council.

The D&E Plan was divided into technical and operational areas of study, with ten technical and eight operational objectives specifically identified. The technical objectives addressed the compatibility of the various GEOSAR components and the determination of the baseline performance characteristics of those components. The operational objectives were structured to assess the performance and effectiveness of the GEOSAR system in supporting actual SAR operations.

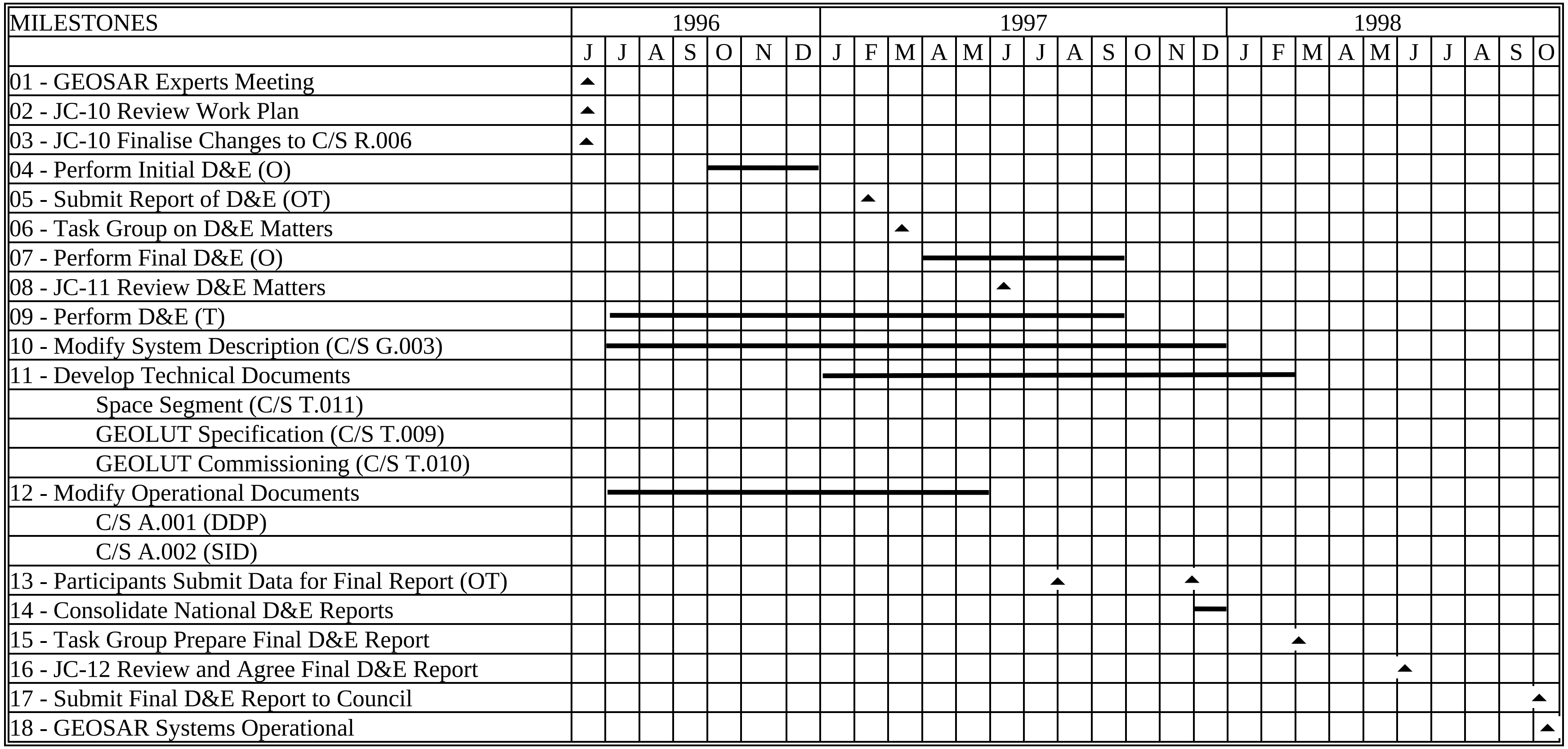
Figure 2.1 provides the complete timeline and milestone dates for the various activities of the D&E, including the development of the technical and operational documents which would be required to support the inclusion of the GEOSAR system as a component of the Cospas-Sarsat System. Data collection for the D&E took place from July 1996 to February 1998.

2.2 D&E Participants

During the 406 MHz GEOSAR D&E, GEOSAR alert data from the experimental GEOLUTs was distributed within the existing Cospas-Sarsat Ground Segment as if it were operational data. Therefore, the D&E was open to participation and input from all Cospas-Sarsat Participants. Technical objectives were designed to be completed by the operators of the experimental GEOLUTs, with the operational objectives to be completed by any MCC Operator receiving GEOSAR alert data. Canada, France, India, the United Kingdom and the United States, submitted data supporting specific technical objectives. Australia, Canada, France, India, Spain, the United Kingdom and the United States submitted data in support of the operational objectives. Several other Participants, including Algeria, Chile, Japan and Russia supplied data for analysis and contributed to the development and drafting of the D&E Report (document C/S R.008).

Figure 2.1: GEOSAR D&E Milestones

as of: 18 June 97



Notes: O - Operational Objectives
T - Technical Objectives
OT- Both

2.3 LEOSAR and GEOSAR Systems Configuration

2.3.1 Status/Description of Ground Segment

The ground segment equipment in place for the D&E consisted of:

- experimental GEOLUTs located in Canada, Chile, France, India, Spain, and the United Kingdom; and
- the existing operational Cospas-Sarsat Ground Segment equipment, which at the end of the D&E data collection period included 39 LEOLUTs and 22 MCCs.

It should be noted that not all LEOLUTs had the capability to process 406 MHz SARR (search and rescue repeater) data from the Sarsat spacecraft (see Table 2.1). In some cases this may have impacted on some D&E results as beacon transmissions may have been detected by overflying LEOSAR satellites with only SARR capability, but not processed because there were no LEOLUTs with mutual visibility with the capability to process the SARR channel (see section 2.3.2 below).

2.3.2 Status/Description of Space Segment

2.3.2.1 <u>406 MHz LEOSAR Space Segment</u>

The Cospas-Sarsat LEOSAR satellite constellation during the D&E period is summarised in Table 2.1. The 406 MHz instrumentation onboard the LEOSAR satellites consists of a search and rescue processor (SARP) and, on Sarsat satellites only, a search and rescue repeater (SARR). The SARP provides "processed" data consisting of beacon identification, received power level and frequency and time measurements for use in location calculation by the LEOLUTs. The SARP operates in both local and global modes so that complete world coverage is attained. The SARR, as a repeater, is effective only in local mode when mutual visibility exists between a satellite, a beacon, and a LEOLUT. With the SARR, beacon identification and frequency and time measurements are accomplished in the LEOLUT using a process commonly referred to as ground-SARP (G-SARP). Not all LEOLUTs had the capability to perform G-SARP processing.

Six LEOSAR satellites with 406 MHz capability were in orbit during the D&E, two more than the nominal complement of four that the Cospas-Sarsat Space Segment Providers have agreed to operate. The additional satellites had the effect of decreasing the time it would take for the LEOSAR System satellites to come within sight of randomly positioned beacons, and thus may have lowered the potential time advantage that a GEOSAR system would have compared to the nominal Cospas-Sarsat System.

Table 2.1: LEOSAR Satellite Configuration and Operational 406 MHz SAR Equipment

Satellite	406 Local Mode	406 Global Mode
COSPAS-4*	SAR Processor (SARP)	SAR Processor (SARP)
COSPAS-6	SAR Processor (SARP)	SAR Processor (SARP)
SARSAT-2	SAR Repeater (SARR)	Not Operational
SARSAT-3	SAR Repeater (SARR)	Not Operational
SARSAT-4	SAR Processor (SARP)	SAR Processor (SARP)
SARSAT-6	SAR Repeater (SARR)	Not Operational

* *limited operation in southern hemisphere*

Table 2.2: GEOSAR Satellites and Associated GEOLUTs

Satellite	GEOLUT					
	Canada	Chile	France*	India	Spain	U K
GOES-8	√	√	√		√	√
GOES-9	√					
INSAT-2A				√		

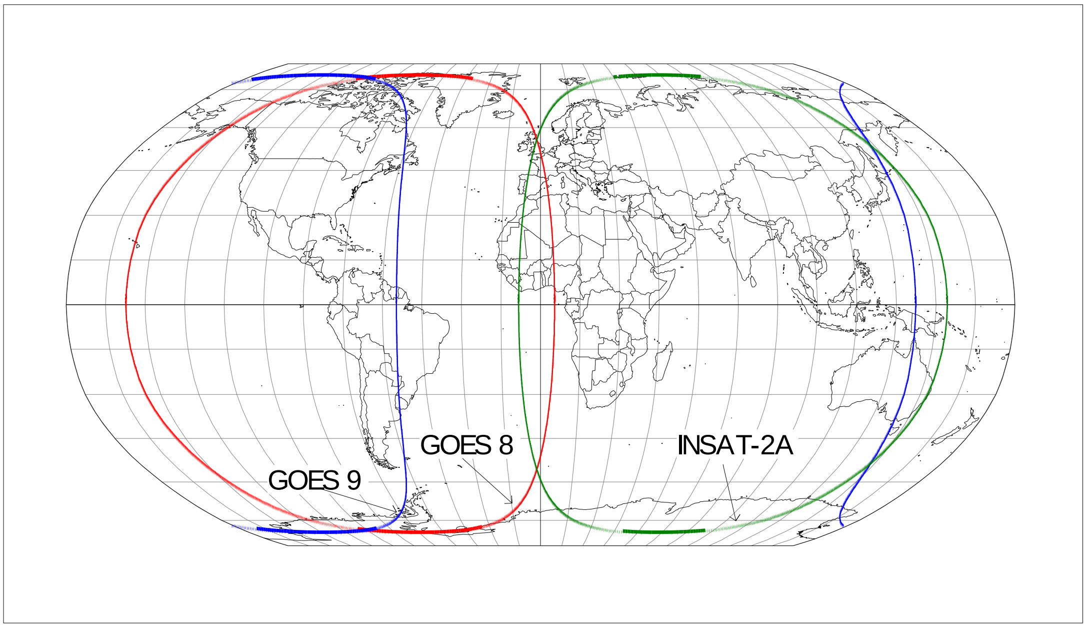
Note France experimental GEOLUT was used for T-1, T-2 and T-7 objectives only.*

2.3.2.2 <u>406 MHz GEOSAR Space Segment</u>

The GEOSAR satellite constellation and GEOLUTs available during the D&E are reflected in Table 2.2. The theoretical footprint (coverage area) of the geostationary satellites is shown in Figure 2.2.

The coverage diagram shown in Figure 2.2 indicates that the zero degree footprint of a GEOSAR satellite covers about 140 degrees, 70 North to 70 South and an equivalent distance East and West of the satellite sub-point (the position on earth directly under the satellite). Although the positions of the satellites were not optimised for international SAR support and therefore the satellites were not spaced equidistant around the equator, the combined coverage of GOES-8, GOES-9 and INSAT-2A provided global GEOSAR coverage to the mid-latitudes during the D&E.

Figure 2.2: GEOSAR Satellite System Coverage during the D&E



2.3.3 Use of Beacon Simulators and Test Beacons

A number of the technical measurements for the D&E required the use of beacons with adjustable transmission power levels and coding. These stringent requirements were met by the use of computer controlled beacon simulators located at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Centre in Maryland, United States, and at the Centre National d'Etudes Spatiale (CNES), in Toulouse, France. The simulators were capable of generating signals simulating multiple beacons transmitting simultaneously. Using these simulators, beacon identification coding, frequency and power level could all be precisely varied and controlled, burst to burst.

Canada and the United States produced detailed joint technical measurements, with the United States beacon simulator providing the uplink signals, and Canada's GEOLUTs providing down-link reception and processing and documentation of the results. The French beacon simulator provided the uplink signals for some of the technical measurements undertaken by India.

Data was collected for the completion of the operational objectives by using existing operational beacon transmissions or by using special "test" coded beacons in known conditions.

2.3.4 Data Distribution Procedures Used during Demonstration and Evaluation

406 MHz GEOSAR alert messages were distributed in accordance with the “Cospas-Sarsat Data Distribution Plan” (C/S A.001) following the procedures provided for the distribution of 406 MHz unlocated alerts. That is, GEOSAR alerts received during the D&E were distributed based on the country code contained in the beacon message since the actual position of the beacon was not known from the use of GEOSAR data alone. It should be noted that there were no type-approved operational beacons providing encoded position data in use during the D&E period. In future, GEOSAR alerts containing encoded position information will be distributed to the relevant RCC based on the encoded position.

3. TECHNICAL OBJECTIVES RESULTS AND DISCUSSION

The technical objectives of the GEOSAR D&E were developed to assess the technical compatibility of the various GEOSAR components and to establish the baseline performance characteristics of the GEOSAR system. Most of the technical tests required a beacon simulator or at least one special test beacon whose power output and message content could be controlled and varied. These tests were conducted over several weeks to collect statistically valid data. Some tests, however, were performed for shorter duration using regular beacons (coded with a test protocol) operated under controlled conditions, in order to assess GEOSAR system performance with typical operational beacons.

There were ten technical objectives to be achieved during the D&E. Summary results and discussion are provided below for each of the corresponding tests. The detailed technical reports are contained in the complete report (C/S R.008). Five of the technical tests could not be completed due to radio frequency interference emanating from Peru[1] which impacted the GOES-8 and GOES-9 satellites.

Despite the fact that the interferer rendered test data unreliable for completing these technical objectives, the GEOSAR system was still able to detect beacons and provide useful operational alert data to SAR services during the interference.

3.1 Processing Threshold and System Margin (T-1)

The **processing threshold** is defined as the minimum value of the ratio of beacon carrier power to noise density (C/No) received at the GEOLUT that results in a 99% probability of detection of an error free message (PDEFM) at the GEOLUT. The **system margin** is defined as the difference between the effective isotropic radiated power (EIRP) of the beacon at threshold C/No and the EIRP of a nominal beacon, which is 37 dBm.

The test objective was to confirm the expectation that nominal Cospas-Sarsat beacons have sufficient power, and that GEOSAR system has sufficient sensitivity, for detecting and processing beacon messages with a high degree of probability, despite the fact that GEOSAR satellites orbit at a much higher altitude than LEOSAR satellites.

The test was carried out using the beacon simulators from NASA Goddard and CNES Toulouse, both of which could simulate multiple beacons at controlled frequencies, codes, and power levels. Values of C/No were provided directly by the GEOLUTs, which also logged the number of error free messages received. This provided a clear means to compute the value of C/No corresponding to the reception, without errors, of 99% of the messages sent. This value was the processing threshold at 99% PDEFM.

[1] A strong interferer, emanating from the telephone company in Juliaca, Peru, consisting of five constant components spaced approximately 1600 Hz apart within the band of 406.022 to 406.025 MHz was present from April 1997 until the end of the scheduled D&E period. This interference source was eliminated after its location was determined by the LEOSAR system and confirmed in subsequent investigation by the Peruvian authorities.

The measured system margin was the difference between the nominal Cospas-Sarsat beacon power of 5 Watts, and the recorded or calculated value of the transmitter power of the beacon simulator which produced the C/No at the processing threshold.

The results, shown in Table 3.1, came from three different GEOLUT designs (Canada, France and India), working with two different GEOSAR satellites (GOES-8 and INSAT-2A). These results clearly indicate that nominal 406 MHz beacon messages are received through the GEOSAR system (at 99% probability) with sufficient power margin.

Table 3.1: Processing Threshold and System Margin at 99% PDEFM

GEOLUT	Satellite	Processing Threshold (dBHz)	System Margin (dB)
Canada	GOES-8	26	12
France	GOES-8	28	6
India *	INSAT-2A	27.7	7

* *Results for the Indian GEOLUT were obtained using a modified but equivalent test procedure than that detailed in document C/S R.006. Specific details are available in Volume II of document C/S R.008.*

To assist in the definition of the GEOLUT specification, additional data was obtained from the Canadian GEOLUT. The corresponding results, provided in Table 3.2, indicate that a 95% probability for the reception of beacon messages could be achieved with a processing threshold (C/No) of 25 dBHz, which corresponds to signals 13 dB below the 5W (37 dBm) specification for 406 MHz beacons.

Table 3.2: Processing Threshold and System Margin at 95% PDEFM

GEOLUT	Satellite	Processing Threshold (dBHz)	System Margin (dB)
Canada	GOES-8	25	13

3.2 Message Transfer Time (T-2)

The **message transfer time (MTT)** is defined as the time between the activation of a beacon with a power output at the GEOLUT's processing threshold and the time the GEOLUT produces the first error free message.

While it is clear that beacon transmissions are relayed in real time by the GEOSAR satellites, relatively weak signals may require the integration of successive beacon transmissions in the GEOLUTs (at 50 seconds intervals, the repetition rate of 406 MHz beacon transmissions) before an error free message is produced.

The test set-up for this evaluation is identical to that reported at section 3.1, and the data was collected at the same time. Table 3.3 shows the time taken to produce the first error free message, with beacon output power at the GEOLUT processing threshold reported in section 3.1 (see Table 3.1). Results are given for 50% (MTT-50), and for 90% (MTT-90), of the transmitting beacons. The variations of results for individual GEOLUTs were probably due to processing differences between the experimental GEOLUTs, but might also have been influenced by the downlink margins.

Table 3.3: Message Transfer Times at the Processing Threshold with 99% PDEFM

GEOLUT	Satellite	MTT 50 (Seconds)	MTT 90 (Seconds)
Canada	GOES-8	50	350
France	GOES-8	240	780
India *	INSAT-2A	no report	618

Table 3.4 provides the message transfer times measured by Canada for a 95% PDEFM (corresponding to the GEOLUT specification) and beacon power output at the GEOLUT processing threshold of 25 dBHz (see also Table 3.2).

Table 3.4: Message Transfer Times at the Processing Threshold with 95% PDEFM

GEOLUT	Satellite	MTT 50 (Seconds)	MTT 90 (Seconds)
Canada	GOES-8	50	350

Although they do not indicate the typical message transfer time characteristic of an operational GEOLUT and operational beacons, the above values, obtained for beacon output power settings at the processing threshold of the GEOLUT, clearly show the GEOSAR system capability to provide a very short alerting time for nominal Cospas-Sarsat 406 MHz beacons.

3.3 Carrier Frequency Measurement Accuracy (T-3)

The objective of this test was to measure the accuracy with which the GEOSAR system could measure the carrier frequency of a beacon transmission. This measurement may be used to improve the accuracy of the Doppler position estimates produced by the LEOSAR System, when beacon signals are detected simultaneously by both systems. The accuracy is expressed as the difference between the measured frequency and the actual frequency of the beacon transmission.

The test set-up for this objective was identical to that used in section 3.1 except that the transmitted power of the simulated beacon was held constant at the nominal value of 5 Watts (37 dBm).

Using the GOES-8 satellite and the Canadian GEOLUT, the frequency measurement of the test beacon operating at 406.025 MHz with an output power of 37 dBm was found to be an average of 407.6 Hz higher than the actual frequency being transmitted. The short-term standard deviation of this measurement over a six-hour period was 4.4 Hz. Temperature sensitive components within the satellite repeater caused a 24 hour period cyclic variation of approximately 50 Hz. The balance of the measurement offset was due to frequency shifts caused by the GEOSAR satellite and the GEOLUT frequency down conversion process.

The test results show that, provided some calibration of the frequency bias is performed, the accuracy of the beacon carrier frequency measurement by a GEOLUT is sufficient to allow combining this data with LEOSAR Doppler shift measurements, in view of possibly improving the LEOLUT Doppler position estimates (see section 3.10).

3.4 Beacon Processing Capacity (T-4)

The objective of this test was to determine the number of simultaneous beacons a GEOSAR system can process before its probability of detection of an error free message (PDEFM) and message transfer time (MTT) performance degrade. The criterion chosen to evaluate the GEOSAR system beacon processing capacity was the number of 406 MHz beacons at nominal power (37 dBm) which result in a reduction of PDEFM from 100% to 99%. The impact on MTT performance was to be noted during the test but was not included in the capacity criterion.

The methodology for the test was to use the NASA beacon simulator to add increasing numbers of beacons transmissions and to determine the values of PDEFM and MTT for GOES-8 and GOES-9. The French beacon simulator at CNES provided similar support to India’s capacity test with INSAT-2A.

However, the interfering signal from Peru (see section 3.5) made it impractical to attempt this test for the GOES satellites. The GOES/Canadian GEOLUT capacity test will be rescheduled as soon as possible and the results reported at a later time.

In November 1997, India performed a modified beacon processing capacity test using the CNES beacon simulator, INSAT-2A and the Indian GEOLUT. The nature of the test was different from that described above. It consisted primarily of determining how many of a number of simulated beacons could be detected within a 10 minute period. This was carried out using 6000 Hz and 7000 Hz GEOLUT bandwidths and beacon frequency separation of 200 to 500 Hz. Beacon bursts were programmed for a 50 second repetition period. No simultaneous bursts were programmed. The results of the test are summarised in Table 3.5.

During the testing period, a number of actual test and operational beacons were also detected (see Table 3.5).

Table 3.5: INSAT-2A Beacon Processing Capacity Test Results

	Beacon Separation (Hz)	GEOLUT Bandwidth (Hz)	Number Simulated Beacons	Simulated Beacons Detected	Other Beacons Detected	Total Beacons Detected	Detected Within 10 Minutes
1	500	6,000	10	9	5	14	13
2	500	6,000	10	9	3	12	12
3	500	6,000	10	10	4	14	12
4	500	7,000	15	12	0	12	12
5	500	7,000	15	12	1	13	5
6	200	7,000	15	14	2	16	14
7	200	7,000	15	14	2	16	15
8	200	7,000	15	10	0	10	10
9	200	7,000	15	14	3	17	13
10	200	7,000	15	15	3	18	12

The tests indicated that the INSAT-2A satellite and experimental GEOLUT system could detect 88% of the simulated beacons in bandwidths of 6000 and 7000 Hz, when 10 and 15 simulated beacons (13 to 18 beacons in total) were transmitting simultaneously.

Since the INSAT-2A test results could not be used to determine the degree of degradation of PDEFM and message transfer times which is expected to occur as the number of simultaneous beacons increased beyond the system design capacity, the T-4 capacity test detailed in document C/S R.006 will be carried out as soon as practical.

If the capacity is not considered adequate for the expected levels of beacon activity, decisions on a more efficient use of the frequency band may be required.

3.5 Impact of Interference (T-5)

The purpose of this test was to evaluate the ability of the GEOLUT to provide valid alert messages and to suppress invalid messages in the presence of various types and strengths of interference and noise in the 406 MHz frequency band. The results of the evaluation could be used to make recommendations concerning modifications to the GEOLUT systems in order to increase their ability to tolerate interference without unnecessarily degrading their ability to recover valid 406 MHz beacon messages.

The planned test procedure was to uplink a known standard 406 MHz beacon signal plus various types of controlled interference to the GEOSAR satellites and to then monitor the effects of the interference on the GEOLUT ability to correctly recover and process the standard beacon signal.

However, due to the presence of the strong uncontrolled interference from Peru (see note 1 on page 3-1), it was not possible to perform the controlled interference portion of the test. The test objective T-5 will be completed according to the procedures described in document C/S R.006 as soon as practical.

Since it was not possible to find a period which was free of interference, a modified test was performed on 28 April 1997 in the presence of the interfering signal. The test was a modification of the “processing threshold” test (T-1) using a test procedure similar to that described in section 3.1. The data obtained were compared to the similar data set obtained during the autumn of 1996, before the interferer was radiating. Only about 20% of the beacon bursts above threshold were recovered in the presence of the interfering signal as compared to about 90% without the interfering signal.

This significantly reduced message throughput could result in a loss of alert data, an increase in the message transfer time, and bit errors in the recovered 406 MHz beacon message. However, as noted in the introduction to section 3, the GEOSAR system was still able to reliably detect beacons and provide useful operational alert data to SAR services during the interference.

3.6 GEOSAR Satellite Coverage (T-6)

The objective of this test was to confirm the GEOSAR satellite footprints, within which detection of nominal Cospas-Sarsat beacons is expected.

Although the footprints can be calculated theoretically from technical considerations, trials with operational beacons were used to confirm coverage. Beacons were carried by a number of expeditions by sea, air and land to locations suitable for testing coverage. Tests of beacon detections near the sub-orbital point of the geostationary satellites were performed to determine if high beacon-to-satellite elevation angles adversely affect detection, and tests near the edge of coverage were performed to determine the system performance where the elevation angle tends toward zero degrees.

There were eleven expeditions: three led by Australia, two led by the United Kingdom, three by the United States, and three by France. Table 3.6 summarises the expeditions, indicating the lead country for the test, the satellites, GEOLUTs, test locations, dates, and maximum or minimum elevation achieved. Figure 3.1 shows the GEOSAR zero degree elevation angle footprints of the satellites and the expedition areas. The angles measured were based on geometric line-of-sight and did not take atmospheric refraction into account.

3.6.1 Beacon Detection at Sub-Orbital Point

The probability of detection of beacons near the sub-orbital points, measured by the Malcolm Baldridge expedition (No.2 in Table 3.6), appeared to be unaffected by the low beacon antenna gain in the vertical direction, even at elevation angles approaching 80 degrees. This probably occurred because of reflections from the metallic surfaces of super structure of the ship which were directed towards the satellite, and possibly because of the limited rolling and pitching motion of the ship which would move the antenna null away from the vertical. This finding is significant for ships at sea near the sub-orbital points of GEOSAR satellites.

On the land side, the French expedition to Guyana[2] achieved successful detections, with vertical beacon antennas, to elevation angles of 63 degrees. The signal power received at the satellite was improved by 9 dB if the beacon antenna was tilted from the vertical and was further enhanced by 6 to 7 dB if the antenna was laid flat on the ground (parallel to the earth's surface).

3.6.2 Beacon Detection at Edge of Coverage

Coverage close to the edge of the footprint degraded slowly as the zero degree elevation angle contour was approached. A significant drop in received signal strength was observed between two and one degrees of elevation, primarily caused by multi-path effects. Multi-path is the term used to describe effects of the same signal arriving at a receiver via two (or more) paths of different lengths. Depending on the difference of the path lengths of the signals, they will be increased or decreased in strength. If the signal components arrive in-phase they will build, if they arrive out-of-phase they will tend to cancel one another, and thereby reduce the power of the received signal.

The Ile de France expedition showed that over land, generally the probability of detection (PD) remained at or above 0.5 (50%) above 1 degree elevation, with some beacons detected at elevation angles as low as - 0.5° to - 0.7° (Figures 3.2 and 3.3).

At sea, the Turakina voyages between Sydney and Auckland (No. 8 and 9 in Table 3.6), showed that a 406 MHz EPIRB could be detected at the edge of the INSAT-2A coverage down to -0.6° elevation during the out-going voyage and -0.9° on the return voyage. Similar results were obtained with GOES-8 in the North sea and in the gulf of Alaska (see No. 1, 3, 4, and 7 in Table 3.6).

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[2] Some Experimentation with the New Location Protocols by P. Pressecq/B. Roger-CEIS TM France and H. Castetbert/L. Fourcade – CNES, France. Proceedings of the 1996 Cospas-Sarsat Seminar, Workshop No. 3 - Presentation No. 6

The T-6 test results analysis showed that detection at low elevation angles was complicated by a number of factors, the most important of which were sensitivity to obstructions and multi-path effects. For these reasons, and the slight movement of the GEOSAR satellites, it was difficult to predict with assurance a minimum elevation angle, and hence footprint, within which beacon detection would be reasonably assured.

Not withstanding the foregoing, the test results from a beacon in northern Canada in representative terrain (hilly to 2000 feet MSL) produced a minimum reception elevation angle of 3.0 degrees. This result coupled with the uncertainty of position of the satellite (+/- 0.5 degree), suggested that 4° could be adopted as a conservative estimate of the minimum elevation angle required to assure reliable GEOSAR reception of 406 MHz beacons transmissions on land.

A 4° minimum elevation angle will be used to define the nominal coverage area of 406 MHz GEOSAR satellites.

Table 3.6 Summary of T-6 Coverage Tests

	Expedition Name	Lead Country	Satellites	GEOLUTs	Test Locations	Test Date	Satellite Elevation Min	Satellite Elevation Max
1	North Sea	United Kingdom	GOES-8	United Kingdom	North Sea	26/03/96 29/03/97	- 0.9*	0.7
2	Malcolm Baldridge	United States	GOES-8.	Canadian	Panama	04/05/96	69.0	80.0
3	Miller Freeman	United States	GOES-8 GOES-9	Canadian	Alaska Gulf	15/07/96 19/07/96	- 0.1* 21.4	2.8 30.7
4	North Sea Return	United Kingdom	GOES-8	United Kingdom	North Sea	15/11/96 17/11/96	- 0.4*	1.7
5	Ile de France	France	GOES-8	Canadian	France	20/01/97 23/01/97	- 0.7 0.4 *	3.0 3.0
6	North Canada	United States	GOES-8 GOES-9	Canadian	Canada Polar circle	06/06/97 18/09/97	1.1* 3.0	5.7 13.2
7	Msc Lauren	Australia	GOES-9 INSAT-2A	Canadian Indian	Australia	02/10/97 12/10/97	- 0.9* 1.88	4.8 32.4
8	Turakina	Australia	INSAT-2A	Indian	Australia New Zealand	23/10/97 27/10/97	- 0.6*	1.9
9	Turakina return	Australia	INSAT-2A	Indian	New Zealand Australia	03/11/97	- 0.9*	33.0
10	Brittany	France	INSAT-2A GOES-8	Canadian	France	28/11/97 03/12/97	- 0.3* 1.4	4.9 3.5
11	Guyana	France	GOES-8	French	Guyana	May 96		63

(*) Last received burst elevation angle

Figure 3.1: Map of Expedition Routes For T-6 Coverage Tests

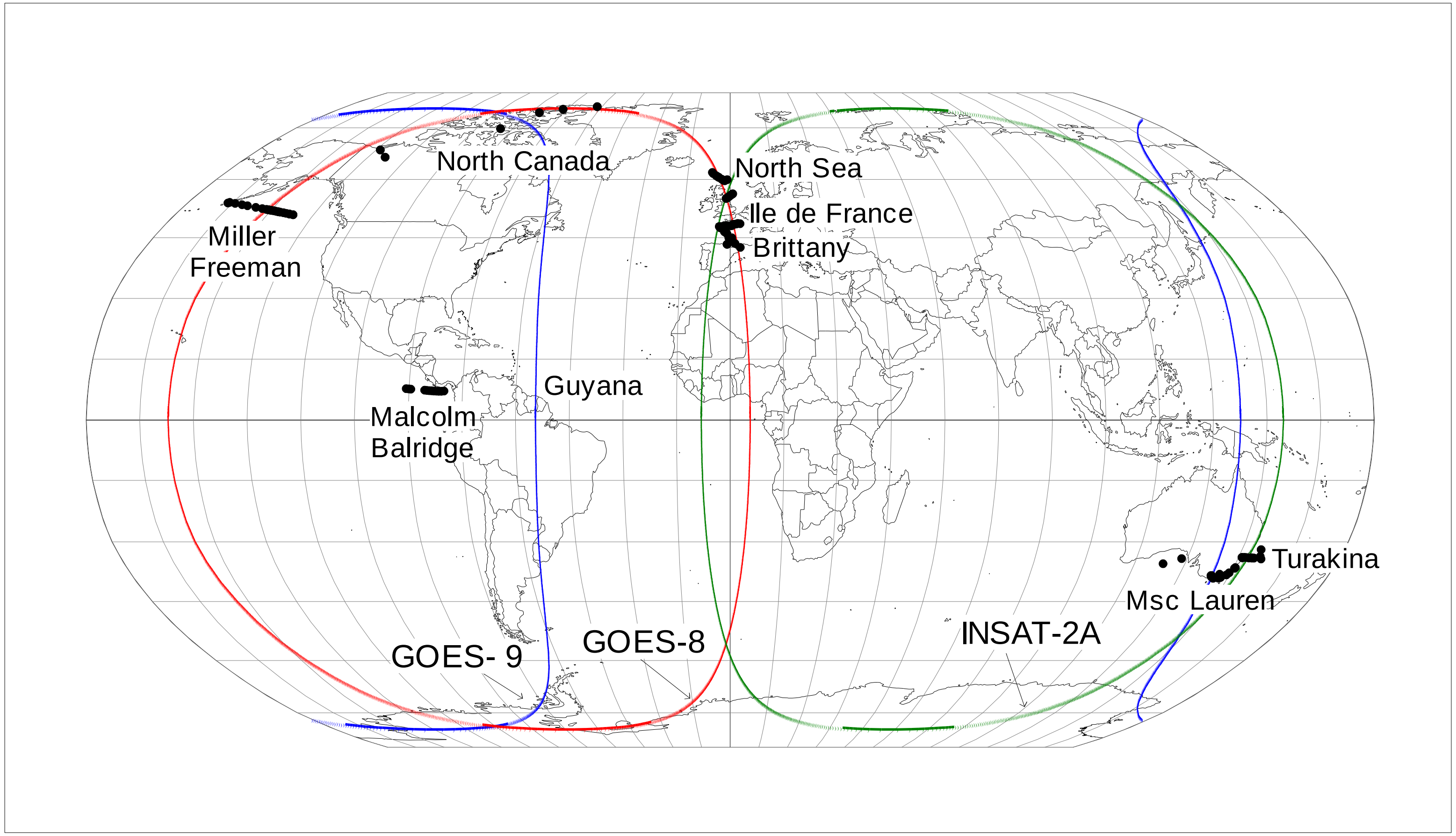


Figure 3.2: Ile de France Expedition Routes, Coverage and Elevation Angles to Satellite GOES-8

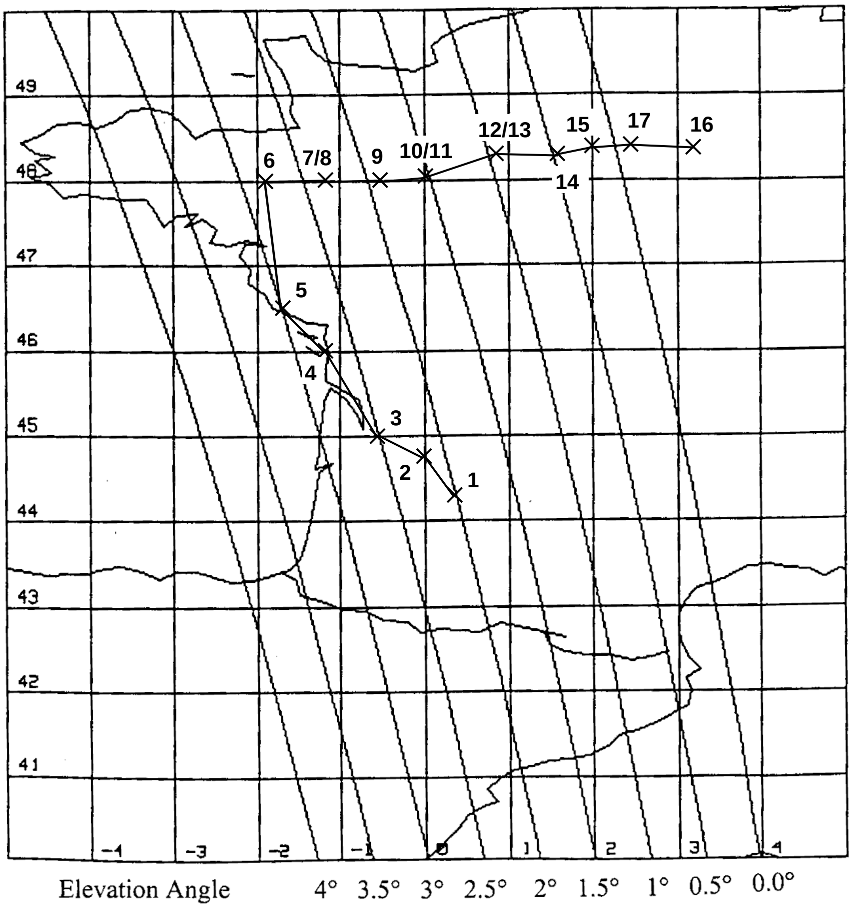
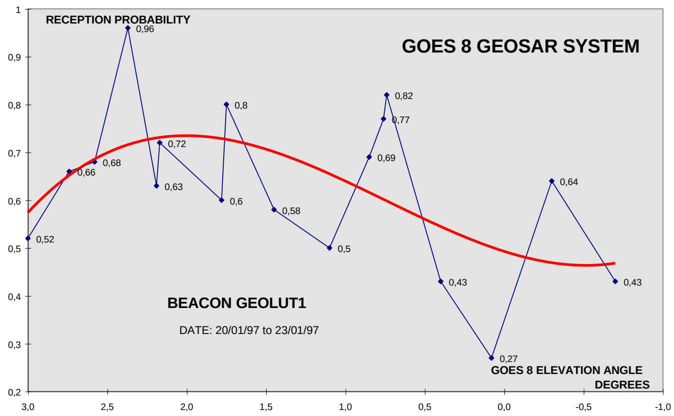


Figure 3.3: Reception Probability and GOES-8 Elevation Angle (Ile de France expedition)



3.7 Impact of Updating Encoded Position Data (T-7)

The objective of this test was to determine the effects on GEOLUT processing of changing the encoded position data, in both the protected data fields PDF-1 and PDF-2 of the 406 MHz beacon messages.

Some 406 MHz beacons are able to periodically update position data encoded in their digital message. This changing beacon message may impact on the PDEFM and MTT of the GEOLUT (see sections 3.1 and 3.2). The results of the test could be used to specify the minimum time interval between position updates. The Cospas-Sarsat beacon specifications, as of October 1999 (C/S T.001, Issue 3, Revision 3) require an interval not less than 20 minutes between updates.

The test was based on the “Processing Threshold” and “Message Transfer Time” methodology (T-1), modified so that the position data in the code is changed in each successive simulated beacon message. The scenario was to be repeated ten times for each power level and the resulting changes to PDEFM and MTTs noted. The test was not completed because of the interferer located in Peru (see section 3.5) and will be rescheduled for completion as soon as possible.

France carried out a modified test in Guyana (see section 3.6) using a GPS encoded beacon which changed its encoded position in real time. Messages were stored in the experimental GEOLUT and later retrieved for analysis. It was found that the position data decoded by the GEOLUT were generally accurate down to transmitted power levels of 33 dBm, but below that power level, uncorrectable bit errors occurred. It was also determined that the second protected field (PDF-2) was more prone to bit errors than the first protected field (PDF-1).

3.8 System Processing Anomalies (T-8)

This test was designed to assess the number and causes of system processing anomalies which could result in false alerts, including any possibly produced by the beacon self-test signal, which has an inverted frame synchronisation bit pattern. This test was not completed due to the Peruvian interferer, but system processing anomalies and false alerts were monitored as part of the operational tests (section 4.5).

New beacon processing requirements have been included in the GEOLUT specification that should further reduce the number of false alerts due to processing anomalies. The T-8 test will be completed as soon as possible.

3.9 Impact of System Beacons (T-9)

This test objective was to assess the impact of 406 MHz orbitography and reference beacons on the available GEOSAR capacity and the message transfer time of the GEOLUT. This test was not completed due to the Peruvian interference problem (section 3.5). However, a decision has already been made by the Cospas-Sarsat Council which requires changing the carrier frequency of all orbitography and test beacons to 406.022 MHz, instead of the channel 406.025 MHz now reserved for distress beacons.

3.10 Combined LEOSAR/GEOSAR Operations (T-10)

The test objective was to characterise possible additional enhancements provided by GEOSAR data, in the processing and distribution of 406 MHz LEOSAR alerts. Such possible processing enhancements include:

- combined processing of LEO and GEO data at the LEOLUT to improve the LEOSAR Doppler position estimates, by incorporating the actual beacon frequency measured by the GEOSAR system into the Doppler position calculation; and
- the use of the GEOSAR measured frequency bias to increase the probability of correctly discriminating between the “true” Doppler position and its image.

The combined processing test was accomplished through a series of theoretical analyses and field testing using the Canadian CTEC LEOLUT.

The tests showed that:

- the location accuracy was improved for Doppler positions based on 5 LEOSAR Doppler measurements or less, with a decrease of the improvement when the number of Doppler points available increased; and
- Doppler positions with acceptable accuracy could be obtained from 2 Doppler data points plus the GEOSAR frequency measurement.

Based on the above results, further work was performed after the GEOSAR D&E to confirm the D&E results which had been achieved with small statistical samples, and develop draft specifications for the possible implementation of this combined LEOSAR/GEOSAR processing in operational Cospas-Sarsat LEOLUTs.

The potential use of the GEOLUT's frequency measurement to help resolve the LEOSAR Doppler position ambiguity was also studied. However, the GEOSAR frequency measurement accuracy available during the test was not adequate for this task. As a consequence, orbitography and reference beacons of known frequency had to be used.

Another factor affecting this test was the very high success rate demonstrated by the current LEOLUT processing, using only Doppler data to distinguish the real position from the image. This success rate was 98.5% without any GEOSAR frequency input.

The results indicated that, when the actual beacon carrier frequency data was combined with LEOLUT solutions having a computed probability assigned to the ‘true’ and ‘image’ solutions in the range of 50-60%, the success rate of correctly identifying the ‘true’ location (and not the ‘image’) was found to be 99.3%, which is approximately 1% higher than the basic success rate using LEOLUT data only. However, when applied to LEOLUT solutions based on three Doppler points only, the use of the actual carrier frequency data was particularly helpful, increasing the success rate of correctly identifying the ‘true’ solution from 66.3% (LEOSAR only) to 84.3% (combined LEOSAR/GEOSAR).

In order to achieve these benefits, the GEOSAR frequency measurement of a 406 MHz beacon frequency must be accurate to +/- 1 Hz.

4. OPERATIONAL OBJECTIVES RESULTS AND DISCUSSION

The GEOSAR D&E operational objectives were developed to:

- assess the performance of individual GEOSAR systems in supporting actual SAR operations;
- provide SAR services in each participating country with experience using GEOSAR alert data and assess the effectiveness of GEOSAR alerts;
- provide Cospas-Sarsat Ground Segment Operators experience in the distribution and use of GEOSAR alerts; and
- evaluate the impact of GEOSAR systems on the Cospas-Sarsat 406 MHz System.

Eight specific operational parameters were measured to provide the basis for this evaluation. The detailed definition of the parameters are presented in "Cospas-Sarsat Demonstration and Evaluation Plan for 406 MHz GEOSAR Systems" (C/S R.006).

The operational data reported here, cover the six month period April to September 1997, with the exception of Objective 8 data, which cover the entire D&E period, and the data from the United Kingdom, which cover only a 3 month period from April to June 1997.

The results are discussed below for each operational objective.

4.1 Potential Time Advantage (O-1)

The Potential Time Advantage (PTA) is the time advantage of a GEOSAR alert notification over the first available LEOSAR alert notification for the same beacon.

Because MCCs received GEOSAR alerts based on the country code in the beacon message and LEOSAR alerts based on the Doppler position or the country code, the data collected by MCCs was limited to beacons from countries within their service area (as determined by the encoded country code), which were activated within that same MCC service area.

A total of 1,926 cases were reported by Australia, Canada, France, India, Spain, the United Kingdom and the United States. In 286, or 15% of the cases, the LEOSAR alert arrived before the GEOSAR alert. These cases were not analysed further and were not considered in the results.

The remaining 1,640 cases were evaluated to determine the mean and median time advantage of the GEOSAR alert. Table 4.1 summarises the time advantage by GEOSAR satellite and by MCC.

The mean time advantage was 46 minutes. The median time advantage (i.e. 50% of cases) was 21 minutes, and the standard deviation was approximately 104 minutes.

There appears to be no significant difference when analysing the results between the two GOES satellites, most likely due to the fact that time advantages were reported for many of the same beacon activations. However, there is a difference in the mean time advantage when comparing the GOES series of satellites and the INSAT-2A satellite. This can be a result of the geographic location of the beacon activations analysed, the sample size of the analysis, the location of operational LEOLUTs, or long space segment delays in the global-mode coverage (the time data is stored in the LEOSAR satellite memory before it is received by a LEOLUT). However, further analysis is required to determine conclusively the reason for the difference in the reported time advantage between the different series of GEOSAR satellites.

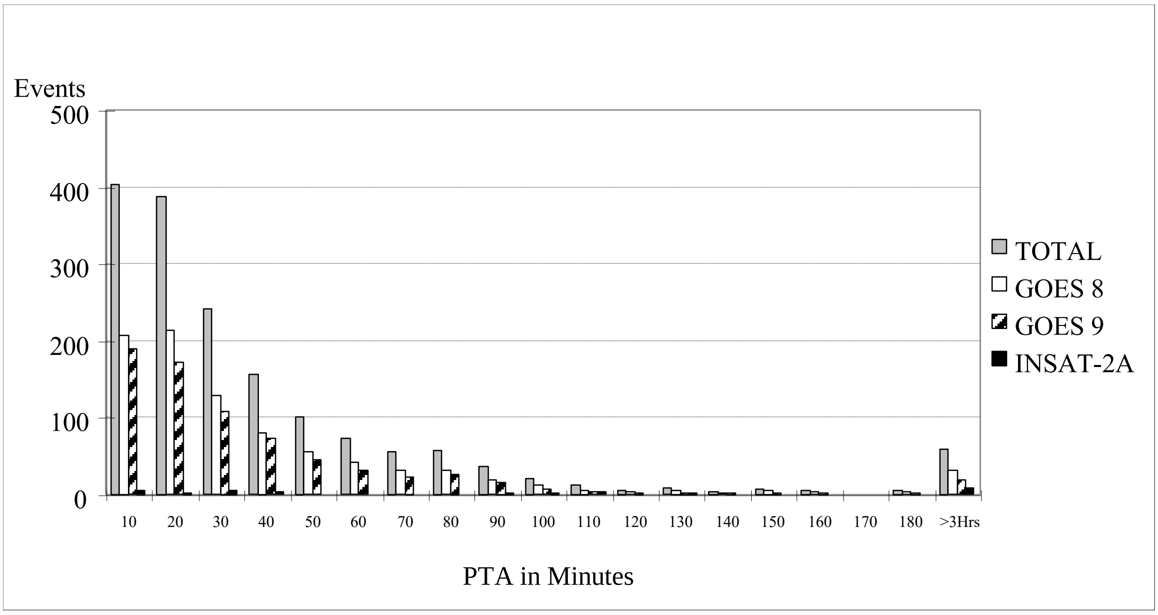
Table 4.1: Time Advantage by GEOSAR Satellite and MCC

	Number of Cases	**Mean (Minutes)**	**Median (Minutes)**	**Standard Deviation (Minutes)**
GEOSAR Satellite				
INSAT-2A	32	98.8	40.0	110.7
GOES-8	884	47.5	21.7	111.6
GOES-9	724	42.0	20.0	91.8
MCC				
Australia	12	94.5	26.8	153.0
Canada	81	44.6	19.4	138.0
France	161	92.0	32.3	206.3
India	5	45.0	60.0	55.8
Spain	32	22.4	17.0	62.0
United Kingdom*	11	35.5	35.5	13.4
United States	1,338	40.8	20.5	79.2
All	**1,640**	**46.0**	**21.2**	**103.6**

* Represents 3 months data only

When analysing the results by MCC, the mean time advantage varied from a low of 22.4 minutes reported by Spain to a high of 94.5 minutes reported by Australia. The possible reasons described above could also explain the time advantage differences by MCC, however, no conclusions can be reached with the analysis performed to date. It should be noted that the results from India only contain data for cases where the time advantage was less than three hours. Figure 4.1 presents the distribution of the time advantages, in 10-minute increments, for each satellite system.

Figure 4.1: Potential Time Advantage of GEOSAR Alert



The data in Figure 4.1 confirms that the median time advantage is 21 minutes. The data also shows that there were a total of 59 cases where the reported time advantage was over three hours. A preliminary investigation showed that delays just over three hours were usually due to lack of LEOSAR coverage in the area after beacon activation (e.g. no LEOSAR satellite with global mode coverage and/or LEOLUTs capable of processing SARR data). However, for some of the very large time advantages, LEOSAR coverage was available, but no LEOSAR alert from the first LEOSAR satellite passes was received at the MCC. In the future, Participants may wish to study long delays in the reporting of alerts from the LEOSAR system.

The mean and median time advantages calculated were a result of six LEOSAR satellites in operation during the D&E data collection period (but only three with global mode coverage). It can be reasonably concluded that the potential time advantage for a nominal four-satellite constellation may be higher because of reduced satellite coverage. Also affecting the time advantage results is the location where operational beacons were activated. Due to their near-polar orbits, the LEOSAR satellites view the polar regions more frequently. Therefore, the time advantage is affected by the latitude at which a beacon is activated, as it will be greatest for beacons activated at the equator and will decrease for beacons activated at higher latitudes.

The mean time advantage of 46 minutes is significant in that this time advantage will permit SAR forces to begin their response sooner. Even if no position information is provided, the beacon registration information can be used to obtain general location information from contact persons, enabling SAR personnel to respond earlier and save additional lives. This time saving is particularly significant in cases where severe trauma or insertion into cold water is a factor. These benefits will become even greater as beacons with encoded position information become operational and SAR personnel receive both alert and location information significantly earlier.

4.2 Complementarity and Effectiveness of the GEOSAR/LEOSAR Systems (O-2)

The complementarity and effectiveness of GEOSAR/LEOSAR systems is evaluated by measuring the percentage of 406 MHz beacon transmissions, within the coverage area of a particular geostationary satellite, that are detected by only the GEOSAR system, only the LEOSAR System, or by both systems.

Data for this objective were collected by Australia, Canada, France, India, Spain, the United Kingdom and the United States. These countries reported on all beacon activations within a GEOSAR footprint that had country codes of countries within their MCC's service area. The INSAT-2A and GOES satellites were used in the analysis. The effectiveness and unique contribution of the LEOSAR and GEOSAR systems are summarised in Table 4.2 and Figure 4.2.

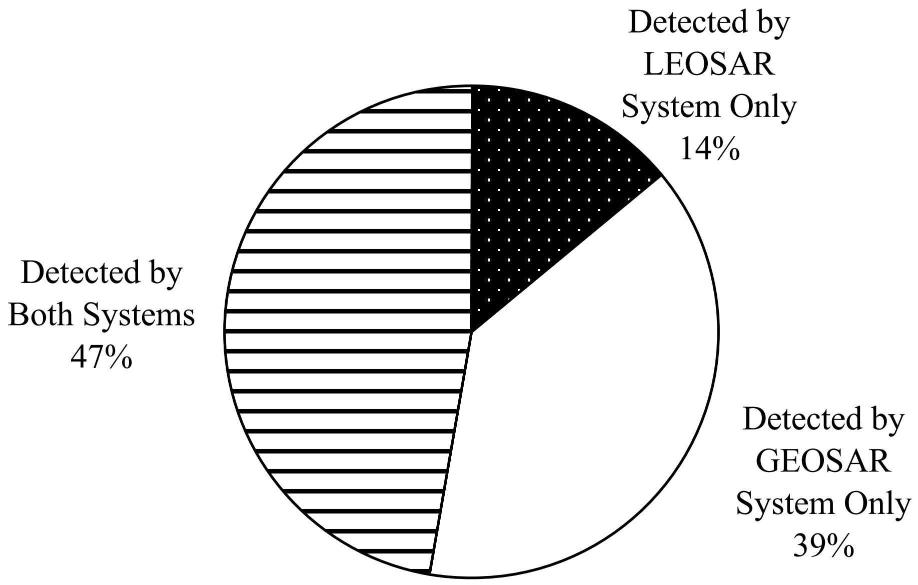
Table 4.2: Complementarity and Effectiveness of GEOSAR/LEOSAR Systems

	INSAT-2A		GOES-8		GOES-9		ALL	
	No.	%	No.	%	No.	%	No.	%
Total alerts in GEOSAR footprint	243		1,931		1,648		3,822	
Alerts Detected Only by LEOSAR	165	67.9%	187	9.7%	180	10.9%	532	13.9%
Alerts Detected Only by GEOSAR	22	9.1%	819	42.4%	639	38.8%	1,480	38.7%
Alerts Detected by Both Systems	56	23.0%	925	47.9%	829	50.3%	1,810	47.4%
GEOSAR Effectiveness		32.1% See note		90.3%		89.1%		86.1%

A total of 3,822 alerts within the theoretical zero degree elevation angle GEOSAR footprints were reported. The GEOSAR system detected 86.1% (3,290) of these alerts and was the only system to detect 38.7% (1,480) of the alerts. Only 13.9% (532) of the alerts were detected by the LEOSAR System and not by the GEOSAR system.

Note: *The effectiveness of the GEOSAR system was consistent between the two GOES satellites, however, the effectiveness for the INSAT-2A satellite was much lower. Further analysis demonstrated that the INSAT-2A effectiveness, as reported by India* *was high (93.8% for a sample size of 16 cases), however the INSAT-2A effectiveness reported by other Participants was much lower (0.0% to 32.8% for a total of 227 cases). This suggests that the INSAT-2A may have detected a greater number of beacons than were transmitted by the Indian MCC to other countries during the test period.*

Figure 4.2: Complementarity/Effectiveness of GEOSAR and LEOSAR Systems



Additional analysis was performed by some of the D&E Participants to verify the GEOSAR effectiveness and to ensure that logical explanations existed for those cases where only the LEOSAR System provided notification (about 10% of the cases for the GOES system). All alerts detected by the LEOSAR System but not detected by the GEOSAR system during a two-week period were analysed in more detail. The investigation included:

- contacting SAR personnel and beacon owners/operators to determine the presence of local obstructions;
- determining the level of interference present within the GEOSAR footprint; and
- determining the received power level of the beacon at the LEOSAR satellite (if the received power level of the beacon can be shown to be below a certain threshold then it is possible to conclude that the GEOSAR system could not have detected the beacon).

The analysis concluded that factors such as local obstructions, low beacon power, MCC processing anomalies, the inability of a GEOLUT to produce an error free message, or bit errors in the frame synchronisation caused the GEOSAR system not to report a beacon activation. Even though the analysis was limited, it was concluded that logical explanations existed for the LEOSAR alerts not detected by the GEOSAR system.

As shown in Table 4.2 and Figure 4.2, the LEOSAR System did not detect 38.7% (1,480) of the alerts detected by the GEOSAR system. The LEOSAR System has few screening or shielding limitations and should detect all nominal Cospas-Sarsat beacons which transmit for a period long enough for a LEOSAR satellite to overfly and detect the beacon. The requirement for a lengthy beacon transmission time was demonstrated during the Exercise of 1990 by the average waiting time of 44 minutes for a LEOSAR satellite to detect a beacon, and confirmed by the 46 minutes mean time advantage of the GEOSAR system (see section 4.1).

Analysis in section 4.3 demonstrates that over half of the beacon activations had transmission durations of less than 10 minutes. Therefore, it may be concluded that the non detection of beacons by the LEOSAR system was probably a result of the short duration of beacon transmissions.

The GEOSAR effectiveness of 86.1% (3,290 alerts) indicates that the GEOSAR system was able to detect most of the 406 MHz beacon activations in the GEOSAR footprint and provide the alert data to SAR forces. For the 47.4% (1,810) of alerts detected by both the GEOSAR and LEOSAR systems, the SAR forces could initiate investigation of incidents sooner using GEOSAR alert data, then use the LEOSAR data to focus search activities. These results demonstrate how the two system complement each other.

Figures 4.3, 4.4 and 4.5 display the actual locations of 406 MHz alerts which were detected by both the LEOSAR and GEOSAR satellite systems. The presentations are provided separately for each geostationary satellite, and alerts in the overlap areas of the geostationary satellite footprints are shown in each presentation. The number of alerts shown on Figures 4.3 through 4.5 is less than that shown in Table 4.2. This is because there were 406 MHz alerts detected by both LEOSAR and GEOSAR systems which did not have location data. These alerts do not appear in these Figures but are counted in Table 4.2.

Figure 4.3: Positions of 406 MHz GEOSAR Alerts as Confirmed by LEOSAR in GOES-8 Footprint

N=622

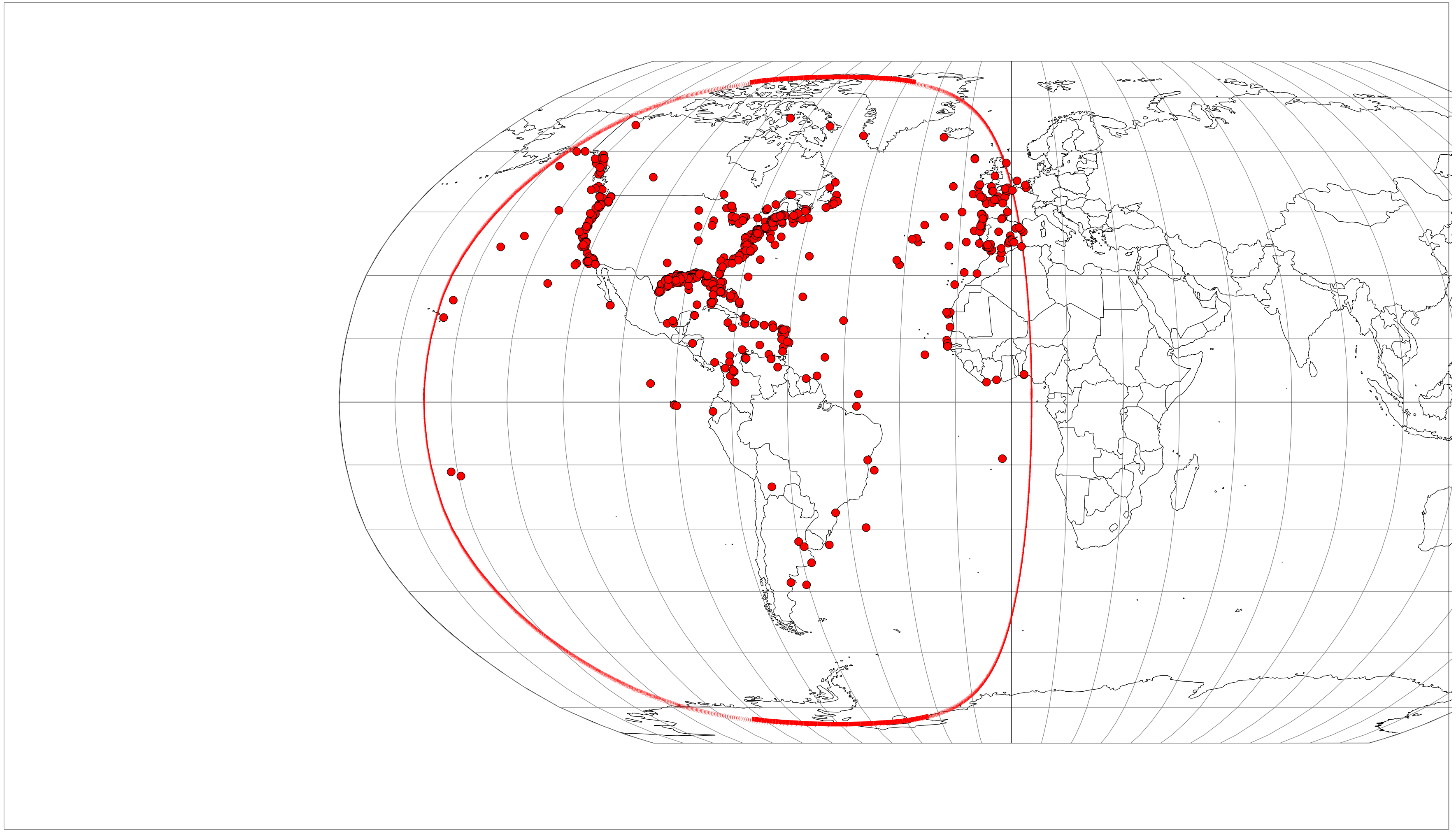


Figure 4.4: Positions of 406 MHz GEOSAR Alerts as Confirmed by LEOSAR in GOES-9 Footprint

N=570

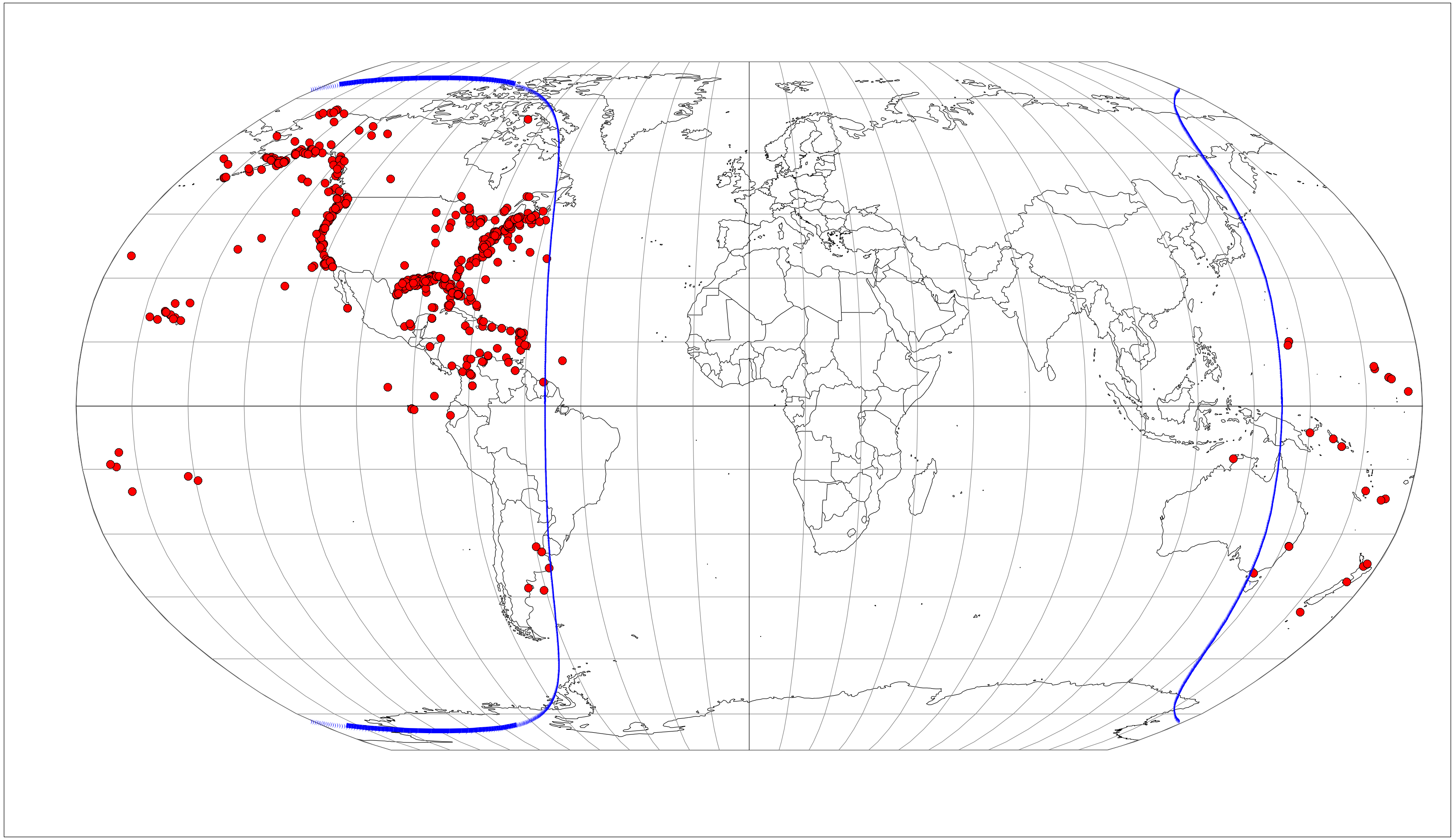
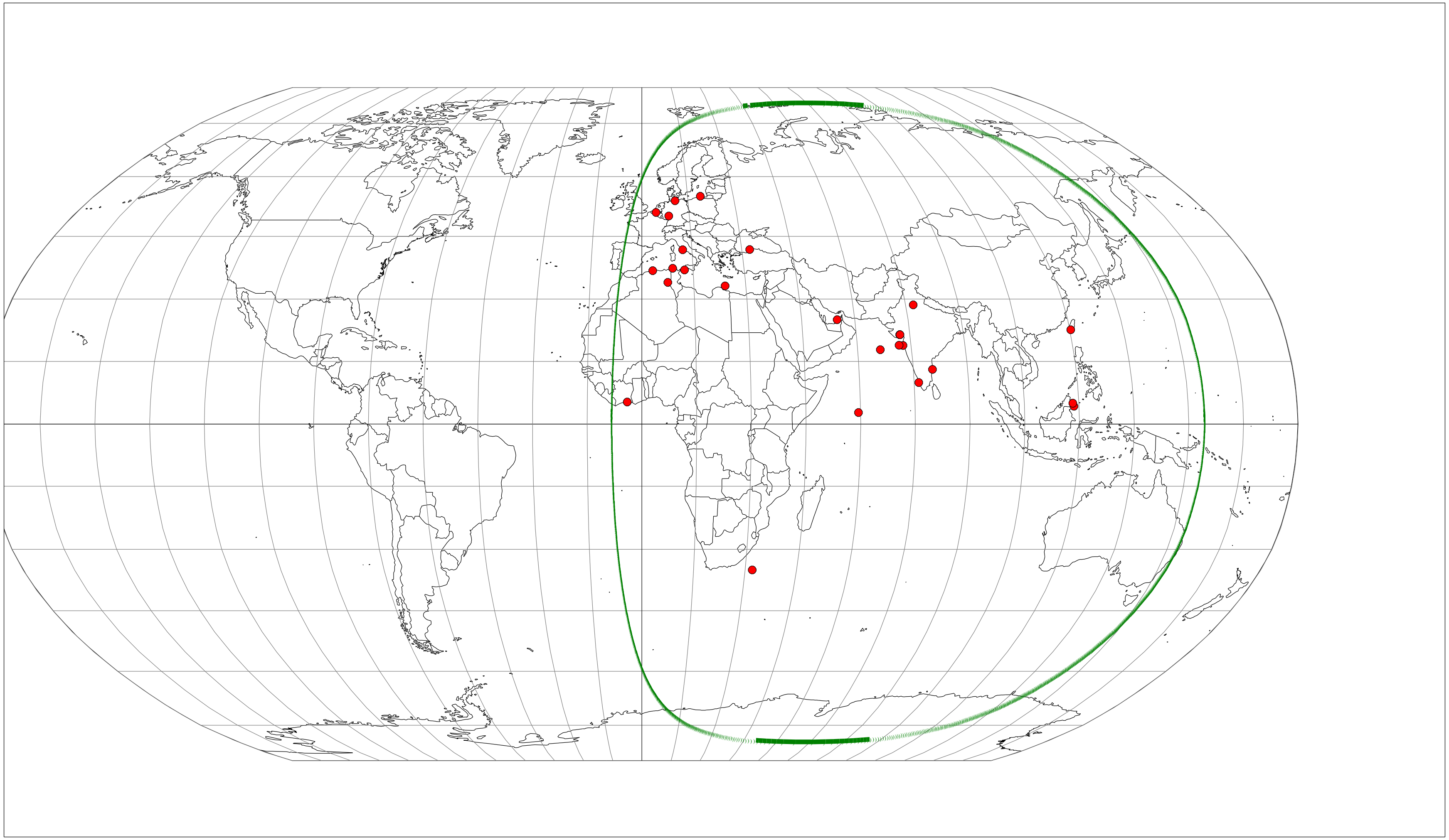


Figure 4.5: Positions of 406 MHz GEOSAR Alerts as Confirmed by LEOSAR in INSAT-2A Footprint

N=29



4.3 Durations of 406 MHz Transmissions (O-3)

The analysis of 406 MHz transmission durations provides information on how long operational beacons are active. Short duration transmissions could be the result of a catastrophic event or the result of a false alert (e.g., inadvertent activation due to testing). Short transmission durations may not be detected by the LEOSAR system, and therefore, provide some assessment of the complementarity of the LEOSAR and GEOSAR systems. Long transmission durations may have a significant impact on system capacity.

Data from the GEOLUTs in Canada, Spain and the United Kingdom were analysed. Table 4.3 summarises the results. Note that differences in signal processing techniques used in the GEOLUTs resulted in different methods of computing the beacon transmission durations, therefore, the data from the various GEOLUTs could not be combined.

Table 4.3: GEOSAR Beacon Durations by GEOLUT Provider

Country	No. of Reports	Mean (Minutes)	Median (Minutes)	Standard Deviation (Minutes)
Canada	2,333	163.2	7.8	667.2
Spain	1,209	152.8	19.1	614.6
United Kingdom*	740	97.8	7.8	n/a

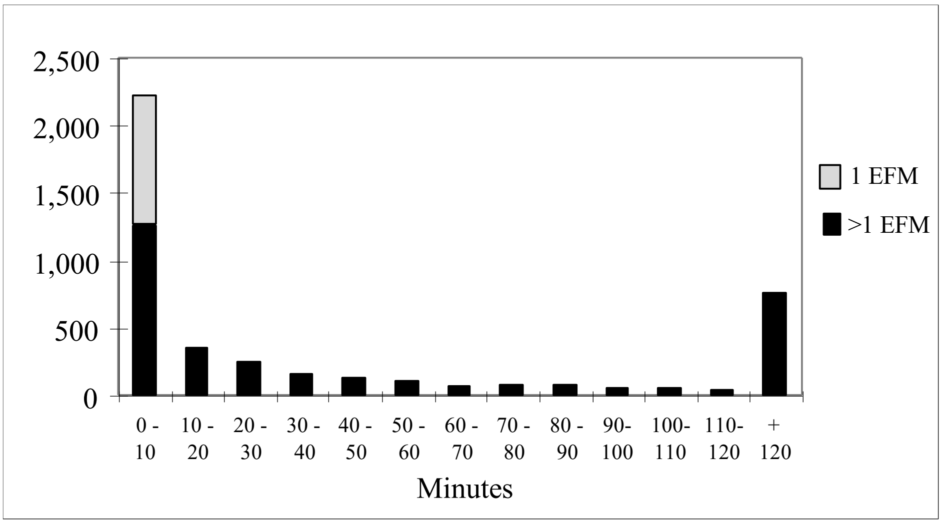
* *Represents 3 months data only, mean and median values estimated for UK.*

A total of 4,282 transmission durations were measured. The mean and median values were not provided by the United Kingdom, however, estimates of them were derived from the distribution of transmission durations. From analysis of the mean and median duration values presented above, it was clear that although the median duration was low, a number of beacons continued to transmit for extended periods causing the mean to be high. There does not appear to be a significant difference in the mean values of 152.8 minutes reported by Spain and 163.2 minutes reported by Canada. However, the value calculated for the United Kingdom GEOLUT was considerably lower.

Figure 4.6 presents the beacon transmission durations in 10-minute increments. Additionally, an indication of the number of error free messages (EFM) is provided for transmissions with a duration less than 10 minutes.

The results in Figure 4.6 indicate a considerable number of alerts with only one error free message and the predominance of short-duration transmissions.

Figure 4.6: Duration of 406 MHz Transmissions



Single error free messages are those where the GEOLUT detected only one burst from a beacon and was able to generate an alert with no bit errors. The Canadian GEOLUT produced a single error free message in 24% (569) of the cases, whereas the United Kingdom GEOLUT produced a single error free message in 36% (263) of the cases.

Overall, just over half of the beacon transmission durations were less than 10 minutes. This percentage varied between GEOLUTs, from 42% for Spain, to 52% for Canada and to 64% for the United Kingdom. These results may explain why the number of alerts detected by only the GEOSAR system is high; most of the transmissions were too short to expect detection by the LEOSAR System. The high percentage of short duration transmissions recorded by the United Kingdom may explain the United Kingdom's lower mean duration transmission value. However, additional analysis is required to determine why a difference in the percentage of transmission durations less than 10 minutes existed between the various GEOLUTs.

The preliminary analysis suggests that improper beacon testing or inadvertent activations may cause over half of all beacon alerts detected by the GEOSAR system. Users of the system should be made aware of the fact that the GEOSAR system can detect and process single burst messages, therefore, care should be exercised when handling or testing beacons. However, it is noteworthy that a beacon transmitting for a short duration may be the only indication of catastrophic events where the beacon is quickly destroyed.

4.4 406 MHz Registration Database Effectiveness (O-4)

The 406 MHz registration database effectiveness is a measure of the usefulness to the SAR forces of 406 MHz registration information available at the time of the GEOSAR D&E.

The database effectiveness was evaluated by calculating the percentage of 406 MHz GEOSAR alerts received at a MCC for which a database existed and the registration information could be used by the SAR forces. As most 406 MHz beacons only contain identification information, the full benefits of the GEOSAR system are only realised if useful registration data is available and can be provided to SAR forces to take advantage of the earlier GEOSAR alert. The results reflect the database effectiveness for Cospas-Sarsat Participants who have established, maintain and provide access to registration databases on a 24-hour access basis.

Table 4.4 presents the results of the database effectiveness in determining if an alert is a real distress. The Ratio of Alert Discrimination is measured by dividing the number of alerts where the registration information was useful in determining whether an alert was a real distress or a false alarm, by the number of alerts provided to SAR forces with registration information.

Table 4.4: 406 MHz Registration Database Effectiveness

Measurement	Canada	France	Spain	United States
Alerts for which database information was acquired and provided to SAR forces	105	198	58	965
Alerts where beacon registration data allowed SAR forces to discriminate between real and false alerts	102	168	n/a	600
Ratio of Alert Discrimination	97.1%	84.8%	≈ 80%	62.2%

There were 1,326 beacon alerts for which database information was available and provided to SAR forces. Of these, the ability to discriminate between real and false alerts varied between 62.2% and 97.1%. Note that Spain estimated that approximately 80% of the registered alerts were useful in resolving the incident. This clearly shows that registration information is valuable to SAR forces in quickly determining if an alert is a real distress incident or a false alarm.

Information from a GEOSAR alert and the corresponding registration data may permit the RCC to initiate a search or determine that an alert is not a distress case earlier than if only a LEOSAR alert is received. The time improvement, for cases where a GEOSAR and LEOSAR alert exists, is the elapsed time between the time when the RCC/SPOC could initiate a search or confirm a false alarm and the time of receipt of the first LEOSAR alert. Table 4.5 summarises the search initiation/false alarm determination time improvement.

Table 4.5: Search Initiation/False Alarm Determination Time Improvement

Country	Number of Cases	Mean Time Improvement (Minutes)	Median Time Improvement (Minutes)	Standard Deviation (Minutes)
Canada	23	51.8	12.0	120.3
France	97	56.0	26.0	91.0
Spain	2	38.4	38.4	50.7
United States	83	18.8	12.0	22.9
All	205	40	16	

Canada, France, Spain and the United States measured the search initiation/false alert determination time improvement on 205 incidents. The mean time improvement was 40 minutes and the median was about 16 minutes. A determination that an alert is real, 40 minutes earlier, is very significant to SAR forces as it may allow releasing SAR resources for other tasks.

Although 406 MHz beacons with encoded position data will provide both identification and position information, the registration information will still be an important element of data provided to SAR forces. Receipt of simultaneous alert and location information will mean that RCCs and SPOCs will need to make prompt decisions regarding the launch of resources. Accurate registration database information is therefore essential to prevent the unnecessary tasking of resources.

Registration database information is an essential complement to GEOSAR alerts and National Administrations should establish registration databases and ensure 24-hour access for the retrieval of information by SAR agencies.

4.5 Operational Impact of GEOSAR Processing Anomalies (O-5)

Several factors may affect the GEOLUT’s ability to properly recover 406 MHz beacon messages (e.g. defective bit synchronisation). These processing anomalies may result in false alerts passed to RCCs. This D&E operational objective was to measure the operational impact of GEOSAR processing anomalies on the SAR forces.

Processing anomalies are defined as those alerts received at an MCC which are generated from non-beacon sources (e.g. interference), or result from beacon transmissions whose data are corrupted in the GEOLUT processing. The number of processing anomalies and the resulting number of false alerts was evaluated by Canada, Spain, India, and the United States.

Table 4.6 provides a summary of the number of GEOSAR alerts and the number of processing anomalies and false alerts detected by the different countries.

Table 4.6: Operational Impact of GEOSAR Processing Anomalies

	Canada		India		Spain		USA		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
GEOSAR alerts received at MCC	234		16		199		4,648		5,097	
GEOSAR alerts received confirmed invalid by MCC	6	2.6%	0	0.0%	0	0.0%	42	0.9%	48	0.9%
GEOSAR alerts passed to RCCs/SPOCs	108		16		137		1,364		1,625	
Invalid GEOSAR alerts forwarded to an RCC/SPOC	0	0.0%	0	0%	3	2.2%	0	0.0%	3	0.2%

The number and percentage of processing anomalies were found to be low. Of the 5,097 GEOSAR alerts transmitted in the MCC network, 48 (0.9%) were determined to be invalid. However, of the 1,625 GEOSAR alerts passed to RCCs/SPOCs, only three (0.2%) were false alerts resulting from processing anomalies.

4.6 Volume of GEOSAR Alert Processing at MCCs (O-6)

The volume of GEOSAR alert messages was collected to evaluate the increase in message traffic and processing requirements resulting from the transmission of GEOSAR alerts between MCCs. The GEOSAR traffic ratio presented in Table 4.7 is calculated by comparing the number of GEOSAR alert messages received and transmitted by an MCC to the total number of LEOSAR alert messages received and transmitted by that MCC.

Table 4.7: Volume of GEOSAR Message Processing

Country	GEOSAR Satellite from which Alerts were Received	Number of GEOSAR Alert Messages	Number of Non-GEOSAR Alert Messages	GEOSAR Traffic Ratio
Australia	INSAT-2A	114	17,940	0.6%
Canada	GOES-8, GOES-9	4,063	25,413	16.0%
France	INSAT-2A GOES-8, GOES-9	4,905	85,000	5.8%
Spain	INSAT-2A GOES-8, GOES-9	1,418	9,824	14.4%
United Kingdom*	GOES-8, GOES-9	881	1,892	46.6%
United States	GOES-8, GOES-9	6,331	151,225	4.2%

* *Represents 3 months data only*

The total number of GEOSAR alert messages processed was 17,728 compared with 296,966 for the LEOSAR System. The GEOSAR traffic ratio ranged from less than 1% for Australia to 46.6% for the United Kingdom. As expected, MCCs with associated GEOLUTs reported higher volumes of GEOSAR alert messages. The high percentage of GEOSAR traffic in the United Kingdom reflects the fact that the UK does not send 121.5 MHz alert messages unless ambiguity is resolved, thereby reducing the number of LEOSAR alerts transmitted.

It should be noted that the traffic reported here is higher than MCCs would normally experience because of the special data distribution procedures in place during the D&E period, where redundant alerts from different sources were transmitted to allow analysis. Following normal operational procedures, redundant alert messages will be filtered out by MCCs.

The GEOSAR D&E results show that the workload increase did not have a significant adverse impact on any MCC's operation.

4.7 Resolution of LEOSAR Location Ambiguity Using GEOSAR Alert Data (O-7)

The LEOSAR Doppler processing produces two solutions for each satellite overflight; a "true" position corresponding to the actual location of the beacon, and an "image" position on the opposite side of the satellite track. If GEOSAR alert data is available, it is possible to use the footprint of the GEOSAR satellite to determine the "true" Doppler location in cases where the "image" solution falls outside the GEOSAR footprint. Table 4.8 summarises the ambiguity resolution effectiveness ratio which is calculated by dividing the number of LEOSAR first locations where ambiguity was resolved successfully using available GEOSAR data, by the total number of LEOSAR first locations processed by the MCC.

Table 4.8: Resolution of LEOSAR Ambiguity using GEOSAR Data

Country	GEOSAR Satellites Used to Resolve Ambiguity	Resolutions using GEOSAR	Total LEOSAR Locations	Ambiguity Resolution Effectiveness
Australia	INSAT-2A, GOES-8, GOES-9	5	82	6.1%
Canada	GOES-8, GOES-9	6	31	19.4%
France	INSAT-2A, GOES-8, GOES-9	93	783	11.9%
Spain	GOES-8, GOES-9	53	1,494	3.5%
United States	GOES-8, GOES-9	123	1,674	7.3%

It should be noted that none of the countries had implemented procedures to automatically resolve LEOSAR location ambiguity with GEOSAR data during the D&E period. Instead, a theoretical analysis was undertaken after the data collection period using all data available at the MCC.

Of the total 4,114 LEOSAR alerts which occurred within the GEOSAR coverage areas, 302 were in positions where one LEOSAR location was inside the GEOSAR system coverage area and the other was not. The data indicated differences in the effectiveness between countries of using GEOSAR alert data to resolve LEOSAR location ambiguity. The effectiveness depended on the location of the GEOSAR footprint boundary, the LEOSAR satellite geometry and the areas where beacon activations are concentrated. The effectiveness varied from a low of 3.5% for Spain to a high of 19.4% for Canada.

The variance may be due to the different interpretation of the guidelines provided in document C/S R.006, resulting in some Participants (Australia and Canada) limiting their analysis to data within their MCC service areas and others (India**,** France, Spain and the United States) reporting on all service areas.

Despite these data collection differences, the analysis demonstrates that using the GEOSAR satellite footprint to resolve LEOSAR Doppler location ambiguity can be of practical use to SAR authorities. Furthermore, enhanced data distribution procedures that use the GEOSAR satellite footprint to resolve LEOSAR location ambiguity may reduce the number of messages transmitted to SAR authorities responsible for the “image” position.

4.8 Evaluation of the Benefits of GEOSAR Systems on SAR Operations (O-8)

This objective was developed to provide an assessment of the direct and indirect benefits of the GEOSAR system to SAR operations. Direct benefits were classified as:

- additional lives saved due to the earlier notification of GEOSAR system;
- reduced search costs resulting from the use of GEOSAR alert data; or
- reduced property losses due to the timeliness of GEOSAR alerting.

Information on indirect benefits, which are harder to quantify, included reports demonstrating the reduced risk to SAR forces and increased public confidence in, and reliance on 406 MHz ELTs, EPIRBs and PLBs.

Most participants experienced difficulty in reporting on this objective and only Canada, France and the United States provided information. Canada reported on a case involving two hunters rescued in the Northwest Territories, which is documented in the Executive Summary. France reported on a rally between Paris and Dakar, which documented the usefulness and reliability of the GEOSAR system including the use of encoded position data. Finally, the United States reported on 19 specific cases where 406 MHz GEOSAR alert data was used in responding to distress events.

The French report documented the use of PLBs by participants in the Paris-Dakar rally held in January of 1998. Many of these PLBs were coded with a Location Protocol which allowed encoding position information provided by an internal GPS receiver. 41 of the 348 PLBs, were activated during the race. Analysis showed that the encoded position information provided by the beacons agreed well with the calculated Doppler locations, and that the GOES-8 GEOSAR system was very effective in detecting the 406 MHz alerts. Table 4.9 summarises the results for GOES-8.

Table 4.9: Paris-Dakar Rally GEOSAR Benefits

Measurement	Result
Percentage of alerts detected by GOES-8	93%
Percentage of alerts with first detection by GOES-8	88%
Percentage of alerts only detected by GOES-8	25%
Time Advantage of GOES-8 (25 cases)	40 minutes

The rally results, therefore, confirmed in a practical way the value of the GEOSAR system as a complement to the LEOSAR System.

The United States reported on direct benefits by evaluating the property protected, property saved, lives protected and lives saved as a result of 406 MHz GEOSAR alert data combined with beacon registration data. Property protected was defined for situations where a craft required outside assistance, but was not in imminent danger of being destroyed. Property saved applied to craft that required outside assistance or could be destroyed. Lives protected were those lives that required outside assistance, but were not in imminent danger of serious injury or loss of life. Finally, lives saved were those lives that required outside assistance to avoid serious injury of loss of life. 19 cases where the GEOSAR system provided early distress notification that assisted SAR operations were analysed.

The results show that the GEOSAR system provided earlier notification than the LEOSAR System, ranging from two minutes to 67 minutes, and in some cases provided the only notification. Overall, in the United States service area, 11 lives were saved and 37 lives were protected during the D&E period, which could be attributed to the GEOSAR system. Additionally, three vessels were saved and nine vessels were protected.

These cases document the complementary nature of the GEOSAR and LEOSAR Systems. In several cases, the SAR forces were able to launch on the GEOSAR alert and then divert resources to the exact position based upon the LEOSAR alert. The usefulness of the information obtained from the contact person identified in the registration database, available at an earlier time due to the GEOSAR alert, was also shown in many cases.

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5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Conclusions based on the analysis of data collected during the D&E are presented below.

The technical results of the D&E show that:

- beacons meeting the requirements of C/S T.001 (406 MHz Beacon Specification) can be reliably detected by the GEOSAR system;
- the time required for a GEOLUT to produce an alert after beacon activation was only a few minutes, indicating that near-instantaneous detection and alerting of 406 MHz beacons could be expected;
- even though beacons were often detected out to the edges (and beyond) of the GEOSAR footprints, 4° should be used as the published minimum elevation angle required to assure reliable GEOSAR reception of 406 MHz beacons;
- sufficient technical data had been collected and analysed to develop GEOLUT specifications; and
- sufficient technical data had been collected to recommend the incorporation of the GEOSAR system as a complement to the Cospas-Sarsat system, despite some of the technical objectives not having been fully completed.

The major operational results from the D&E are summarised in the following paragraphs.

In respect of the potential GEOSAR system alerting time advantage over the LEOSAR System, the D&E results indicate that:

- on average, a GEOSAR alert was received 46 minutes before the first corresponding LEOSAR alert, with a median time of 21 minutes; and
- the time advantage gained by the GEOSAR system's near-instantaneous alerting was clearly shown to benefit the outcome of the SAR activities as additional lives and property were saved.

Concerning the availability and use of 406 MHz beacon registration data bases, the D&E results show that:

- the usefulness of the earlier GEOSAR alert notification was dependent to a large extent on the availability, completeness and accuracy of information in a 406 MHz registration database;
- beacon registration information, when available, could be used to obtain rough location information from emergency contact persons, enabling SAR personnel to take advantage of the earlier notification provided by the GEOSAR system even when encoded position information was not available in the beacon message; and

- for GEOSAR and LEOSAR alerts, database information often allowed the RCCs and SPOCs to gather the information necessary to quickly distinguish between real and false alerts thereby preventing the launch of resources on false alerts.

In respect of the measurements of 406 MHz beacons transmission duration, the D&E results show that:

- because of the near-instantaneous detection capability of 406 MHz distress beacons by the GEOSAR system, beacons which transmit for only a short duration (e.g. catastrophic incidents or beacon failure) would probably be detected by the GEOSAR system; and
- a large proportion of the GEOSAR alerts were derived from beacons with a very short transmission durations. This would suggest inadvertent activation or testing of beacons. This finding confirmed the need for improved information and training of users in beacon handling, testing, and maintenance procedures.

The D&E results show that the beacon detection capability of GEOSAR satellites within their coverage area provided a good complement to the LEOSAR System. The vast majority of alerts within the GEOSAR satellite footprints were detected by the GEOSAR system, and valid explanations existed for those beacons that were not detected.

In respect of the GEOSAR impact on the Cospas-Sarsat Ground Segment operation, the D&E results indicate that:

- the volume of GEOSAR alert traffic processed at MCCs was generally considered to have minimal impact on the workload of those MCCs;
- the number of GEOSAR processing anomalies which resulted in false alerts reaching a RCC or SPOC was extremely low as the D&E participants took effective measures to filter alerts before transmission; and
- GEOSAR alert data was effective in resolving LEOSAR Doppler location ambiguity, even though manual processes had to be used during the D&E period.

In summary, the D&E confirmed that the GEOSAR system was a good complement to the Cospas-Sarsat LEOSAR System and provided significant benefits, including the potential for saving additional lives and property.

Finally, the D&E highlighted the fact that the 406 MHz beacon user community needs to be informed of the 406 MHz GEOSAR system performance, and that greater care in the use of the 406 MHz beacons will be required, as inadvertent activations (even of short-term duration) would probably be detected by the GEOSAR system, setting off an unnecessary chain of events with a corresponding use of SAR resources.

5.2 Recommendations

As the D&E results had confirmed the expected benefits of the GEOSAR satellite system, the Cospas-Sarsat Council, at its Twenty-First Session in October 1998, decided to:

1. adopt the 406 MHz GEOSAR satellite system as an enhancement and complement to the Cospas-Sarsat LEOSAR system;

2. initiate all actions necessary for implementing this enhancement as soon as possible, including the commissioning of the experimental GEOLUTs used during the GEOSAR D&E; and

3. request the Cospas-Sarsat Secretariat to publish and widely distribute the results of the GEOSAR D&E.

In order to ensure the optimal technical and operational performance of the enhanced Cospas-Sarsat System, the Cospas-Sarsat Council further recommended that:

4. responsible administrations should establish and maintain complete, accurate, and up-to-date beacon registration databases, and make the corresponding information available to SAR agencies on a 24-hour a day basis;

5. all manufacturers, administrations and others who develop educational programs and materials, should stress the importance of proper handling, shipping, storage and testing of 406 MHz beacons in view of avoiding false alerts; and

6. responsible administrations should review 406 MHz beacon test policies and procedures, and revise them as necessary to avoid possible alerts from test transmissions being forwarded to RCCs as a result of the incorporation of GEOSAR components in the Cospas-Sarsat 406 MHz system.

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