COSPAS-SARSAT 406 MHz FREQUENCY MANAGEMENT PLAN

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COSPAS-SARSAT 406 MHz FREQUENCY MANAGEMENT PLAN

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1. INTRODUCTION

The Cospas-Sarsat System provides distress alert and location data for search and rescue (SAR), using spacecraft and ground facilities to detect and locate the signals of distress radiobeacons operating on 406 MHz. To ensure that the System satisfies future capacity requirements and remains capable of servicing the growing 406 MHz beacon population, the use of the band 406.0 to 406.1 MHz by Cospas-Sarsat must be monitored and procedures for its efficient management must be defined.

1.1 Purpose

The purpose of this document is to describe the policies, procedures, and detailed technical analyses developed by Cospas-Sarsat for managing the use of the 406.0 - 406.1 MHz frequency band. Cospas-Sarsat Council decisions in respect of 406 MHz channel assignments are summarised at Annex H in the Cospas-Sarsat 406 MHz Channel Assignment Plan. Specifically this document provides:

a. mathematical models for determining the capacity of the Cospas-Sarsat System;

b. procedures for assessing the current and future 406 MHz distress beacon population;

c. procedures for assessing the current and future 406 MHz beacon message traffic load on the System;

d. a description of the channelisation of the 406 MHz band used by Cospas-Sarsat;

e. procedures for meeting System capacity requirements by opening new channels in the 406 MHz band, as required to satisfy the growth of the 406 MHz traffic load; and

f. the current status of the use of the 406.0 to 406.1 MHz frequency band by Cospas-Sarsat and a record of the Cospas-Sarsat Council decisions in respect of the future use of additional frequency channels, as required to accommodate the forecast 406 MHz beacon population.

1.2 Scope

This document presents the analysis of relevant issues concerning the assessment of capacity requirements, and a description of the policies and procedures adopted by Cospas-Sarsat for managing its use of the 406 MHz band.

Section 2 provides definitions of the capacity of the LEOSAR and GEOSAR systems, a general description of the 406 MHz LEOSAR and GEOSAR systems’ capacity models and their validation.

Section 3 provides a description of how 406 MHz message traffic requirements are assessed and forecast by Cospas-Sarsat.

Section 4 describes the overall 406 MHz channel assignment plan and the Cospas-Sarsat policy on the use of assigned frequency channels.

Section 5 details the procedures used by Cospas-Sarsat to decide on the assignment of new frequency channels in the 406.0 to 406.1 MHz frequency band.

The detailed analysis of the LEOSAR and GEOSAR system capacity, the current and forecast 406 MHz beacon population and message traffic, and the approved 406 MHz Channel Assignment Plan are provided in the Annexes to this document.

1.3 Background

The International Telecommunication Union (ITU) has allocated the 406.0 - 406.1 MHz frequency band for the dedicated use of low power satellite position-indicating radiobeacons (see ITU Radio Regulations, Article S5, note S5.266). Since the overall capacity of the Cospas-Sarsat System is directly related to the distribution of beacon carrier frequencies within the band, there is a requirement to assess and manage the number of beacons operating in various portions of the allocated spectrum. Cospas-Sarsat has determined that the best way to ensure that the distress beacon message traffic does not exceed the System capacity in any portion of the available frequency band, is to divide the 406.0 - 406.1 MHz frequency band into channels, and to open the channels for beacon production as demand dictates.

The schedule for opening new channels for beacon production must account for:

a. the capability of Cospas-Sarsat equipment; i.e. Cospas-Sarsat must ensure that space and ground segment equipment capable of processing beacon transmissions in a given channel will be available prior to opening that channel for use;

b. the capacity of each frequency channel; i.e. the number of beacons operating simultaneously in a given channel that can be successfully processed by the Cospas-Sarsat System;

c. the forecast 406 MHz traffic load resulting from the beacon population and other sources of 406 MHz signals (e.g. test and reference beacons);

d. the advance notice required by administrations and organizations to adapt their regulations to authorise 406 MHz beacon operation in new frequency channels; and

e. the advance notice required by beacon manufacturers to design and produce beacons which will operate in new 406 MHz channels.

In addition, there may be a need to develop procedures for terminating the production of beacons operating in channels that are approaching their capacity limit.

1.4 Existing 406 MHz Channel Assignments Prior to the Adoption of the Frequency Management Plan

The first Cospas-Sarsat channel opened for use by operational beacons was established with a centre frequency at 406.025 MHz. To accommodate the forecast growth of the population of beacons operating at 406.025 MHz, Cospas-Sarsat has required that all System beacons (orbitography and other reference beacons used for System calibration) be moved to the channel 406.022 MHz.

Following the closure of channel 406.025 MHz, new channels were available for Cospas-Sarsat type approval of beacon models at 406.028 MHz from 1 January 2000 until 1 January 2007, 406.037 MHz from 1 January 2004 until 1 January 2012 and 406.040 MHz from 1 January 2010 until 1 January 2017. New beacon models submitted for Cospas-Sarsat type approval after 1 January 2017 are required to operate at 406.031 MHz as provided in the Cospas-Sarsat 406 MHz Channel Assignment Table (see Annex H). Beacon models type approved for operation in channels that had been closed may continue to be produced at that frequency after their closure date. However, to ensure that the capacity in closed channels will not be exceeded in future, manufacturers of Cospas-Sarsat beacons type approved for operation in closed channels are encouraged to move the carrier frequency of these models to 406.031 MHz or other assigned channels as appropriate, subject to the demonstration by the manufacturer that the beacon model continues to meet the requirements of document C/S T.001 (406 MHz beacon specification).

1.5 Reference Documents

a. C/S G.003: Introduction to the Cospas-Sarsat System;

b. C/S S.011: Cospas-Sarsat Glossary;

c. C/S T.001: Specification for Cospas-Sarsat 406 MHz Distress Beacons;

d. C/S T.002: Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines;

e. C/S T.003: Description of the Payloads Used in the Cospas-Sarsat LEOSAR System;

f. C/S T.005: Cospas-Sarsat LEOLUT Commissioning Standard;

g. C/S T.007: Cospas-Sarsat 406 MHz Distress Beacon Type Approval Standard;

h. C/S T.009: Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines;

i. C/S T.010: Cospas-Sarsat GEOLUT Commissioning Standard;

j. C/S T.011: Description of 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System; and

k. C/S A.003: Cospas-Sarsat System Monitoring and Reporting.

- END OF SECTION 1 -

2. COSPAS-SARSAT SYSTEM CAPACITY

2.1 Definitions of LEOSAR and GEOSAR Capacity

The capacity of Cospas-Sarsat LEOSAR and GEOSAR systems is the number of 406 MHz distress beacons active in the field of view of a satellite that can be successfully processed, with a stated probability, under nominal conditions.

Each Cospas-Sarsat processing channel (i.e. the GEOSAR, LEOSAR SARR and LEOSAR SARP channels) must be analysed separately, since the method of processing 406 MHz beacon signals and the results produced are different for each system. For example, GEOLUTs in the GEOSAR system are designed to integrate bursts received from individual beacons until they are able to decode the 406 MHz beacon message, whereas the LEOSAR system search and rescue processor (SARP) and search and rescue repeater (SARR) processing channels are designed to decode individual beacon messages and produce Doppler locations.

Therefore, specific capacity definitions are given for the GEOSAR and for the LEOSAR processing channels.

The "nominal conditions" quoted in the definitions refer to applicable detailed technical parameters and ambient conditions. The nominal conditions applicable to each definition are provided at Annex B.

2.1.1 Definition of Cospas-Sarsat LEOSAR SARP and SARR System Capacity

The number of 406 MHz distress beacons operating simultaneously in the field of view of the LEOSAR satellite that can be successfully processed by the SARP or the SARR channel to provide beacon message and Doppler location information, under nominal conditions, 95% of the time.

2.1.2 Definition of Cospas-Sarsat GEOSAR System Capacity

The number of 406 MHz distress beacons operating simultaneously in the field of view of a GEOSAR satellite that can be successfully processed by the System to provide beacon message information, under nominal conditions, within 5 minutes of beacon activation 95% of the time.

The GEOSAR capacity analysis shows that, if the above probability of successful processing within 5 minutes is satisfied, then the probability of successful processing within 10 minutes is greater than 99% in the worst-case scenario, under nominal conditions, or 99.9% on average.

2.2 LEOSAR System Capacity Model

Annex C provides a detailed description of the LEOSAR capacity model and the results of the capacity computations for beacons with short and long message formats, under the following hypotheses that characterise the LEOSAR system operation:

- the beacons are evenly distributed in the LEOSAR satellite visibility area;
- the beacon burst arrival times at the satellite follow a Poisson distribution;
- beacon bursts that overlap in time and frequency cannot be successfully processed;
- the probability of collision between beacon bursts takes into account all beacons in the satellite visibility area defined with a 0º elevation angle;
- although a Doppler position can be computed with only 3 frequency measurements (and possibly with only two measurements complemented by an independent measurement of the beacon transmit frequency), under nominal conditions a successful Doppler processing requires the reception of at least four beacon messages; and
- the required probability of successful Doppler processing must be achieved for all beacons that have a maximum cross-track angle (CTA) of 22º, which provides for the possible reception of five bursts with an elevation angle of at least five degrees.

The analysis shows that the probability of beacon burst collision in the frequency domain is not uniform, but depends on the Doppler shift that affects the received burst (i.e. on the position of the beacon in the satellite visibility area). It also shows that, because of a Doppler spreading of +/-9 kHz, frequency channels separated by 3 kHz are not independent and the transmissions from beacons in one channel may interfere with transmissions from beacons in other channels. Therefore, because of inter-channel interference, the total capacity does not increase linearly with the number of available frequency channels.

For consistency with the GEOSAR capacity model the 95% probability criterion should be applied to the successful Doppler processing of valid long messages, with a population of beacons transmitting only long messages. The analysis detailed at Annex C, and simulations of the system performance, show that this would result in an overly conservative LEOSAR capacity figure, considering in particular that the 95% probability criterion is applied to beacons with a CTA of 22º, which is already a very conservative constraint. The LEOSAR capacity figures would significantly increase if the calculations were based on beacon events with a CTA less than 22º (i.e. satellite passes that provide for the possible reception of more than 5 bursts with a minimum elevation of 5º). Therefore, the nominal LEOSAR capacity will be based on the maximum number of active beacons in the satellite visibility circle that allows for a 95% probability of successful Doppler processing of a beacon with a CTA of 22º, assuming a population of beacons transmitting short messages.

On the basis on the above hypotheses, and in particular because of the choice of a scenario for achieving the required probability of successful Doppler processing that specifically addresses beacons at the edge of the satellite visibility area (i.e. with a CTA of 22º), the model used in the computation of the LEOSAR capacity is conservative. Nevertheless, the capacity figures provided by this model indicate that a worldwide beacon population greater than one million can be supported by a single frequency channel, and that a beacon population of about

3.15 million can be supported if the available frequency band is used in accordance with the optimum channel assignment scheme (see section 4).

In respect of the management of the 406.0 – 406.1 MHz frequency band, it is important to note that, for a capacity computation based on the specific case of beacon events characterised by a CTA of 22º, three adjacent channels provide less capacity than a single frequency channel, and five adjacent channels provide less capacity than three channels. To increase the LEOSAR system capacity, it is necessary to separate the new channels by at least 9 kHz to ensure a degree of independence between the channels. Total independence in term of frequency collisions between channels in the LEOSAR system would require a separation of 18 kHz.

The detailed analysis of the optimum frequency assignment scheme is provided in section 4.

2.3 GEOSAR System Capacity Model

Annex D provides a detailed analysis of the GEOSAR capacity model and the results of the capacity computations performed under the following hypotheses:

- GEOSAR channels separated by at least 3 kHz are independent (bursts from beacons in different channels do not collide in frequency);

- for the first burst transmitted by a beacon, all burst arrival times at the satellite antenna, from other beacons in the same channel, are assumed to be uniformly distributed over the duration of the repetition period;

- for subsequent transmissions of the same beacon, the probability of collision in time is affected by the random spreading of the repetition period as specified in document C/S T.001 (i.e. 50 seconds +/- 5 %);

- for a beacon satisfying the nominal conditions described at Annex B, a successful GEOLUT processing requires at least 3 beacon bursts received with no collisions; and

- the total system capacity increases linearly with the number of channels in use (the total load on the satellite repeater has no impact on the channel capacity).

The analysis of the GEOSAR capacity provided at Annex D demonstrates that the requirement for a 95% probability of successful processing within 5 minutes is always more restrictive than a requirement for 99% within 10 minutes. Therefore, the determination of the nominal GEOSAR capacity on the basis of a 95% probability of successful processing is consistent with the conservative approach adopted for the LEOSAR capacity model.

However, this criterion will be applied to the successful recovery of valid long messages (i.e. the recovery of the first protected field of a long message, assuming all beacons are transmitting long format messages), noting that a valid long message is sufficient to generate a GEOSAR alert, and that a complete long message (first and second protected fields) will be retrieved within 10 minutes with a probability of 99.9% (see Table D.5 of Annex D).

In addition, the analysis shows that, under the criterion 95% of valid messages successfully processed within 5 minutes, a complete long message will be confirmed (second successful processing of an identical message) within 10 minutes with a probability greater than 96%, or within 15 minutes with a probability greater than 99% in the worst-case scenario (see Table D.6 of Annex D)

With the above hypotheses the nominal GEOSAR channel capacity is 14 beacons in the visibility area of a GEOSAR satellite that are simultaneously active in the same channel.

The performance of the GEOSAR system is highly dependent upon the quality of the link, which itself depends on a number of factors (e.g. beacon EIRP). This link quality is reflected in the GEOSAR capacity model with the selection of the parameter K: minimum number of bursts required, with no frequency collisions, to ensure successful processing. The selection of K = 3 reflects a conservative approach to the determination of the nominal GEOSAR capacity and, under nominal conditions, some GEOSAR systems are expected to exhibit higher capacity performance than described above.

2.4 Validation of Capacity Models

The system capacity figures derived from the models described above must be verified on the basis of controlled tests, using real 406 MHz beacons and/or beacon simulators to generate known traffic loads in one or several 406 MHz channels. The output from Cospas-Sarsat LEOLUTs or GEOLUTs in presence of the simulated traffic load will be analysed to determine the performance of the system. The process is repeated for increasing (or decreasing) traffic loads, until the tested system exhibits a performance commensurate with the probability level of the capacity definition (i.e. 0.95).

The test procedures used to validate the GEOSAR and LEOSAR (SARP/SARR) capacity models are provided at Annex E.

- END OF SECTION 2 -

3. ASSESSMENT OF CAPACITY REQUIREMENTS

The Cospas-Sarsat System capacity requirement is the load of 406 MHz transmissions from operational beacons or other sources that the System should be able to process or accommodate. The list below identifies the sources which contribute to this load:

a. 406 MHz distress beacons which have been activated in their operational mode;

b. 406 MHz distress beacons which have been activated in their self-test mode;

c. transmissions from faulty 406 MHz beacons;

d. Cospas-Sarsat System beacons (i.e. orbitography and reference beacons);

e. 406 MHz test beacons; and

f. interference.

3.1 Measure of Traffic Loads and System Capacity

The load on the System caused by a single active beacon transmitting a short format message, or a long format message, and operating in accordance with the requirements of document C/S T.001 (406 MHz beacon specification), is a well-defined and well understood amount of traffic which can be used as a unit of measure. Therefore, it is practical to convert all components of the 406 MHz traffic load into an equivalent number of active beacons as defined above.

For example, knowing the technical characteristics of 406 MHz beacon self-test mode signals, it is possible to represent the average load resulting from self-test mode transmissions which may occur in the system, as an equivalent number of simultaneously active beacons.

The end result is that the overall capacity requirement corresponding to the sum of all sources of 406 MHz transmissions can be expressed as an equivalent number of simultaneously active beacons. This approach provides a standard unit of measure that can also be used in the definition of System capacity, the capacity models, and Cospas-Sarsat test procedures for assessing capacity. Because this standard unit of 406 MHz traffic is used in all these applications, it allows a simple comparison of capacity requirements against the actual or forecast System capacity.

An estimate of 406 MHz transmission loads on the System requires:

a. an assessment of the 406 MHz beacon population;

b. a method for determining the traffic load on the System caused by the distress beacon population, actual or forecast, expressed as an equivalent number of active beacons; and

c. appropriate methods for converting other components of the load into an equivalent number of active 406 MHz beacons.

Considering that the Cospas-Sarsat 406 MHz system includes satellites in low-altitude polar Earth orbit (LEOSAR system) and in geostationary orbit (GEOSAR system), and since each of these systems has unique operating characteristics, it is necessary to establish the capacity requirements for the LEOSAR and GEOSAR systems separately. Furthermore, since the use of the 406 MHz band is managed by controlling the number of beacons in each 406 MHz channel, there is a requirement to determine the traffic load generated in each 406 MHz channel.

3.2 406 MHz Beacon Population Assessment and Forecast

An accurate assessment of the 406 MHz beacon population and a forecast of its evolution are essential for determining current and future System capacity requirements (i.e. the beacon message traffic to be supported by the System).

The capacity of the System depends on the bandwidth available for beacon use. Therefore, to satisfy the capacity requirements resulting from the growth of the beacon population, the carrier frequency of 406 MHz beacons must be spread over an increasing number of frequency channels in the 406.0 to 406.1 MHz band. Each channel contributes a specific capacity figure which cannot be exceeded if the specified System performance is to be maintained in the channel. Therefore, the beacon population and the corresponding capacity requirements must be assessed and forecast for each Cospas-Sarsat 406 MHz frequency channel.

3.2.1 Total Beacon Population

The total 406 MHz beacon population is determined from the results of a survey of manufacturers of type approved beacons conducted annually by the Cospas-Sarsat Secretariat. This survey requests the manufacturer to provide:

a. the number of distress beacons that were manufactured in the previous calendar year;

b. the number of those beacons that were purchased as replacements for 406 MHz beacons which had been removed from service; and

c. an estimate of the growth rate of the number of beacons that manufacturers will produce in future years.

This information is consolidated with information obtained from other sources (e.g. reports provided by national Administrations and international organizations) to produce a 10 year forecast of the overall 406 MHz beacon population. A model of the 406 MHz beacon population forecast is provided at Annex F.

As a check to ensure that the forecast beacon population remains consistent with the size of the potential user population, an analysis of available statistical data on aircraft and vessel fleets has been conducted. The potential beacon population is based on the size of fleets for each category of aircraft and vessel, assuming an estimated maximum percentage of each category could be equipped, and a global estimate of the total personal locator beacon (PLB) market. A summary of this analysis is also provided at Annex F.

3.2.2 Beacon Population per Channel

The actual beacon population operating in each 406 MHz channel ($P_{channel}$) can be estimated by tracking the ratio of Cospas-Sarsat alerts received from each channel to the total number of alerts received, and applying this ratio to the total beacon population.

$$P_{Channel} = \frac{\text{Number of alerts received in channel}}{\text{Total number of alerts received}} \times \text{Total beacon population}$$

Having determined the actual beacon population in a channel, the forecast of the population in that channel can be developed on the basis of responses to the annual survey of beacon manufacturers by applying appropriate growth ratios. However, the forecast of the population in individual channels requires detailed information and complex analyses which may not be as reliable as global production figures or growth ratios. In particular, it may prove extremely difficult to predict on a long term basis reliable figures of beacon model production, or the termination of production of a beacon model and the replacement rate of existing beacons with new models.

Because of the difficulty of forecasting the beacon population in individual frequency channels, and the corresponding traffic demand, adequate margins will need to be introduced in the forecast of capacity requirements per channel when deciding on the use of additional frequency channels.

3.3 406 MHz Traffic Forecast

To determine capacity requirements, it is necessary to forecast the average and peak traffic loads in each 406 MHz channel. As described above, the load is comprised of 406 MHz transmissions from many sources, including operational beacons, System beacons, test beacons, and interference. The various sources of 406 MHz transmissions and the mathematical model used to forecast the 406 MHz beacon message traffic in the LEOSAR and GEOSAR systems are detailed at Annex G. An outline of the traffic model is provided below. The impact of faulty beacons and interference is further addressed in section 3.4.
The peak traffic load in the coverage area of a GEOSAR or LEOSAR satellite is obtained by:

a. monitoring the 406 MHz band to assess the contribution of each source to the total load;

b. conducting analyses to forecast long-term changes in the load contributed from each source (e.g. develop methods for assessing trends in the traffic load resulting from active beacons, self-test mode transmissions, test beacons, etc.);

c. converting the load generated from each source into an equivalent number of operational beacons active world-wide;

d. determining the corresponding load in the coverage area of the system considered (LEOSAR or GEOSAR) by applying the satellite coverage area to earth surface area ratio to each component of the load, as appropriate;

e. monitoring the load from each source to determine fluctuations which are function of time or geographic regions, taking into account the systems' coverage area;

f. applying the fluctuation factors described above (peak-time factor and geographic density ratio), to obtain worse case loads from each source; and

g. summing the load from each source to establish the peak total traffic load.

The process described above provides capacity requirements for the LEOSAR and the GEOSAR systems, expressed as an equivalent number of active beacons, which are a function of the actual or forecast beacon population. Similar computations can also be performed for each 406 MHz channel, on the basis of the actual or forecast proportion of the total beacon population in each channel, to ensure that the capacity of each individual channel is not exceeded.

The detailed computation of the 406 MHz peak traffic load for each source of 406 MHz transmissions is described in detail in the "Cospas-Sarsat 406 MHz Message Traffic Model" provided at Annex G.

3.4 Interference and Faulty Beacons

Non-beacon transmitters which emit signals in the 406 MHz band and defective beacons can seriously impact on the System capacity.

Every effort is made by Cospas-Sarsat to identify and locate the sources of 406 MHz interference, using in particular the LEOSAR system and Doppler location techniques, so that these sources may be eliminated with the assistance of responsible Administrations. However, such elimination requires lengthy efforts and, during this period of time, interference can affect the System's capability to detect and locate 406 MHz distress alerts in some areas of the globe.

One particular beacon failure mode has been observed by Cospas-Sarsat. Some 406 MHz beacons transmit repetitively in the self-test mode (see document C/S T.001) a message with an inverted frame synchronisation pattern which is not processed by the System but does generate a 406 MHz traffic load. Additional tests have been introduced in the type approval process to eliminate this problem in future. However, in the interim, faulty beacons can have a significant impact on the total 406 MHz traffic at a particular time due to very short repetition periods of the self-test mode transmissions.

Having monitored the impact of such emissions for extended periods of time, Cospas-Sarsat concluded, that:

a. although some channels in the 406.0 to 406.1 MHz frequency band seem to experience periodic interference patterns, it is not possible to reliably predict when interference sources or faulty beacons will be active, the duration that they will be active, nor their impact while they are active;

b. therefore, it is not possible to estimate a “typical load” that could be used to assess their impact on the 406 MHz traffic; and

c. consequently, the Cospas-Sarsat 406 MHz traffic model should not include an additional traffic level to account for faulty beacons or interference.

However, it is also recognised that, during particular periods of time, in some geographic areas and within particular 406 MHz beacon channels, the System capacity could be affected by interference or faulty beacon transmissions and these aspects should be taken into account in the management of the use of the 406 MHz band.

- END OF SECTION 3 -

4. COSPAS-SARSAT CHANNEL ASSIGNMENT PLAN IN THE BAND 406.0 - 406.1 MHz

The following sections discuss the rationale for the development of a Cospas-Sarsat 406 MHz channel assignment plan, the Cospas-Sarsat policy in respect of the use of assigned 406 MHz frequency channels, the 406 MHz bandwidth needed to satisfy capacity requirements for both the LEOSAR and GEOSAR systems, and the strategy for ensuring an optimum use of the available frequency spectrum.

The procedures developed by Cospas-Sarsat for the management of the 406 MHz beacon message traffic demand through the opening of additional frequency channels in the assignment table are discussed in section 5 of this document.

4.1 Cospas-Sarsat 406 MHz Channel Assignment Plan

Pursuant to Article 9 of the International Cospas-Sarsat Programme Agreement, the functions of the Cospas-Sarsat Council include, inter alia:

- the development of the necessary technical, administrative and operational plans;
- the preparation, consideration and adoption of technical specifications for the System space and ground facilities and radiobeacons, as well as the adoption of Cospas-Sarsat technical and operational documentation; and
- the assessment of the need for technical and operational enhancements of the System.

To ensure adequate system performance and the timely adjustment of the System capacity as demand requires, the Cospas-Sarsat Council must ensure that 406 MHz beacons are produced in accordance with a co-ordinated frequency assignment plan. The frequency assignment plan shall take into account:

- the constraints of the space segment (see section 5);
- the constraints of 406 MHz beacon development, production and testing, in particular the manufacturers' need for sufficient advance notice for implementing any changes to their beacon development and production programmes;
- the constraints of Administrations and international organisations responsible for regulatory matters; and
- the need to optimise the use of the available spectrum and reserve bandwidth for future system evolution, including the possible development of new types of 406 MHz distress beacons.

As decisions on matters of beacon specification, testing and type approval may impact on Administrations and users world-wide, the Cospas-Sarsat Council decisions in respect of the use of 406 MHz frequency channels for new beacon models must be co-ordinated with Administrations and the responsible international organisations, and publicised with sufficient advance notice.

In view of its responsibilities, the manufacturing and regulatory constraints described above and the need for advance planning and co-ordination, the Cospas-Sarsat Council has decided to adopt a long term Cospas-Sarsat 406 MHz Channel Assignment Plan, and to publicise the Cospas-Sarsat 406 MHz Channel Assignment Table, as provided at Annex H to this document. The Cospas-Sarsat 406 MHz Channel Assignment Table summarises the current assignments of 406 MHz channels for the production of type approved beacons and for type approval of new models of Cospas-Sarsat 406 MHz beacons. It also provides a summary of future channel assignments in the 406.0 to 406.1 MHz frequency band as planned by Cospas-Sarsat to ensure that future capacity requirements will be met.

4.2 Cospas-Sarsat Policy on the Use of Assigned 406 MHz Channels

The use of assigned frequency channels will be monitored on an annual basis. Cospas-Sarsat will update its forecast of capacity requirements and make changes to the 406 MHz Channel Assignment Plan as required. To allow for appropriate co-ordination with manufacturers, Administrations, and competent international organisations, Cospas-Sarsat will endeavour to decide on any changes to the 406 MHz Channel Assignment Plan with a minimum advance notice of three years before the date such changes would become applicable. The Cospas-Sarsat 406 MHz Channel Assignment Table provided at Annex H defines the current and planned status of channels in the 406.0-406.1 MHz band, as assigned by Cospas-Sarsat for type approval of 406 MHz beacon models.

The Cospas-Sarsat policy for the use of assigned 406 MHz channels is summarised as follows:

a. Beacon models submitted for Cospas-Sarsat type approval testing shall comply with the applicable carrier frequency assignment as at the date the beacon is submitted to a Cospas-Sarsat accepted laboratory for type approval testing.

b. If a beacon model is designed to operate in several 406 MHz frequency channels, Cospas-Sarsat will determine the frequency channel(s) in which production beacons of that model should operate, in accordance with the Channel Assignment Table (Annex H), and/or any applicable restrictions, depending on the particular design characteristics of the beacon model submitted for type approval and the type approval testing performed on that model.

c. After successful completion of the Cospas-Sarsat type approval testing procedure, the Secretariat will issue a Cospas-Sarsat type approval certificate. The Cospas-Sarsat type approval certificate shall indicate the nominal carrier frequency, or frequencies, at which production beacons of that model should operate, as per the type approval testing performed on the model provided by the manufacturer.

d. The nominal carrier frequency(ies) for a beacon model, as stated on the Cospas-Sarsat type approval certificate, will be published in the document Cospas-Sarsat System Data, updated by the Cospas-Sarsat Secretariat on an annual basis, and will be made available on the Cospas-Sarsat web-site.

e. When issuing national type approval for a beacon model, or licences for the use of a beacon, Administrations should ensure that 406 MHz beacons of the model are operating in the appropriate frequency channel(s), as provided in the Cospas-Sarsat type approval certificate and in accordance with the Cospas-Sarsat 406 MHz Channel Assignment Table.

f. The Cospas-Sarsat 406 MHz Channel Assignment Table will be amended as required on an annual basis, and publicised in the revisions of this Cospas-Sarsat 406 MHz Frequency Management Plan (C/S T.012), issued by the Cospas-Sarsat Secretariat after approval of the Cospas-Sarsat Council.

g. If the 406 MHz beacon message traffic in a particular frequency channel approaches its capacity limit, the Cospas-Sarsat Council may decide, as appropriate, to:

- close that channel for type approval of new beacon models and amend the 406 MHz Channel Assignment Table accordingly;
- request manufacturers to switch their production to another frequency channel, subject to the beacon model continuing to satisfy Cospas-Sarsat performance requirements; and
- recommend that Administrations consider amending their national regulations / legislation to encourage the transition to alternative frequency channels.

4.3 Bandwidth Requirements and Channel Assignment Strategies

Analysis conducted by Cospas-Sarsat has determined that the most effective way to manage the 406 MHz band was to divide the available spectrum into individual channels and open these channels for operational use as demand requires. The following sections discuss the bandwidth requirements for the GEOSAR and the LEOSAR systems, on the basis of 3 kHz frequency channels, and the optimum channel assignment strategy.

The Cospas-Sarsat frequency channels in the 406.0 - 406.1 MHz band are defined by the nominal carrier frequency of the beacons operating in the channel.

4.3.1 Bandwidth Requirements for the GEOSAR System

Based on the observed spectral characteristics of operational 406 MHz beacons, Cospas-Sarsat has determined that the nominal separation of beacon carrier frequencies should be at least 3 kHz in order to minimise inter-channel interference between adjacent channels in the GEOSAR system and ensure that adjacent channels can be considered as independent in terms of the GEOSAR system capacity. As the channels are independent, the total GEOSAR system capacity is the sum of the capacity of individual channels open for beacon operation.

4.3.2 Bandwidth Requirements for the LEOSAR System

The analysis of the LEOSAR system capacity shows that, due to a Doppler spreading of about +/- 9 kHz, frequency channels separated by 3 kHz are not independent in the LEOSAR system. Furthermore, the analysis provided at Annex C to this document, shows that a single channel has considerable capacity, but because of mutual interference between channels, three adjacent channels have less capacity than a single channel, and five adjacent channels have less capacity than three channels. This paradox is the result of the increase in the probability of frequency collision for beacon bursts received with small Doppler shifts.

If required, a capacity increase can only be achieved by opening new channels separated from existing channels by at least 9 kHz. Total independence between existing and new channels would require a separation of 18 kHz.

Figure 4.1 illustrates the LEOSAR capacity (number of active beacons in the satellite visibility area) achieved when various channels or groups of channels are open for use, with channel A corresponding to 406.022 MHz (reserved for System beacons), and channel S corresponding to 406.079 MHz (channel 19). The capacity figure for a group of channels is plotted with reference to the highest channel in the group, e.g. the capacity corresponding to channels ABC+FG+JK is plotted as channel K (i.e. 11).

Figure 4.1: LEOSAR Capacity and Bandwidth Requirements

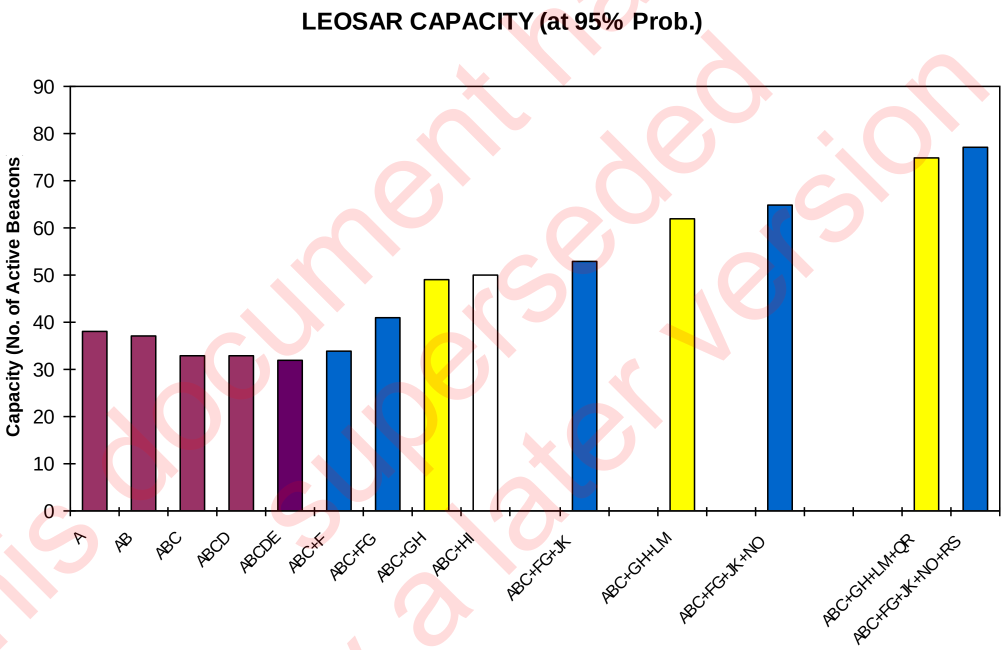


Figure 4.1 shows that:

- opening new channels adjacent to the three channels already in use (ABC) does not increase the LEOSAR capacity;
- the best result is achieved with pairs of adjacent channels separated by 12 kHz (i.e. ABC+G or ABC+GH); and
- a similar result is achieved with a separation of 9 kHz between pairs of channels (i.e. ABC+FG+JK+ etc.), but with less efficiency from a LEOSAR perspective as more channels need to be opened for the same end result.

The computed LEOSAR capacities illustrated in Figure 4.1, expressed as a number of active beacons in the satellite visibility circle, are provided in Table 4.1 below.

Note that the case of single additional channels (e.g., ABC+F, or ABC+G) has also been considered but would not provide for sufficient GEOSAR capacity (see section 4.3.3).

4.3.3 Optimum Channel Assignment Strategy

The capacity of a single independent channel in the LEOSAR system is considerably higher than the capacity of a single independent channel in the GEOSAR system. However, because of cross channel interference in the LEOSAR system, the LEOSAR system capacity does not increase linearly with the number of channels, while the capacity of the GEOSAR system does increase linearly with the number of channels opened for use. To achieve optimum use of the frequency spectrum, the strategy for assigning new channels, or groups of channels, with the appropriate frequency separation, should ensure that the LEOSAR and GEOSAR capacities remain balanced.

Taking into account the three channels already opened for use (i.e. 406.022 MHz, 406.025 MHz and 406.028 MHz), and the fact that the channel 406.022 MHz is currently reserved for System beacons (orbitography and reference beacons), Table 4.1 provides a comparison of the LEOSAR and GEOSAR capacities achieved under various channel assignment schemes. As the beacon message traffic models are different for the LEO and the GEO systems, the equivalent numbers of active beacons that correspond to the capacity of the LEOSAR and the GEOSAR systems cannot be compared directly. Therefore, for the purpose of this comparison, the capacity is expressed as the worldwide population of operational beacons that can be accommodated while maintaining adequate system performance.

From the above remark, it should be noted that the capacity, expressed as the worldwide beacon population that can be accommodated by the System, may vary with the model of beacon message traffic, while the capacity expressed as a number of active beacons in the satellite visibility area is only dependent upon the system performance and will remain constant, unless the system performance is enhanced/degraded.

Columns 1 to 3 of Table 4.1 identify the various channels and column 4 (Channels in Use) illustrates possible combinations of channels for a variety of assignment strategies.

Columns 5 (LEO Capa) and 7 (GEO Capa) provide the respective capacity of the LEOSAR and GEOSAR systems expressed as the number of active beacons in a satellite visibility area that can be processed with the required level of system performance, and computed using the capacity models provided at Annexes C and D. Note that the GEOSAR capacity is 0 for 406.022 MHz as this channel is reserved for System beacons. The LEOSAR capacity for 406.022 MHz is provided as illustration of a single independent LEOSAR channel capacity.

Columns 6 (LEO Channels) and 8 (GEO Channels) provide the LEO and GEO systems' capacity figures expressed in terms of the worldwide beacon population assessed in accordance with the 406 MHz beacon message traffic models detailed at Annex G.

**Table 4.1: Comparison of LEO/GEO Capacity
for Various Channel Assignment Strategies**

	Channels	MHz	Channels in U	LEO Capa	LEO-Channels	GEO Capa	GEO-Channels
1	1 - A	406.022	A	38	3,048,915	0	0
2	2 - B	406.025	AB	37	2,956,523	14	1,297,257
3	3 - C	406.028	ABC	33	2,586,958	28	2,948,312
4	4 - D	406.031	ABCD	33	2,586,958	42	4,599,366
5	5 - E	406.034	ABCDE	32	2,494,566	56	6,250,420
6	6 - F	406.037	ABC+F	34	2,679,349	42	4,599,366
7	7 - G	406.040	ABC+FG	41	3,326,089	56	6,250,420
8	8 - H	406.043	ABC+GH	49	4,065,219	56	6,250,420
9	9 - I	406.046	ABC+HI	50	4,157,611	56	6,250,420
10	10 - J	406.049					
11	11 - K	406.052	ABC+FG+JK	53	4,434,785	84	9,552,529
12	12 - L	406.055					
13	13 - M	406.058	ABC+GH+LM	62	5,266,307	84	9,552,529
14	14 - N	406.061					
15	15 - O	406.064	ABC+FG+JK+	65	5,543,481	112	12,854,638
16	16 - P	406.067					
17	17 - Q	406.070					
18	18 - R	406.073	ABC+GH+LM-	75	6,467,394	112	12,854,638
19	19 - S	406.076	ABC+FG+JK+	77	6,652,177	140	16,156,747

Note: The worldwide beacon populations (LEO-Channels, GEO Channels) are computed on the basis of the 2024 LEO and GEO traffic models.

Table 4.1 shows that, with Channel A reserved for System beacons, the GEOSAR system would limit the capacity of the group of channels (ABC) to about 2.9 million. If channels D and E are used, the GEOSAR capacity would increase to about 6.3 million, but the LEOSAR capacity would not increase with these channel assignments.

Therefore, a better strategy would be to open channels F and G (or G and H), which would significantly increase the LEOSAR capacity to 3.3 (or 4.1) million and allow for growth. Based on the 2024 LEO and GEO traffic models, the optimum assignment would be channels ABC+HI, which would provide a capacity of about 4.2 and 6.3 million for LEO and GEO systems.

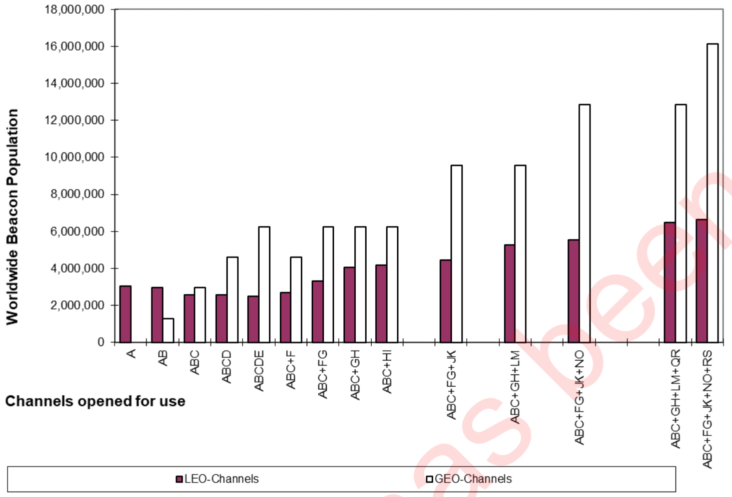
Figure 4.2 illustrates the LEOSAR and GEOSAR capacities given in Table 4.1, and in particular two possible assignment schemes:

a) the channels ABC plus additional groups of two adjacent channels separated by 9 kHz (e.g., ABC+FG+JK+NO+RS); and

b) the channels ABC plus additional groups of two adjacent channels separated by 12 kHz (e.g., ABC+GH+LM+QR).

Note that the worldwide beacon population figures given in Figure 4.2 are derived from the capacity expressed as the equivalent number of beacons simultaneously active in the field of view of a satellite. These population figures are therefore dependent on the traffic model used and are significantly different from those obtained in 2002, when document C/S T.012 was first issued, which were more conservative. It should also be noted that these population figures assume that each available channel accommodates the maximum population allowed (i.e., matching the capacity).

Figure 4.2: Comparison of Channel Assignment Strategies for Combined LEO/GEO Operation



Note: Worldwide beacon population is based on 2024 LEO and GEO traffic models.

From Figure 4.2 and Table 4.1 it can be seen that:

- a separation of 12 kHz between channel pairs (ABC+GH+LM+QR) is more "efficient" from a LEOSAR perspective, as it provides the required capacity with the minimum spectrum occupancy; and
- a separation of 9 kHz between channel pairs (ABC+FG+JK+NO+RS) provides the maximum capacity within the 19 available channels (7.8 million) and maintains a reasonable match between the LEOSAR and the GEOSAR capacities.

On the basis of the traffic model available in 2002 which showed more balanced LEO and GEO capacities using the 9 kHz separation, Cospas-Sarsat has selected a channel assignment strategy which calls for the opening, when required by the expected growth of the beacon population, of pairs of adjacent channels separated by 9 kHz from the previous pair (i.e., alternating pairs of empty channels and pairs of channels open for use).

This channel assignment strategy is illustrated in the Channel Assignment Plan provided at Annex H to this document.

4.4 Cospas-Sarsat System 406 MHz Frequency Protection Requirements

Even though not all channels have been made available for use, the 406 MHz Cospas-Sarsat satellite payloads in orbit are relaying/processing transmissions in the complete 406.0 - 406.1 MHz frequency band. Therefore, any energy radiated in that band may have an impact on both the LEOSAR and GEOSAR system capacity. In particular, interference in the frequency band can severely affect the capability of the system to detect and process 406 MHz distress beacon transmissions.

For the reasons outlined above:

- any party planning to make use of non-assigned channels, or of channels assigned for use in future by Cospas-Sarsat 406 MHz beacons, should undertake appropriate co-ordination with Cospas-Sarsat, in accordance with the applicable ITU co-ordination procedures; and
- out-of-band transmissions should not generate a spectral power flux density in the 406.0 - 406.1 MHz band, as received by the Cospas-Sarsat satellites, in excess of the levels shown in ITU Recommendation ITU-R M.1478 (protection requirements for the Cospas-Sarsat SARP instruments).

- END OF SECTION 4 -

5. PROCEDURES FOR THE ASSIGNMENT OF 406 MHz CHANNELS

The 406.0 to 406.1 MHz available spectrum is divided into 3 kHz channels which are assigned for use as required, taking into account the following factors:

a. the bandwidth of Cospas-Sarsat LEOSAR space segment instruments and the induced Doppler frequency shift on 406 MHz beacon transmissions;

b. the bandwidth of Cospas-Sarsat GEOSAR space segment equipment;

c. the total capacity requirements, current and forecast, as a function of the existing and forecast beacon population;

d. the existing and forecast traffic loads in each active channel; and

e. particular circumstances which may affect the capacity of specific channels.

The following sections describe the constraints imposed by LEOSAR and GEOSAR space segment instruments, the Cospas-Sarsat procedure applied for determining the need for new frequency channels, and the methods available to Cospas-Sarsat for managing capacity requirements.

5.1 Description of LEOSAR and GEOSAR Satellite Constraints

5.1.1 Bandwidth of LEOSAR Space Segment Instruments

As described in Cospas-Sarsat System document C/S T.003, entitled "Description of the Payloads Used in the Cospas-Sarsat LEOSAR System", the future generations of SARP instruments will be able to receive signals in the band 406.01 - 406.09 MHz. Therefore, taking into account a maximum Doppler shift of about ± 9 kHz caused by the relative velocity between the satellite and the beacon, plus a 1 kHz margin at the edge to provide for some spreading of the beacon carrier frequency around the central frequency of a channel, the channel assignment plan should not include operational channels below 406.02 MHz (406.01 MHz + 10 kHz) or above 406.08 MHz (406.09 MHz - 10 kHz) to ensure compatibility with the second generation (SARP-2) instruments of the LEOSAR system.

5.1.2 Bandwidth of GEOSAR Space Segment Instruments

The bandwidth of GEOSAR satellite payloads is described in Cospas-Sarsat System document C/S T.011, entitled "Description of 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System". Since, for management purposes, the bandwidth constraints imposed by GEOSAR space segment instruments need not include additional overhead to accommodate Doppler shift, the entire bandwidth covered by GEOSAR satellites (406.01 - 406.09 MHz) would be suitable for GEOSAR use.

5.2 Principles of 406 MHz Channel Assignment

The objective of the Cospas-Sarsat 406 MHz channel assignment process is to ensure that the number of 406 MHz beacons operating in a given channel does not generate a peak traffic load in excess of the channel capacity. To achieve this, the actual number of beacons produced for operation in each channel must be monitored, and its growth must be forecast to allow for decisions to be taken with sufficient advance notice.

However, Cospas-Sarsat does not have direct control of the production of 406 MHz beacons in each frequency channel, or of their sale. Cospas-Sarsat can only influence the production of beacons through the Cospas-Sarsat 406 MHz beacon type approval process, and by working closely with Administrations and international organizations which mandate or provide specification requirements for 406 MHz beacons.

5.2.1 Assignment of Frequency Channels for Type Approval of New Beacon Models

To ensure that 406 MHz beacons are compatible with Cospas-Sarsat satellite instruments and ground processing equipment, and do not adversely impact on the System performance, Cospas-Sarsat has established specific technical requirements and testing procedures for 406 MHz beacons. The technical requirements are described in the document "Specification for Cospas-Sarsat 406 MHz Distress Beacons" (C/S T.001) and the testing procedures are defined in the document "Cospas-Sarsat 406 MHz Distress Beacon Type Approval Standard" (C/S T.007). Upon successful completion of the testing of a beacon model in accordance with the requirements of C/S T.001 and C/S T.007, a Cospas-Sarsat type approval certificate is issued by the Cospas-Sarsat Secretariat to the manufacturer.

Cospas-Sarsat Participants, and the majority of Administrations from other countries, require that manufacturers obtain a Cospas-Sarsat type approval certificate before authorising the use and registration of 406 MHz beacon models in accordance with their national legislation and/or regulations.

Therefore, through the Cospas-Sarsat type approval procedure, Cospas-Sarsat can influence the production of new beacon models in a particular frequency channel by imposing that, from a given date, new models submitted for Cospas-Sarsat type approval operate in specific frequency channels. However, Cospas-Sarsat has no mandate to control the actual production of beacons and, once issued, the Cospas-Sarsat type approval certificate remains valid with no time-limit, unless the produced beacons of the type cease to meet the specified performance requirements. The production of type approved beacon models can continue for as long as the manufacturer decides, i.e., many years after the frequency channel has been closed for use by new beacon models.

As a consequence, Cospas-Sarsat must consider the need to open new frequency channels on the basis of production forecast, well before the active channels approach their capacity limit. This advance notice is also required by manufacturers who must plan in advance the design and production of new beacon models, as well as regulatory Administrations that may have to adapt the applicable regulation/licensing requirements.

In view of the above constraints, Cospas-Sarsat has agreed to:

a. decide on opening new frequency channels for type approval of new beacon models with a minimum three year advance notice; and

b. adopt type approval testing procedures which allow a particular beacon model to be tested and type approved for a range of frequency channels, provided that the manufacturer accepts the commitment to cease the production of the beacon model in frequency channels closed for type approval, and to transition its production to other channels open for type approval, as provided in the Cospas-Sarsat 406 MHz Channel Assignment Table (see Annex H).

5.2.2 Transition of Type Approved Beacon Models to New Frequency Channels

Because beacon models type approved for operation in a single channel can continue to be produced after the frequency channel has been closed for type approval of new models, the population of beacons in a particular channel could eventually grow beyond the capacity limit for that channel. Therefore, it may be necessary for Cospas-Sarsat to encourage the transition of production of these beacon models to other channels.

To facilitate such transition, Cospas-Sarsat has adopted streamlined retesting requirements for beacon models already type approved, to permit their operation in new frequency channels. However, Cospas-Sarsat relies on co-ordination with Administrations to enforce the transition on a national basis and may take measures, in coordination with beacon manufacturers and using C/S T.007 certification procedures, to transition beacon production, should the termination of production in a designated channel become an urgent requirement to ensure adequate System performance.

5.3 Procedure for Deciding on New Channel Assignments

As Cospas-Sarsat cannot directly control the actual number of beacons operating in a given 406 MHz channel, it is not possible to wait until a channel is at full capacity before requiring new beacon models to be type approved to operate in a different frequency channel. Instead, the schedule for closing channels for type approval of new beacon models must take into account the long-term production estimate of all type approved beacons designed to operate in the 406 MHz channel under consideration. Furthermore, since beacon model production rates are difficult to estimate, it is necessary to develop a schedule for opening and closing channels that provides for a reasonable channel capacity margin.

Taking into account the various factors which could affect beacon population growth, a channel should be closed for the type approval of new beacon models at the date when the forecast channel load would reach 75% of the nominal channel capacity.

To assist Council decisions and provide adequate advance notice to manufacturers and Administrations of the opening and closing of frequency channels for type approval of new beacon models, a ten-year frequency channel assignment plan has been developed on the basis of the forecast growth of the 406 MHz beacon population. The plan will be reviewed on an annual basis to ensure consistency with the actual evolution of the beacon population. The annual review of the plan will also need to consider:

a. the actual and forecast evolution of the beacon population and 406 MHz traffic in all channels open for the production of type approved beacons; and

b. the actual and forecast growth of the beacon population and 406 MHz traffic in channels open for type approval of new beacon models.

As wide variations of the production of particular beacon models can significantly affect the forecast channel traffic, appropriate adjustments of the planned dates for opening new channels for type approval might be required. Co-ordination with Administrations and manufacturers will be undertaken if it becomes necessary to consider a transition of the production of type approved models into new channels.

- END OF SECTION 5 -

ANNEXES
TO THE COSPAS-SARSAT
406 MHz FREQUENCY
MANAGEMENT PLAN

ANNEX A

LIST OF ABBREVIATIONS AND ACRONYMS

COSPAS	COsmicheskaya Sistema Poiska Avarinykh Sudov (Satellite System for the Search of Vessels in Distress)
CTA	Cross-track angle
C/S	Cospas-Sarsat
DRU	Data Recovery Unit of the SARP instrument
EIRP	Equivalent Isotropically Radiated Power
ELT	Emergency Locator Transmitter
EPIRB	Emergency Position Indicating Radio Beacon
GEO	Geostationary Earth Orbit
GEOLUT	Local User Terminal (LUT) in the GEOSAR System
GEOSAR	Geostationary Satellite System for Search and Rescue
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
kHz	Kilohertz
LUT	Local User Terminal
LEO	Low-altitude Earth Orbit
LEOLUT	LUT in the LEOSAR system
LEOSAR	Low-altitude Earth Orbit System for Search and Rescue
MHz	Megahertz
MCC	Mission Control Centre
N/A	not applicable
NOCR	Notification of country of beacon registration message
PLB	Personal Locator Beacon
PSK	Phase-shift keying (modulation)
SAR	Search And Rescue
SARP	Search And Rescue Processor
SARR	Search And Rescue Repeater
SARSAT	Search And Rescue Satellite Aided Tracking
SPOC	SAR point of contact

TCA	Time of closest approach
WRC	World Radiocommunication Conference (ITU)

- END OF ANNEX A -

ANNEX B

NOMINAL CONDITIONS APPLICABLE FOR SARP, SARR AND GEOSAR CAPACITY DEFINITIONS AND TESTING

B.1 GENERAL

The capacity of Cospas-Sarsat 406 MHz channels are affected by many factors, such as the performance and technical characteristics of the beacon, satellite performance, the presence of interferers in the channel, and the performance of the ground processing equipment. Although these factors must be defined and quantified for the definition of Cospas-Sarsat capacity to be technically complete and for conducting capacity testing and analysis, the detailed values for these parameters are not required for a general understanding of capacity. In view of this, all such factors have been grouped together and are collectively referred to as "nominal conditions". The nominal conditions applicable for each Cospas-Sarsat system (i.e., GEOSAR, LEOSAR SARP and LEOSAR SARR) are described below.

B.2 NOMINAL CONDITIONS FOR LEOSAR SARP AND SARR SYSTEMS

a. Ambient Conditions. There are no significant sources of interference operating in the LEOSAR satellite uplink or downlink bands.

b. 406 MHz Beacon Performance. The 406 MHz distress beacons satisfy the requirements of Cospas-Sarsat document C/S T.001 (beacon specification).

c. Beacon Transmit Frequency. The beacon transmit frequencies in each channel follow a Gaussian distribution, with a mean value equal to the channel centre frequency and a standard deviation of 300 Hz.

d. Beacon Message Processing. The beacon event is considered to have been successfully processed if the LEOLUT produces a valid* message. The nominal condition for achieving successful message processing is a beacon to satellite elevation angle of at least 5^0.

e. Doppler Processing. The Doppler processing is considered to have been successful if the Doppler solution is accurate to within 20 km. For the purpose of capacity computation and testing, the probability of successful Doppler processing should be achieved for all beacon events characterised by a cross-track angle less than, or equal to 22^0 (this allows for the possible reception of at least five beacon messages with an elevation angle $\geq 5^0$).

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* The definition of a valid beacon message is provided in the Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines (document C/S T.002).

f. Coverage Area. In respect of beacon message processing and Doppler processing (see d. and e. above), a beacon is considered to be in the coverage area of the SARP / SARR channel if:

(i) SARP. The beacon to satellite elevation angle at TCA is equal to or greater than 6.2° (this allows for the possible reception of at least 4 bursts with an elevation angle to the LEOSAR satellite of at least 5^0).

(ii) SARR. The beacon to satellite elevation angle at TCA is equal to or greater than 6.2° and a LEOLUT was also in the field of view of the satellite during this period of time.

However, for the purpose of evaluating the beacon message traffic, and for the purpose of assessing the probability of burst collisions, a coverage area at 0^0 elevation angle will be considered.

g. Satellite Performance. The Cospas-Sarsat LEOSAR satellite conforms to the description of document C/S T.003 (Description of the Payloads Used in the Cospas-Sarsat LEOSAR System).

h. LEOLUT Performance. The LEOLUT satisfies the requirements detailed in the document, "Cospas-Sarsat LEOLUT Performance Specification and Design Guidelines" (C/S T.002).

i. Relationship Between Beacon Population and 406 MHz Channels. When assessing the maximum LEOSAR system capacity, the beacons in the field of view of the satellite are assumed to be spread equally amongst the 406 MHz channels specified by Cospas-Sarsat. However, the assessment of the capacity of individual frequency channels (or group of channels) should also be performed for non-even distributions of the population among the available frequency channels.

j. Distribution of Beacon Transmissions in Time. Beacon activations occur randomly in time, and the repetition period of beacon transmissions satisfies the C/S T.001 requirement, i.e., 50 seconds ± 5 %.

k. Geographical Distribution of Beacons. The active beacons are evenly distributed throughout the field of view of the satellite.

l. SARP Memory Limitation. There are no SARP memory limitations that affect the capacity.

m. Distribution of Short and Long Format Messages. Unless otherwise specified, the capacity figures assume that all beacons transmit short format messages.

B.3 NOMINAL CONDITIONS FOR GEOSAR SYSTEMS

a. Ambient Conditions. There are no significant sources of interference operating in the GEOSAR satellite uplink or downlink bands.

b. 406 MHz Beacon Performance. The 406 MHz distress beacons satisfy the requirements of Cospas-Sarsat document C/S T.001 (beacon specification), and the beacons' EIRP in the direction of the satellite is greater than or equal to [32 dBm].

c. Beacon Transmit Frequency. The beacon transmit frequencies in each channel follow a Gaussian distribution, with a mean value equal to the channel centre frequency and a standard deviation of 300 Hz.

d. Beacon Message Processing. Beacons are considered to have been successfully processed if the GEOLUT produces a valid* message.

e. Coverage Area. Beacons are considered to be in the coverage area of a GEOSAR satellite if the beacon to satellite elevation angle is equal to or greater than 4°, and there are no obstructions shielding the beacon from the satellite.

f. Satellite Performance. The Cospas-Sarsat GEOSAR satellite conforms to the description of document C/S T.011 (Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System).

g. GEOLUT Performance. The GEOLUT satisfies the requirements detailed in the document, "Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines" (C/S T.009).

h. Relationship Between Beacon Population and 406 MHz Channels. When assessing the GEOSAR system capacity, the beacons in the field of view of the satellite are assumed to be spread equally amongst the 406 MHz channels specified by Cospas-Sarsat.

i. Distribution of Beacon Transmissions in Time. Beacon activations occur randomly in time, and the repetition period of beacon transmissions satisfies the C/S T.001 requirement, i.e., 50 seconds ± 5 %.

j. Geographical Distribution of Beacons. The active beacons are evenly distributed throughout the field of view of the satellite.

k. Distribution of Short and Long Format Messages. Unless otherwise specified, the capacity figures assume that all beacons transmit long format messages.

- END OF ANNEX B -

* The definition of a valid beacon message is provided in the Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines (document C/S T.009).

ANNEX C

LEOSAR CAPACITY MODEL

See separate file [SD/Updates/T12AnnexC-Draft 8.doc]

ANNEX D

GEOSAR CAPACITY MODEL

See separate file [SD/Updates/T12AnnexD-Draft 8.doc]

ANNEX E

TEST PROCEDURES FOR VALIDATING THE GEOSAR CAPACITY MODEL

This annex describes the methodology and test procedures to be followed for evaluating the capacity of individual 406 MHz channels in the GEOSAR system.

E.1 BACKGROUND

- The channel capacity in the 406 MHz GEOSAR system is the number of simultaneously active beacons for which the system can provide a valid beacon message within 5 minutes of beacon activation, 95% of the time.

The capacity of a GEOSAR 406 MHz channel is determined by generating traffic loads from known numbers of active beacons in the channel, and evaluating the capability of the GEOSAR system to produce valid 406 MHz alert messages for each beacon in the channel.

The traffic load generated for the test should be comprised of beacon messages which are representative of the nominal conditions as stated at Annex B. Specifically the test transmissions should:

- simulate the performance of operational beacons as specified in Cospas-Sarsat document C/S T.001 (beacon specification);
- be all long format beacon messages, however, a combination of short and long format messages is acceptable provided the precise composition of the population is known;
- transmit at an EIRP of 32 ± 0.5 dBm in the direction of the GEOSAR satellite;
- originate from within the coverage area of the GEOSAR satellite with a beacon to satellite elevation angle not less than 4 degrees, furthermore, there should be no obstructions shielding test source transmitters from the satellite; and
- include an appropriate number of beacons that overlap in time and frequency as required to simulate beacon activations starting randomly in time.

Finally, the ambient conditions during the test should be monitored to ensure that there were no sources of significant interference or real beacons operating in the channel being tested, since these could significantly affect the results.

E.2 TEST PROCEDURE USING A BEACON SIMULATOR

Beacon simulators are capable of transmitting overlapping as well as non-overlapping beacon messages, thus allowing all necessary testing to be performed using only the simulator's transmissions. Two approaches can be used to generate overlapping beacon transmissions that are representative of actual operational beacon transmissions.

a. All Simulated Signals with C/S T.001 Burst Repetition Interval
Transmission times of all beacons in the simulated population are generated in accordance with the C/S T.001 specification, with pseudo-random start times for the first transmission sequence. The statistical evaluation of the System ability to process successfully beacons within five minutes can be performed using the transmissions of all simulated beacons in the sample population. An example of such a procedure is provided at Appendix A.

b. Non-overlapping Signals to Generate the Background Load
The simulator is used to generate a background traffic load comprised of simulated beacon signals that do not overlap in time. The simulator is also used to generate "test" signals which can overlap with the background traffic load and each other. The ability of the System to process the "test" signals is evaluated statistically. An example of such a procedure is provided at Appendix B.

E.3 DATA REDUCTION, ANALYSIS AND RESULTS

The data collected from conducting the test procedures described at either Appendix A or Appendix B is to be recorded at Table E.1. The information listed at Table E.2 should be completed for each simulated traffic load.

Table E.1: Data to be Collected for GEOSAR Capacity Test

Simulated Traffic Load (Number of simultaneously occurring beacon events)_____________ Script Number ___ Date/Time of start of test run 1___________				
15 Hex ID Tx by Simulator	Time of First Burst in Bcn Event	Time GEOLUT provided First Valid Msg	Time GEOLUT provided first Complete Msg	Time GEOLUT Confirmed Complete Msg

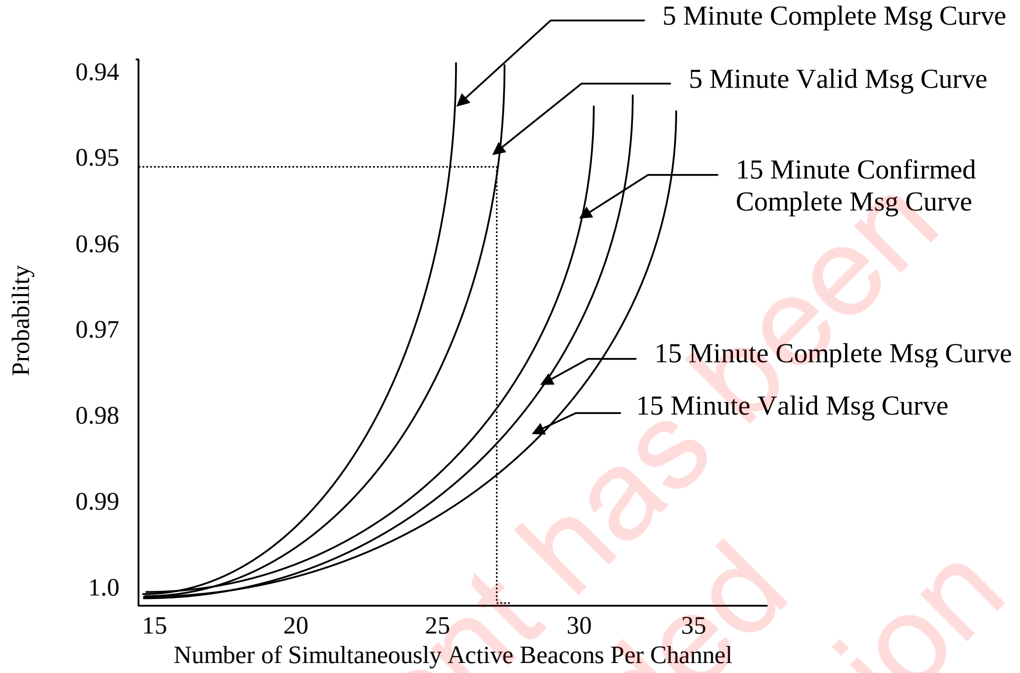
Table E.2: Sample Table for Capacity Statistics

Channel: (Frequency and C/S T.012 Channel Identifier)					
# of Active Bcn Events	**% Valid Msg within 5 Min**	**% Complete Msg within 5 Min**	**% Valid Msg within 15 Min**	**% Complete Msg within 15 Min**	**% Confirmed Complete Msg within 15 Min**
15					
20					
25					
30					
35					

The data provided in Table E.2 should be graphed against the respective beacon channel population as indicated at Figure E.1. The capacity of the channel is obtained from the graph as the number of active beacons corresponding to the 95th percentile of the valid message 5-minute curve. Using the fictitious example provided at Figure E.1, the capacity would be 26.5 simultaneously active beacons.

Although the definition of GEOSAR capacity only pertains to the production of valid messages within 5 minutes, the statistics on complete and complete confirmed messages are also calculated as they provide additional information about the performance of the GEOSAR system.

Figure E.1: Graph Depicting Capacity of a 406 MHz Channel in a GEOSAR System



APPENDIX A TO ANNEX E

SAMPLE PROCEDURE FOR GEOSAR CAPACITY TESTING USING TRANSMISSIONS WITH TIME OVERLAPS

The capacity of a 406 MHz channel in a GEOSAR system is determined by generating traffic loads equivalent to known numbers of simultaneously active beacons transmitting long format messages in a Cospas-Sarsat 406 MHz channel. The time required for the GEOLUT to produce a valid beacon message, a complete message and confirm the complete message is recorded for each beacon event. The number of simultaneously occurring beacon events is changed and the time required for the GEOLUT to produce valid, complete and complete confirmed messages is calculated and recorded for the new 406 MHz traffic load.

The test scripts transmitted by the beacon simulator should conform to the nominal conditions detailed in Annex B to C/S T.012. Furthermore, the beacon events transmitted by the simulator should replicate the randomness of the beacon burst repetition period defined in the Cospas-Sarsat 406 MHz beacon specification (C/S T.001). In view of the above, the uplink test signals will include a number of beacon messages that overlap in time and frequency. Nevertheless, due to the randomness of the beacon pulse repetition period, subsequent transmissions of these beacon events might or might not overlap again.

The test should be coordinated to avoid potential interference from non-test sources in both the GEOSAR uplink and downlink channels. Specifically the test scripts should be scheduled to ensure that no signals are uplinked whilst the GEOLUT is in the footprint of a LEOSAR satellite downlink. Furthermore, the 406 MHz channel under test should be free of any signals from operational or test beacons. To minimise the impact on LEOSAR operations, the 406 MHz test channel should be outside the operational processing bandwidth of all LEOSAR SARP instruments.

The test will replicate scenarios of 15, 20, 25, 30 and 35 simultaneously active beacons.

The test should be conducted as follows**:**

a. A beacon simulator test script is developed which replicates 15 simultaneously active beacons, with each beacon event having a unique identification (ID). The time of the first burst for each beacon event should be developed using a random process that ensures that the first burst of each beacon is transmitted within 50 seconds of the start of the test. The transmit time for subsequent transmissions for each beacon event shall conform to the repetition period defined in the Cospas-Sarsat beacon specification (C/S T.001). Each beacon event will replicate a beacon being active for a 15 minute period.

b. After ensuring that the GEOLUT is not in the downlink footprint of a Cospas-Sarsat LEOSAR satellite, the test script is transmitted. The time of the first burst for each beacon event should be recorded in tabular format as provided at Table E.1.

c. For each beacon event the time when the GEOLUT produces the first valid message, first complete message and first confirmed complete message should be recorded in Table E.1. The time measurements recorded should correspond to the time stamps assigned by the GEOLUT when it produces the respective message, not the time that the message is sent to or received at the MCC.

d. Repeat the test with different test scripts that also replicate 15 active beacons, until 10 different test scripts have been transmitted.

e. Compute the probabilities for valid, complete and confirmed complete messages to be recorded in Table E.2.

f. Repeat the process for scenarios in which the beacon simulator replicates 20, 25, 30, 35 simultaneously active beacons, incrementing the load by 5 beacons until the probabilities recorded in Table E.2 fall below 80%.

APPENDIX B TO ANNEX E

SAMPLE PROCEDURE FOR GEOSAR CAPACITY TESTING USING NON-INTERFERING BACKGROUND TRANSMISSIONS

The capacity of the 406 MHz channel is determined by generating traffic loads equivalent to known numbers of active beacons transmitting long format messages in a Cospas-Sarsat 406 MHz channel. The traffic load generated by the beacon simulator is comprised of background signals and test signals. The background signals are transmitted with a constant 50 second burst repetition interval, with starts times selected that ensure that the beacon bursts do not collide with each other. The test signals generated by the simulator conform completely to the Cospas-Sarsat beacon specification and, therefore, can collide with each other and with the background signals.

The combination of the background and test signals represent the beacon load on the GEOSAR channel. The time required for the GEOLUT to produce a valid message, a complete message and confirm a complete message is recorded for the test signals (not the background signals). The background traffic load is changed and the process repeated with the new traffic load.

The test should be coordinated to avoid potential interference from non-test sources in both the GEOSAR uplink and downlink channels. Specifically the test scripts should be scheduled to ensure that no signals are uplinked whilst the GEOLUT is in the footprint of a LEOSAR satellite. Furthermore, the 406 MHz channel under test should be free of any signals from operational or test beacons. To minimize the impact on LEOSAR operations, the 406 MHz channel should be outside the operational processing bandwidth of all LEOSAR SARP instruments.

The test will replicate scenarios of 15, 20, 25, 30 and 35 simultaneously active beacons.

The test should be conducted as follows:

a. A beacon simulator test script is developed which replicates 15 simultaneously active beacons, comprised of 10 background beacons and 5 test beacons. The beacon IDs for the 10 background beacons are provided at Table E-B.1 and are indicated as beacons 1 through 10. The beacon IDs for the test beacons are beacons 60 through 65.

   The time of the first burst for each of the test beacon events should be developed using a random process that ensures that the first burst is transmitted within 50 seconds of the start of the test. The transmit time for subsequent test beacon transmissions shall conform to the repetition interval defined in document C/S T.001.

b. After ensuring that the GEOLUT is not in the downlink footprint of a Cospas-Sarsat LEOSAR satellite, the test script is transmitted. The time of the first burst for each test beacon event should be recorded as per Table E.1.

c. For each test beacon event the time when the GEOLUT produces the first valid message, first complete message and first confirmed message should be recorded as per

Table E.1. The time measurements recorded should correspond to the time stamps assigned by the GEOLUT when it produces the respective message, not the time that the message is sent to or received at the MCC.

d. Repeat the test with the same traffic load until a statistically valid amount of data has been recorded.

e. Compute the probabilities for valid, complete and confirmed complete messages to be recorded in Table E.2.

f. Repeat steps a) though d) incrementing the background beacon load by 5 beacons, until the probabilities recorded in Table E.2 fall below 80%.

BCN	ID (b26-85)	Bit-Shifted (b25-84)	BCN	ID (b26-85)	Bit-Shifted (b25-84)
1	ADDC078003D0928	56EE03C001E8494	**36**	ADDC078089549A0	56EE03C044AA4D0
2	ADDC078007A1250	56EE03C003D0928	**37**	ADDC07808D252C8	56EE03C04692964
3	ADDC07800B71B78	56EE03C005B8DBC	**38**	ADDC078090F5BF0	56EE03C0487ADF8
4	ADDC07800F424A0	56EE03C007A1250	**39**	ADDC078094C6518	56EE03C04A6328C
5	ADDC07801312DC8	56EE03C009896E4	**40**	ADDC07809896E40	56EE03C04C4B720
6	ADDC078016E36F0	56EE03C00B71B78	**41**	ADDC07809C67768	56EE03C04E33BB4
7	ADDC07801AB4018	56EE03C00D5A00C	**42**	ADDC0780A038090	56EE03C0501C048
8	ADDC07801E84940	56EE03C00F424A0	**43**	ADDC0780A4089B8	56EE03C052044DC
9	ADDC07802255268	56EE03C0112A934	**44**	ADDC0780A7D92E0	56EE03C053EC970
10	ADDC07802625B90	56EE03C01312DC8	**45**	ADDC0780ABA9C08	56EE03C055D4E04
11	ADDC078029F64B8	56EE03C014FB25C	**46**	ADDC0780AF7A530	56EE03C057BD298
12	ADDC07802DC6DE0	56EE03C016E36F0	**47**	ADDC0780B34AE58	56EE03C059A572C
13	ADDC07803197708	56EE03C018CBB84	**48**	ADDC0780B71B780	56EE03C05B8DBC0
14	ADDC07803568030	56EE03C01AB4018	**49**	ADDC0780BAEC0A8	56EE03C05D76054
15	ADDC07803938958	56EE03C01C9C4AC	**50**	ADDC0780BEBC9D0	56EE03C05F5E4E8
16	ADDC07803D09280	56EE03C01E84940	**51**	ADDC0780C28D2F8	56EE03C0614697C
17	ADDC078040D9BA8	56EE03C0206CDD4	**52**	ADDC0780C65DC20	56EE03C0632EE10
18	ADDC078044AA4D0	56EE03C02255268	**53**	ADDC0780CA2E548	56EE03C065172A4
19	ADDC0780487ADF8	56EE03C0243D6FC	**54**	ADDC0780CDFEE70	56EE03C066FF738
20	ADDC07804C4B720	56EE03C02625B90	**55**	ADDC0780D1CF798	56EE03C068E7BCC
21	ADDC0780501C048	56EE03C0280E024	**56**	ADDC0780D5A00C0	56EE03C06AD0060
22	ADDC078053EC970	56EE03C029F64B8	**57**	ADDC0780D9709E8	56EE03C06CB84F4
23	ADDC078057BD298	56EE03C02BDE94C	**58**	ADDC0780DD41310	56EE03C06EA0988
24	ADDC07805B8DBC0	56EE03C02DC6DE0	**59**	ADDC0780E111C38	56EE03C07088E1C
25	ADDC07805F5E4E8	56EE03C02FAF274	**60**	ADDC0780E4E2560	56EE03C072712B0
26	ADDC0780632EE10	56EE03C03197708	**61**	ADDC0780E8B2E88	56EE03C07459744
27	ADDC078066FF738	56EE03C0337FB9C	**62**	ADDC0780EC837B0	56EE03C07641BD8
28	ADDC07806AD0060	56EE03C03568030	**63**	ADDC0780F0540D8	56EE03C0782A06C
29	ADDC07806EA0988	56EE03C037504C4	**64**	ADDC0780F424A00	56EE03C07A12500
30	ADDC078072712B0	56EE03C03938958	**65**	ADDC0780F7F5328	56EE03C07BFA994
31	ADDC07807641BD8	56EE03C03B20DEC			
32	ADDC07807A12500	56EE03C03D09280			
33	ADDC07807DE2E28	56EE03C03EF1714			
34	ADDC078081B3750	56EE03C040D9BA8			
35	ADDC07808584078	56EE03C042C203C			

Table E-B.1: BSim HEX ID

- END OF ANNEX E –

ANNEX F

FORECAST OF 406 MHz BEACON POPULATION

F.1 POTENTIAL LONG-TERM 406 MHz BEACON POPULATION

The objective of this exercise is to define realistic lower and upper limits of the potential population of ELTs, EPIRBs and PLBs, for Cospas-Sarsat management planning purposes. However, the world-wide potential 406 MHz beacon population is based on a number of assumptions which are difficult to validate. Therefore, the figures provided in Table F.1 below will be updated as necessary, on the basis of available information.

The actual user base for 406 MHz ELTs, EPIRBs and PLBs is highly dependent on a number of factors which are not under the control of Cospas-Sarsat. These include regulatory decisions by Administrations, the retail cost of beacons, alternative means for providing the distress alerting function, etc. The basic hypotheses used in the following calculations, in particular the world-wide fleet statistics and the percentage of those fleet which may be equipped with 406 MHz beacons, will be reviewed and adjusted from time to time.

No attempt has been made to assess the size of naval and air force fleets world-wide. Even if these figures were known, an educated guess could not be made as to the percentage of these fleets which could be equipped with 406 MHz beacons.

Table F.1: Estimate of Potential 406 MHz Beacon Population

	Estimated size of world-wide fleets	% of craft [1] with 406 MHz beacons	Numb. per craft	Potential 406 MHz beacon population
Merchant vessels over 100 GT	100,000	100 %	1 at least 2 (20%)	100,000 to 120,000
Fishing vessels over 100 GT	25,000	90 %	1 at least	22,500 to 25,000
Small non-commercial craft	2,000,000 to 2,500,000	30 %	1	600,000 to 750,000
Commercial Aircraft General Aviation Aircraft	20,000 400,000 to 500,000	80 % 50%	2 1	32,000 200,000 to 250,000
PLB and military	-	-		500,000 to 1,000,000
TOTAL (world-wide)	**-**	**-**		**1,454,500 to 2,177,000**

Note 1: These percentages correspond to the estimated maximum fraction of the total fleet which may be equipped with 406 MHz beacons

The figures provided in Table F.1 show that the larger numbers correspond to potential markets for which little or no statistical data is available (small non-commercial craft and PLBs). As a consequence, the actual beacon populations could be vastly different from the above assessment. For planning purposes, it would be prudent to consider a potential 406 MHz beacon population of at least 1,500,000, with a possible maximum of 2,500,000.

F.2 BEACON POPULATION FORECAST

The forecast for the period 2015-2025 assumes that the population will continue to grow in all segments, but at a decreasing rate after the initial build-up of production. The model is based on estimated growth rates of the annual production for each segment of the population (i.e., EPIRBs, ELTs and PLBs). The annual production covers both the replacement market, based on a beacon life time of about 10 years, and the actual growth of the population.

The model is reviewed annually and updated on the basis of the results of the annual survey of beacon production.

Figure F.1: Forecast of Beacon Population
(2024 Forecast)

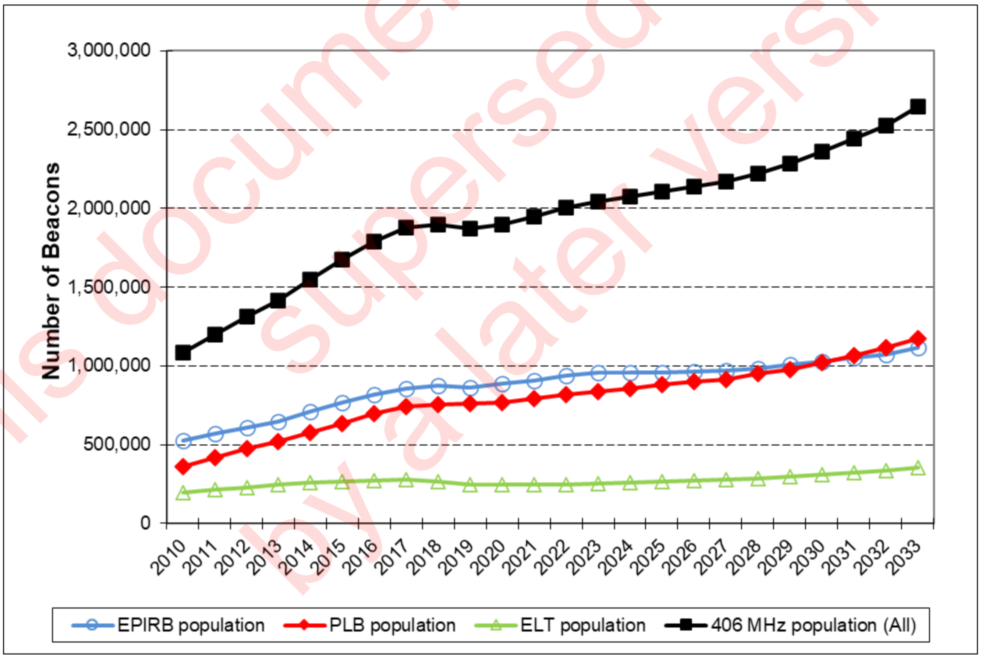


Table F.2: 406 MHz Beacon Population Model

(June 2024 forecast / 2023 manufacturers' production survey)

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
EPIRB production increase	**2.8%**	**-3.2%**	**-9.1%**	**12.4%**	**-2.6%**	**5.7%**	**-15.1%**	*10%*	*5%*	*2%*	*5%*	*2%*	*5%*	*2%*	*5%*	*2%*	*5%*
EPIRB production	98,552	95,434	86,750	97,472	94,959	100,380	85,208	*93,729*	*98,415*	*100,384*	*105,403*	*107,511*	*112,886*	*115,144*	*120,901*	*123,319*	*129,485*
EPIRB replacement	58,967	77,733	96,372	76,986	71,838	69,344	68,931	*91,374*	*97,741*	*95,845*	*98,552*	*95,434*	*86,750*	*97,472*	*94,959*	*100,380*	*85,208*
EPIRB population	**857,009**	**874,710**	**865,088**	**885,574**	**908,695**	**939,731**	**956,008**	***958,363***	***959,037***	***963,576***	***970,426***	***982,503***	***1,008,639***	***1,026,311***	***1,052,254***	***1,075,193***	***1,119,470***
PLB production increase	**10.7%**	**-14.3%**	**17.4%**	**-16.1%**	**13.4%**	**3.0%**	**-8.6%**	*12%*	*5%*	*5%*	*5%*	*5%*	*5%*	*5%*	*5%*	*5%*	*5%*
PLB production	92,554	79,354	93,186	78,155	88,609	91,254	83,412	*93,421*	*98,093*	*102,997*	*108,147*	*113,554*	*119,232*	*125,194*	*131,453*	*138,026*	*144,927*
PLB replacement	48,529	66,825	88,860	69,132	60,569	68,862	64,065	*72,143*	*75,076*	*83,608*	*92,554*	*79,354*	*93,186*	*78,155*	*88,609*	*91,254*	*83,412*
PLB population	**741,693**	**754,222**	**758,548**	**767,571**	**795,611**	**818,003**	**837,350**	***858,628***	***881,645***	***901,034***	***916,627***	***950,827***	***976,873***	***1,023,912***	***1,066,757***	***1,113,529***	***1,175,044***
ELT production increase	**21.8%**	**10.2%**	**-22.0%**	**12.9%**	**-5.3%**	**-3.0%**	**13.4%**	*10%*	*5%*	*2%*	*5%*	*2%*	*5%*	*2%*	*5%*	*2%*	*5%*
ELT production	26,817	29,554	23,055	26,039	24,656	23,904	27,105	*29,816*	*31,306*	*31,932*	*33,529*	*34,200*	*35,910*	*36,628*	*38,459*	*39,228*	*41,190*
ELT replacement	20,879	42,089	43,377	26,792	24,318	21,968	23,168	*24,982*	*24,151*	*22,026*	*26,817*	*29,554*	*23,055*	*26,039*	*24,656*	*23,904*	*27,105*
ELT population	**280,184**	**267,649**	**247,327**	**246,574**	**246,912**	**248,848**	**252,785**	***257,619***	***264,774***	***274,680***	***281,392***	***286,038***	***298,892***	***309,481***	***323,284***	***338,609***	***352,693***
406 MHz population (All)	**1,878,886**	**1,896,581**	**1,870,963**	**1,899,719**	**1,951,218**	**2,006,582**	**2,046,143**	***2,074,610***	***2,105,456***	***2,139,290***	***2,168,446***	***2,219,368***	***2,284,405***	***2,359,705***	***2,442,294***	***2,527,330***	***2,647,207***

The above model estimates appropriate growth rates of beacon production based on an annual survey of manufacturers' forecast and takes into account the regulatory environment. For example, the ICAO decision to mandate 406 MHz ELTs on all aircraft under the ICAO Convention jurisdiction and the phase-out of 121.5 MHz satellite alerting services on 1 February 2009 had a significant impact on the production of ELTs prior to that date. Expected changes to National regulations in respect of PLBs are also factored in the estimated growth rates of PLB production. The production growth model assumes a continuing decrease of beacon retail costs, at least for the next few years.

However, the model does not take into account possible policy decisions by some States which could result in a significant surge of the population over a few years, e.g., mandating the carriage of 406 MHz ELTs on general aviation aircraft in the USA and/or Canada.

- END OF ANNEX F -

ANNEX G

COSPAS-SARSAT 406 MHz MESSAGE TRAFFIC MODEL

G.1. SOURCES OF 406 MHz TRAFFIC

G.1.1 Operational 406 MHz Beacons

There is a direct correlation between the total 406 MHz beacon population and the average number of beacons activated in a given period of time. This relationship is expressed as the ratio of the total number of beacon activations observed during one year over the corresponding beacon population (i.e., the annual activation ratio given as a percentage of the total beacon population). For a given beacon population the average number of active beacons at any point in time will also depend on the average length of time that a distress beacon remains active. It should be noted that annual activation rates and average duration of beacon transmissions can be different for each segment of the beacon population. The actual activation rate and average transmission duration are monitored by Cospas-Sarsat on an annual basis.

An analysis of operational alerts has also shown that alerts are not evenly distributed over the surface of the Earth, rather, there are regions of higher concentrations that must be accounted for in the model. Similarly, the number of active beacons fluctuates as a function of time. The detailed procedures used by Cospas-Sarsat for evaluating the fluctuation of the traffic load caused by the geographic distribution of the beacon population, and for the time fluctuations are detailed in section G.4. These peak-time and density factors are assessed on an annual basis. Because of the large difference in size between the instantaneous coverage area of LEOSAR satellites and the GEOSAR satellite coverage, the peak-time and density factors are specific to each system and are evaluated separately for each system.

G.1.2 Self-Test Mode Transmissions

A review of data collected over an extended period of time has shown that there is a direct correlation between the traffic load resulting from self-test mode transmissions and the beacon population. Furthermore, the factors that influence the peak traffic load as a result of geographic region and time are also applicable to self-test mode transmissions.

G.1.3 System Beacons

The term System beacons is used to describe those 406 MHz beacons active on a permanent or semi-permanent basis which are required for the successful operation of the System.

System beacons provide:

a. calibrated signals that are used by LUTs to calculate updated satellite orbit vectors;

b. a method for calculating and distributing time calibration data required for LUTs to use the data from Sarsat SARP instruments; and

c. a reliable and standardised test source which can be used for evaluating the performance of the System.

Since all System beacons operate in a dedicated frequency channel at 406.022 MHz, for GEOSAR load calculations, they do not contribute to the traffic in the other 406 MHz channels.

With respect to the LEOSAR system, the Doppler shift causes System beacon transmissions to be received at frequencies as high as 406.032 MHz. This is accounted for in the LEOSAR capacity model, which provides a capacity figure that includes the System beacons in channel 406.022 MHz. Therefore, the traffic from System beacons must also be accounted for in the LEOSAR traffic model.

G.1.4 Test Beacons

Test beacons are identical to operational beacons, except that they are coded with a test protocol. They are typically used by national Administrations, beacon manufacturers or LUT operators for conducting tests to evaluate the performance of Cospas-Sarsat equipment. It has been demonstrated that the number of test beacons active at any time is not related to the beacon population, but rather to the amount of testing in the System. Additionally, since the activation of test coded beacons should be co-ordinated with national Administrations it is possible to co-ordinate their use, and, therefore, control their impact on the traffic load.

For the purposes of forecasting the impact of test coded beacons on the beacon message traffic load, the number of active test coded beacons has been tracked over several years, and values for LEOSAR and GEOSAR beacon message traffic models have been determined as shown in section G.5 of Annex G.

G.2. BEACON POPULATION AND 406 MHz MESSAGE TRAFFIC

G.2.1 Evaluation of Peak Traffic as a Function of the Total Beacon Population

To effectively manage the use of the 406 MHz band, the traffic load for both GEOSAR and LEOSAR systems must be assessed. The following steps are necessary to establish a forecast of the peak volume of 406 MHz beacon message traffic for a given beacon population. The detailed calculation methods and data collection procedures are provided in sections G.3 and G.4, respectively.

G.2.1.1 Methodology for Evaluating the Peak Traffic from Distress Beacons

a. Assess the annual rate of 406 MHz beacon activations (Ra).

The annual rate of 406 MHz beacon activations can be evaluated by Cospas-Sarsat Participants by collecting the following data on an annual basis:

- the number of registered beacons in their database (NRB); and
- the annual number of activations, world-wide, of registered beacons with their country code (NARB).

The rate of activation is the ratio of the number of activations over the number of beacons in the population:

$$Ra = NARB / NRB$$

The product of the total population by the annual rate of beacon activation provides the average number of beacons activated during the year, or a 24-hour period when divided by 365.

b. Assess the Estimated Total Population (ETP)

The ratio of registered beacons (RtR) is the ratio of the number of active beacons for one or several country code(s) that were actually registered (NARB) over the total number of active beacons with the same country code(s) observed during the year (TNAB):

$$RtR = NARB / TNAB$$

The estimated total population for a given country code is the number of registered beacon divided by the ratio of registered beacons:

$$ETP = NRB / RtR$$

Note that the estimated population can be established for each frequency channel if specific NRB, NARB and RtR values are available for each channel. This can then be used to assess the existing traffic in specific channels.

c. Assess the mean duration of 406 MHz transmissions (D) and the average number of active beacons (NAB)

The beacon transmission duration is the difference in minutes between the last time a beacon was observed in the Cospas-Sarsat System and the first time the same beacon was observed.

The statistical evaluation of the average duration of 406 MHz beacon transmissions can be provided by MCCs for alerts located in their service area, and by nodal MCCs on a global basis.

This average duration, expressed as a fraction of the day, multiplied by the average number of active beacons during 24 hours, provides the average number of active beacons at any time (NAB).

d. Assess the average number of beacons active in the instantaneous coverage area of a LEOSAR or a GEOSAR satellite.

The average number of active beacons (ANAB) in the coverage area of a satellite is the product of the average number of active beacons, world-wide, as determined in step (c) above, by the fraction of the Earth surface covered by the satellite.

ANAB(Leo) = NAB*Rleo, with Rleo = 0.07
ANAB(Geo) = NAB*Rgeo, with Rgeo = 0.42

e. Assess the geographical distribution of beacon activations to compute a geographic density factor (Df).

The geographical distribution of the located alerts is used to compute:

- the maximum to average ratio of the number of active beacons in the instantaneous coverage area of a LEOSAR satellite (LEO density factor = Df(leo)) which is applied to the average number of active beacons in the coverage area of a LEOSAR satellite; and
- the maximum to average ratio of the number of active beacons in the instantaneous coverage area of a GEOSAR satellite (GEO density factor = Df(geo)) which is applied to the average number of active beacons in the GEOSAR coverage area.

f. Assess, over a given period of time, the peak-to-average ratio of beacon messages (Rt):

- in the instantaneous coverage area of a LEOSAR satellite: Rt(leo); and
- in the coverage area of a GEOSAR satellite Rt(geo).

These LEOSAR and GEOSAR peak-to-average ratios (peak-time factors) characterise the uneven distribution in time of 406 MHz beacon transmissions and are applied to the numbers of active beacons determined at step (e) above to obtain a peak number of active beacons in the coverage area of the satellite considered (i.e., LEO or GEO). The determination is made separately for the LEO and the GEO systems (see section G.4).

For consistency with the LEO and GEO capacity determination, which assume a probability of processing success of 95% for the peak traffic, the selected peak-time factor corresponds to the ratio of the number of active beacons that is not exceeded more than 2% of the time over the average number of active beacons, both figures being measured in the highest density region. The detailed computation of the LEO and GEO peak-time ratios is described at section G.4.

G.2.1.2 Other Sources of Traffic

The result of the above computation is an assessment of the peak 406 MHz message traffic from operational beacons as a function of the total beacon population, expressed as a number of active beacons.

Similar computations must be made for the other sources of 406 MHz signals identified in section G.1 above: i.e. self-test mode transmissions and test beacons.

Self-test mode transmissions are proportional to the operational beacon population and must be taken into account accordingly. Their contribution to the total traffic is estimated as a fraction of the operational beacon traffic previously computed (see section G.3).

Test beacon transmissions can be controlled by MCCs and their impact limited as necessary. Their contribution to the total traffic has been evaluated in the worst case as a fixed number of active beacons in the coverage area of the satellite (see section G.3).

System beacons also contribute to the total traffic in the LEOSAR and GEOSAR systems. However, they are all operating at 406.022 MHz and do not affect the traffic in adjacent channels in the GEOSAR system. Therefore, this traffic can be ignored in the GEOSAR traffic model, as long as the 406.022 MHz channel is not expected to accommodate distress beacons.

In the LEOSAR system, System beacon transmissions can interfere in time and frequency with operational beacon transmissions in other channels. As the message traffic from System beacons remains well within the estimated capacity of the 406.022 MHz channel, they have only a limited impact on the capacity requirements of adjacent channels. Nevertheless, this traffic must be evaluated as part of the peak LEOSAR message traffic.

G.2.1.3 Capacity Requirements

The peak of the total 406 MHz traffic demand represents the capacity requirement for the system considered. It is the sum of the contributions of all sources of traffic in the channels open for use by distress beacons, as described above. Faulty beacon transmissions and interference may affect the load of a channel but are not accounted for in the traffic forecast (i.e., the capacity requirement resulting from legitimate transmissions). Their impact is accounted for, where necessary, as a reduction of the channel capacity.

G.2.2 Peak Message Traffic in 3 kHz Channels

The 406 MHz beacon message traffic model is used to determine the beacon population which corresponds to the saturation threshold of the LEOSAR or the GEOSAR systems (i.e. the system capacity expressed as the maximum numbers of typical 406 MHz beacons transmitting in the LEOSAR satellite coverage area at any point in time, or transmitting in the GEOSAR coverage area, which can be successfully processed with a given probability).

However, a traffic forecast must also be provided for each channel used by Cospas-Sarsat to ensure that the individual capacity of each channel is not exceeded.

G.2.2.1 Actual Population and Traffic in Channel

Several methods can be considered to assess the actual population in the channel under consideration.

The first option is to assess the actual beacon population in the channel by multiplying the total 406 MHz beacon population by the 406 MHz beacon population channel ratio (Cr), which represents the fraction of the actual total traffic resulting from sources operating in the channel under consideration.

The value of Cr is provided by monitoring received alerts and performing the following calculation:

$$Cr = \frac{\text{Number of alerts from beacons in the channel}}{\text{Total number of alerts received}}$$

The second option is to determine the population in each channel using the methodology applied for the forecast of the total population, i.e., determining the population operating in a specific channel on the basis of the history of beacon production at each frequency.

Experience shows that the second method produces estimates that anticipate by one or two years the channel population determined according to the first method, using a channel traffic ratio based on the actual channel traffic. When possible (when actual production data is available for each frequency channel) the second method should be used for estimating the current population in each channel and producing a population forecast for each channel.

G.2.2.2 Forecast Population and Traffic in Channel

On the basis of the assessment of the actual beacon population in a channel, as described above, a forecast of the population in the channel can be developed.

The channel traffic forecast is derived from the population forecast in the channel by following the steps of the computation described in section G.2.1.1 above. Adjustments to the various factors used in the computation may be required to take into account the specific characteristics of the population in a particular channel, e.g., specific activation rates, average beacon transmission duration, etc. (see section G.3.4)

However, it should be noted that the forecast evolution of the beacon population in specific channels can be unreliable as it requires a number of hypotheses concerning the commercialisation of a small number of beacon models. Therefore, adequate margins should be included when comparing the channel traffic demand and the channel capacity.

G.3 MODEL OF 406 MHz BEACON MESSAGE TRAFFIC

The following sections provide the mathematical expression of the computation described in section G.2. The message traffic, expressed as an equivalent number of active beacons, is a function of the beacon population (P). The model described below is applied to the total beacon population to derive a peak traffic in the entire system. It can also be applied to the actual population of beacons in a particular channel ($P_{channel}$ = P x Cr, see G.2.2.1), or to the forecast of the beacon population in the channel, subject to appropriate adjustments of the various factors, to compute a peak traffic (actual or forecast) in the channel.

G.3.1 Average Number of Active Beacons World-wide

The number of active distress beacons (NAB) at any time over the surface of the Earth is:

$$NAB = P * Ra/365 * D/(24*60)$$

Where:

P is the 406 MHz beacon population considered (i.e. total or in a channel, actual or forecast).

Ra is the annual activation rate (may be global or specific to each channel),

D is the average duration of 406 MHz beacon transmissions (in minutes),

G.3.2 Equivalent Number of Active Beacons in the LEOSAR System

The peak number of active distress beacons in the LEOSAR coverage area, taking into account the uneven geographical distribution of beacons and the uneven distribution of activations in time, is:

$$PNAB (leo) = NAB * Rleo * Df(leo) * Rt$$

where:

Rleo is the ratio LEOSAR coverage area / Earth surface (Rleo = 0.07);

Df(leo) is the density factor reflecting the maximum to average ratio of the beacon population in the instantaneous coverage area of a LEOSAR satellite, which depends on the geographical distribution of the 406 MHz beacons;

Rt is the peak-time factor which corresponds to the ratio of peak (98% probability) over average traffic in the highest density region.

The number of operational beacons activated in self-test mode in the instantaneous coverage area of the satellite (single burst with inverted frame synchronisation received but not processed by the system) can be expressed as a ratio of the beacon population (STR), which may include a specific peak-time factor.

The equivalent traffic form self-test mode transmissions in the coverage area of a LEOSAR satellite is then expressed as:

$$Self\text{-}Test\ Traffic (leo) = P * STR * Rleo * Df(leo)$$

Where: P is the beacon population considered;
Rleo and Df(leo) have the same definition as above; and
STR is a “Self Test Ratio” to be measured for a given population.

The traffic from test coded beacons which is not dependent on the actual beacon population, is expressed as an equivalent number of active beacons in the instantaneous coverage area of the satellite:

TB(leo)

The traffic from System beacons (orbitography, time reference) expressed as a fixed equivalent number of active beacons in the satellite visibility area.

SB(leo)

The total traffic to be considered in the coverage area of a LEOSAR satellite (the LEOSAR capacity requirement) is the sum of the traffics calculated above as equivalent numbers of active 406 MHz beacons:

LEO Traffic (P) = PNAB (Leo) + Self-Test Traffic (leo) + TB(leo) + SB(leo)

This expression can be developed as the following mathematical function of the beacon population:

LEO Traffic (P) = TB(leo) + SB(leo) + P ∗ [[(Ra/365 ∗ D/24 ∗ Rt) + STR] ∗ Rleo ∗ Df(leo)]

G.3.3 Equivalent Number of Active Beacons in the GEOSAR System

The peak number of active distress beacons in the GEOSAR coverage area, taking into account the uneven geographical distribution of beacons and the uneven distribution of activations in time, is:

PNAB (geo) = NAB ∗ Rgeo ∗ Df(geo) ∗ Rt

where:

Rgeo is the ratio GEOSAR coverage area / Earth surface (Rgeo = 0.42);

Df(geo) is the density factor reflecting the maximum to average ratio of the beacon population in the coverage area of a GEOSAR satellite, which depends on the geographical distribution of the 406 MHz beacons;

Rt is the peak-time factor which corresponds to the ratio of peak (98% probability) over average traffic in the highest density region.

The number of operational beacons activated in self-test mode in the coverage area of the satellite (single burst with inverted frame synchronisation received but not processed by the system) can be expressed as a ratio of the beacon population (STR), which may include a specific peak-time factor.

The equivalent traffic form self-test mode transmissions in the coverage area of a GEOSAR satellite is then expressed as:

$$\text{Self-Test Traffic (geo)} = P * STR * Rgeo * Df(geo)$$

where: P is the beacon population considered;
Rgeo and Df(geo) have the same definition as above; and
STR is a "Self Test Ratio" to be measured for a given population.

The traffic from test coded beacons which is not dependent on the actual beacon population, is expressed as an equivalent number of active beacons in the instantaneous coverage area of the satellite:

$$TB(geo)$$

The total traffic to be considered in the coverage area of a GEOSAR satellite (the GEOSAR capacity requirement) is the sum of the traffics calculated above as equivalent numbers of active 406 MHz beacons:

$$\textbf{GEO Traffic (P)} = \textbf{PNAB (geo)} + \textbf{Self-Test Traffic (geo)} + \textbf{TB(geo)}$$

This expression can be developed as the following mathematical function of the beacon population:

$$\textbf{GEO Traffic (P)} = \textbf{TB(geo)} + \textbf{P} * [\,[\,(\textbf{Ra}/365 * \textbf{D}/24 * \textbf{Rt}) + \textbf{STR}\,] * \textbf{Rgeo} * \textbf{Df(geo)}\,]$$

Note: System beacons are not included in this traffic as their transmissions at 406.022 MHz do not impact on the capacity of the distress beacon channels, as computed in accordance with the model of Annex D.

G.3.4 LEOSAR and GEOSAR Traffic Per Channel

The above calculations of the traffic as a function of the total population can also be followed to assess the actual or forecast traffic per channel, using the actual or forecast figure of the population in a given frequency channel.

G.3.4.1 Estimate and Forecast of the Channel Population

The actual figure of the population in a particular channel can be estimated by applying the channel ratio (Cr = fraction of the total traffic load generated from beacons transmitting in that channel) to the total beacon population:

$$Cr = \frac{\text{Number of alerts from beacons in the channel}}{\text{Total number of alerts received}}$$

The actual channel population is then: $P_{Channel} = P \times Cr$, where P is the total beacon population.

The channel population can also be estimated using manufacturers’ production figures for each frequency channel as described in section G.2.2.1.

The forecast beacon population per channel cannot be assessed with a forecast value of the channel traffic ratio, Cr, which would be unreliable. Instead, a specific forecast of the channel population must be established, using information on the beacon models type approved to operate in the channel and manufacturers’ forecast of production.

G.3.4.2 Application of the Traffic Model to the Channel Population

The following parameters that are population dependent, may need to be reassessed on a channel basis to account for non-homogenous samples of the beacon population in particular channels.

a. Annual activation ratio: Cospas-Sarsat has observed that beacons with automatic activation mechanism (g-switch in ELTs or automatic release of EPIRBs) generate a higher number of false alerts than beacons with manual activation only. This results in a higher activation rate for automatically activated beacons. If a channel has a large proportion of manually activated beacons, the annual activation ratio could be significantly lower than for the total population, or other channels with a higher percentage of automatically activated beacons.

b. Mean duration of 406 MHz transmissions: For the same reason as above, different categories of beacons could have a different average duration of transmissions. This matter may need to be monitored in future.

The other parameters of the model described in section G.2.1 (items d. to f.) seem to be less dependent of the segments of the beacon population and should remain identical in all channels.

G.4 ESTIMATION OF THE MESSAGE TRAFFIC MODEL PARAMETERS

Figure G.1 summarises the global traffic data that are to be collected by France and the USA for the determination of the Rate of Activation (Ra), the Estimated Total Population (ETP) and the Average Transmission Duration (D). The data collection procedures for these parameters plus the Density Factors (Df) and Peak-Time Factors (Rt) are provided in the following sections.

G.4.1 406 MHz Beacon Activation Rate (Ra)

To allow for a possible merging of the data collected, France and the USA should provide:

- the numbers of registered beacons (NRB) for each beacon type (ELT, EPIRB, PLB) as at the middle of the year, including, where appropriate, special beacon programmes; and

- the number of active registered beacon (NARB) from all available sources (LEOLUTs, GEOLUTs or other MCCs), observed during one year, for each beacon type, including single burst activations (SBAs).

For the computation of the rate of activation (Ra), France should consider the French registered beacon population and count only the number of worldwide activations of French registered beacons. The USA should use the USA registered beacon population, including special program beacons as appropriate, and count the number of worldwide activations of USA registered beacons.

The rate of activation is the ratio of the number of activations over the number of beacons in the population:

$$Ra = NARB / NRB$$

The activation rate should be computed for each type of beacon ELT, EPIRB and PLB, and for each population (France or USA). The average activation rate to be used in the beacon message traffic model is obtained after adding the French and US beacon population and beacon activation figures.

G.4.2 Estimated Total Population (ETP)

The ratio of registered beacons (RtR) is the ratio of the number of active beacons for one or several country code(s) that were actually registered (NARB) over the total number of active beacons with the same country code(s) observed during the year (TNAB)

France and the USA should provide the number of observed active beacons in their respective reference populations that were actually registered (NARB) for each beacon type. The estimated total population is derived from the count of registered beacons (NRB) and the observed ratio of active beacons that are actually registered (RtR), as follows:

$$RtR = NARB / TNAB$$

$$ETP = NRB / RtR$$

Figure G.1: Global Traffic Data to Be Collected by France and the USA for the Determination of the Rate of Activation (Ra), the Estimated Total Population (ETP) and the Average Transmission Duration (D)

		ELT	EPIRB	PLB	Other	ALL	Comments
Number of Registered Beacons	NRB						US registered or French registered, Mid-Year (average) population
Number of Active Registered Beacons	NARB						Include all single point alerts (SPA), all data sources (LEO & GEO)
Activation Rate for Registered Beacons	RaR = NARB/NRB						Ra, the rate of activation of the model is assumed to be equal to RaR
Total Number of Active Beacons	TNAB						Include registered and non-registered beacons (French or US)
Ratio of Total Active that are Registered	RtR = NARB/TNAB						For French or US beacons
Estimated Total Population	ETP = NRB/RtR						French or US beacons
US Beacons Activation Duration	∑ (LTO – FTO) / N (US coded beacons)						(Last time observed) minus (First time observed) SPA duration = 60 seconds
French Beacons Activation Duration	∑ (LTO – FTO) / N (French coded beacons)						(Id)

G.4.3 Mean Duration of 406 MHz Transmissions (D)

The beacon transmission duration is the difference in minutes between the last time a beacon was observed in the Cospas-Sarsat System and the first time the same beacon was observed.

Alert data from all available sources (LEOLUTs, GEOLUTs or other MCCs) shall be used to determine the beginning and end of transmission of a beacon, i.e., the first and last detection times. If the first detection is a LEO Doppler solution, the beginning of transmission time is taken as the TCA of the Doppler solution. If the last detection is a LEO Doppler solution, the end of transmission time is taken as the TCA of the Doppler solution. Single burst activations should be included in the statistics with an associated duration of 60 seconds (one minute). In the case of single LEOSAR Doppler solutions for which only a TCA is available, a transmission duration of 8 minutes should be assumed (from TCA - 4 to TCA + 4).

All transmission duration data should be provided separately for each type of beacon (i.e., ELT, EPIRB, PLB, other) and for their combined total. The average transmission duration should be computed separately for French coded beacons and USA coded beacons.

A consolidated average transmission duration will be determined by averaging the durations (France, USA) weighted by the respective estimated populations.

G.4.4 Geographical Distribution Factors (Df (leo) and Df (geo))

France and the USA should annually provide the geographical distribution of all located alerts observed worldwide, using a grid of 15º in latitude per 15º in longitude, for all types of beacons, except orbitography, test or reference beacons. The data should be provided in tabular form (Excel spreadsheet) as well as graphically. All resolved positions or the "A" solution of unresolved Doppler locations should be included.

The LEO density factor is approximated by adding the number of located beacons (N leo) within the area composed of 5 times 4 basic 15º "squares" at mid-latitude, or 4 times 4 at the Equator, and dividing by the average number of locations that should be observed in the same area, assuming a uniform worldwide distribution; i.e. the total number of locations (N tot) multiplied by the ratio of coverage for a LEO satellite (R leo = 0.07).

The highest value of the ratio N leo / (N tot x R leo) for various LEO coverage areas is the LEO density factor: Df (leo).

The GEO density factor is obtained by adding the number of located beacons (N geo) within all basic 15º "squares" comprised between the longitudes Long. - 60º to Long. + 60º, and dividing by the average of number of locations that should be observed in the same area assuming a uniform worldwide distribution; i.e. the total number of locations (N tot) multiplied by the ratio of coverage for a GEO satellite (R geo = 0.42).

The highest value of the ratio N geo / (N tot x R geo) obtained for the longitudes of existing GEO satellites is the GEO density factor: Df (geo).

G.4.5 406 MHz Beacon Peak-Time Traffic Ratio (Rt)

G.4.5.1 GEO Peak-Time Factor

France and the USA collect all activations that have at least one GEO data point (i.e., GOES-East detections for the USA and MSG detections for France), including single point activations. The corresponding regions (GOES-East coverage area and MSG coverage area) are expected to be regions of high traffic densities.

The beginning of beacon transmission time and end of beacon transmission time are determined for each activation, per the procedure described in section G.4.3 for the assessment of the duration of transmission. For single point activation a duration of sixty seconds is assumed and for single Doppler locations either the number of point times fifty seconds is used or an average 8 minutes pass duration (TCA – 4 to TCA + 4).

For each successive five-minute time slot within the observation period (e.g., May to August), a beacon is considered active during the whole duration of the time slot (i.e., 5 minutes) if the beginning of transmission (BoT) and end of transmission (EoT) span the middle of the time slot.

The cumulative number of slots during which the number of active beacons (NAB) was greater than X is computed to derive the distribution of traffic illustrated at Figure 2.

The GEO peak-time factor (Rt) is the ratio of the number of active beacons in a time slot (NAB) that is exceeded 2 % of the time and the average number of active beacons (ANAB) observed in the GEO area during the year.

The highest Rt as determined for the GOES-East and MSG satellite coverage should be used as GEO peak-time factor for the beacon message traffic model (Rt (geo)).

Alternatively, the highest product Rt*Df for each satellite (GOES-East and MSG) can be considered for use in the traffic model.

G.4.5.2 LEO Peak-Time Factor

France and the USA collect alert data from LEO satellite passes in visibility of the Toulouse LEOLUT or the Maryland LEOLUT, respectively.

The LUT acquisition of signal (LUT AOS) and loss of signal (LUT LOS) are determined for each observed pass to determine the duration of observation. Only real-time alert data are selected, including single points or unlocated alerts acquired in real-time.

The number of active beacons (NAB) observed during each LEO satellite pass is normalised to the duration of the satellite pass as follows:

$$\text{NNAB} = \text{NAB x Average D pass / D pass}$$
$$\text{with D pass} = (\text{LUT LOS} - \text{LUT AOS})$$

The cumulative number of satellite passes with more than X normalised active beacons is computed to derive the distribution of traffic illustrated at Figure G.3.

The LEO peak-time factor (Rt) is the ratio of:

- the normalised number of active beacons that is exceeded during 2% of the passes; and
- the average normalised number of active beacons per pass for the complete data sample.

Alternatively, the number of active beacons (NAB) observed in real-time, is computed for each five-minute slot when a satellite is in visibility of the LEOLUT. The cumulative distribution of five-minute slots during which NAB is greater than X is established and the computation of Rt is performed as described at Figure G.2 for the GEO traffic.

The highest Rt as determined for the Maryland and Toulouse LUTs should be used as LEO peak-time factor for the beacon message traffic model (Rt (leo)).

Note: Calculations of Rt for the LEO and GEO traffic models do not have to be performed annually. The need for re-evaluation of the peak-time factors and for separate values for Rt (leo) and Rt (geo) will be reconsidered periodically.

G.4.6 Channel Ratios (Cr)

France and the USA should annually provide the distribution of alerts (absolute numbers of activations and ratios over the total number of alerts) in each channel used by operational beacons, except 406.022 MHz. The distribution should be provided separately for each type of beacon and for the total population.

All beacon transmissions of less than 10 minutes duration should be removed from the sample to eliminate unstable transmission frequencies.

Note that the channel ratio cannot be used to forecast the channel traffic, as it is not fixed in time and the future evolution of a measured ratio is not easily predictable. The main purpose of the measured channel ratio is to provide a means to verify the validity of channel population estimates developed on the basis of manufacturers' production data and the population forecast model.

G.4.7 Self-Test Traffic Ratio (STR)

The beacon self-test traffic should be measured from time to time as follows:

- the total number of points (self-test bursts) is assessed during a certain time period of observation, in a GEOLUT or a LEOLUT coverage area and each point is assumed to have a 50 seconds duration to derive the total duration of self-test transmissions;
- the self-test transmission duration is divided by the duration of the observation period (the total duration of observed satellite passes for a LEOLUT) to obtain the observed self-test traffic (OSTT).

For the computation of the self-test ratio (STR), a peak-time ratio (STRt) may be introduced. The self-test ratio is:

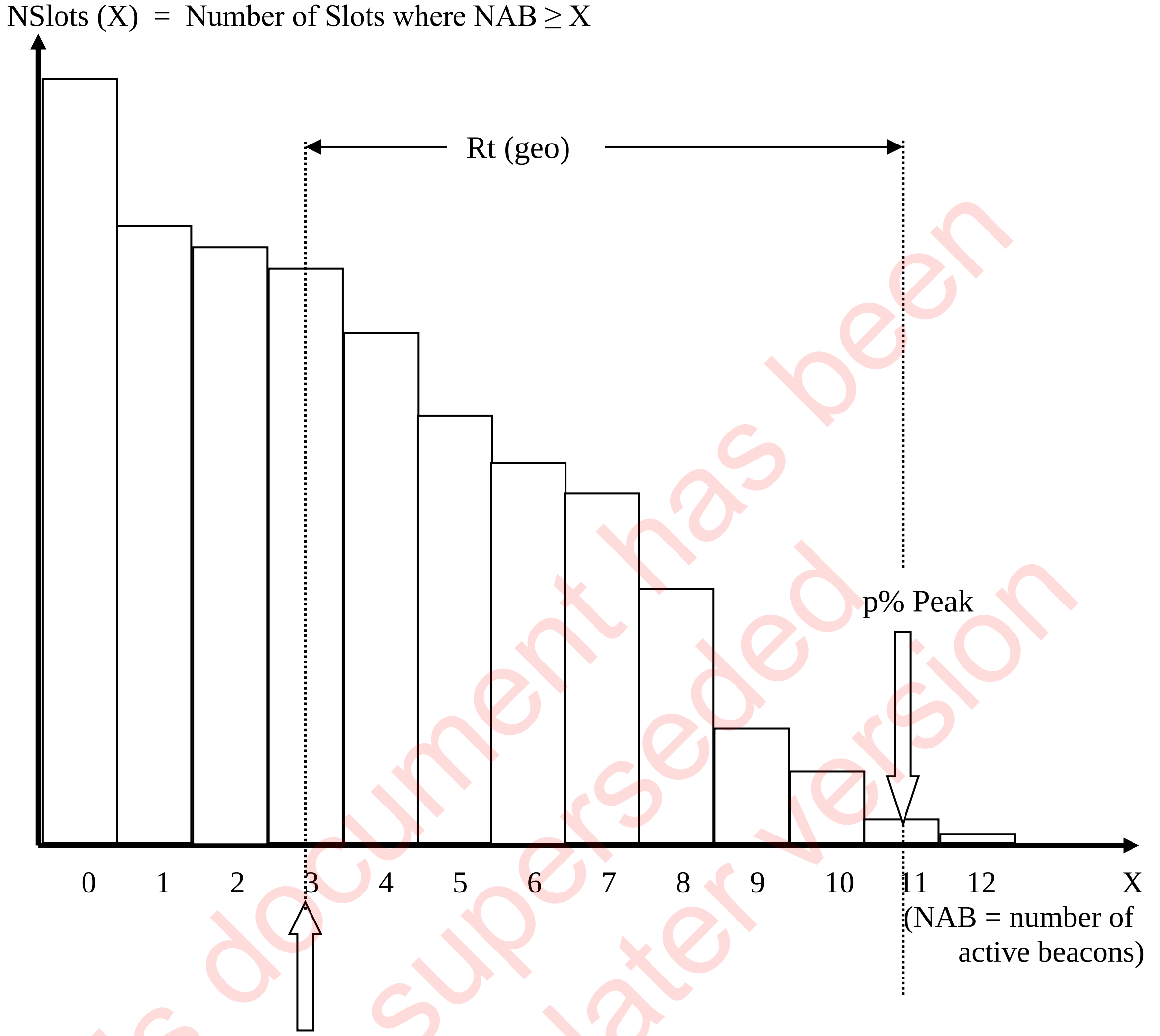
$$STR = [OSTT \times STRt] / [R(geo) \times Df(geo) \times P]$$

or, as appropriate,

$$STR = [OSTT \times STRt] / [R(leo) \times Df(leo) \times P]$$

where "P" is the worldwide beacon population at the time of the observation.

Figure G.2: Distribution of GEO Traffic in Time



Average NAB over the observation period (ANAB)

ANAB = [Σ Beacon activation durations] / Duration of observation period

= [Σ_X (NSlots(X)-NSlots (X+1))$*$X$*$5] / Duration of observation period (in minutes)

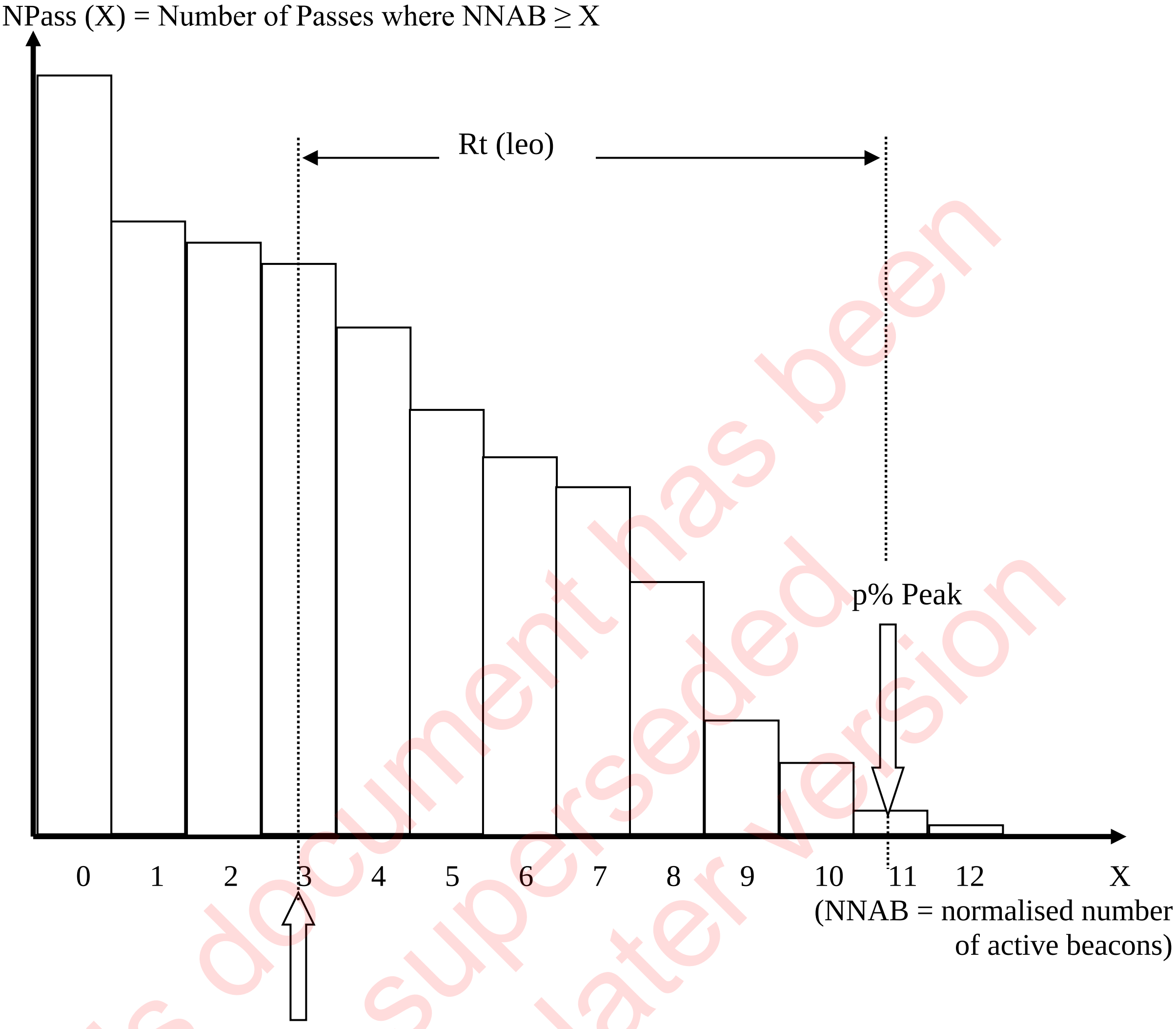
Assuming the accepted probability of observing a traffic higher than the selected peak value is p%, then:

p% Peak = X, such that [NSlots(X) / NSlots(0) = p%]

and

Rt (geo) = p% Peak / ANAB

Figure G.3: Distribution of LEO Traffic in Time



Average per Pass: APP = Σ_x [(NPass(X) – NPass(X+1)) $*$ X] / NPass(0)

Assuming the accepted probability of observing a traffic higher than the selected peak value is p%, then:

p% Peak = X such that [NPass(X) / NPass(0) = p%]

and

Rt (leo) = p% Peak / APP

G.5 APPLICATION OF THE BEACON MESSAGE TRAFFIC MODEL TO THE LEOSAR AND GEOSAR SYSTEMS

Table G.1 illustrates the computation of the beacon message traffic for the LEOSAR and GEOSAR systems to year 2033, using model parameters updated in 2023 (2022 data).

As activation rates and duration of transmission vary according to the category of beacon (ELT, PLB and EPIRB), the traffic is computed for each category and then summed-up with other traffic sources (self-test, System beacons) to provide a total peak traffic, which represents the capacity requirement for the LEO or the GEO system.

Figure G.4 illustrates the LEOSAR and GEOSAR curves of traffic in time, function of the beacon population forecast provided at Annex F to C/S T.012.

Figure G.4: LEOSAR and GEOSAR Beacon Message Traffic Forecast
(Peak Traffic – 2024 model parameters/2023 population and traffic data)

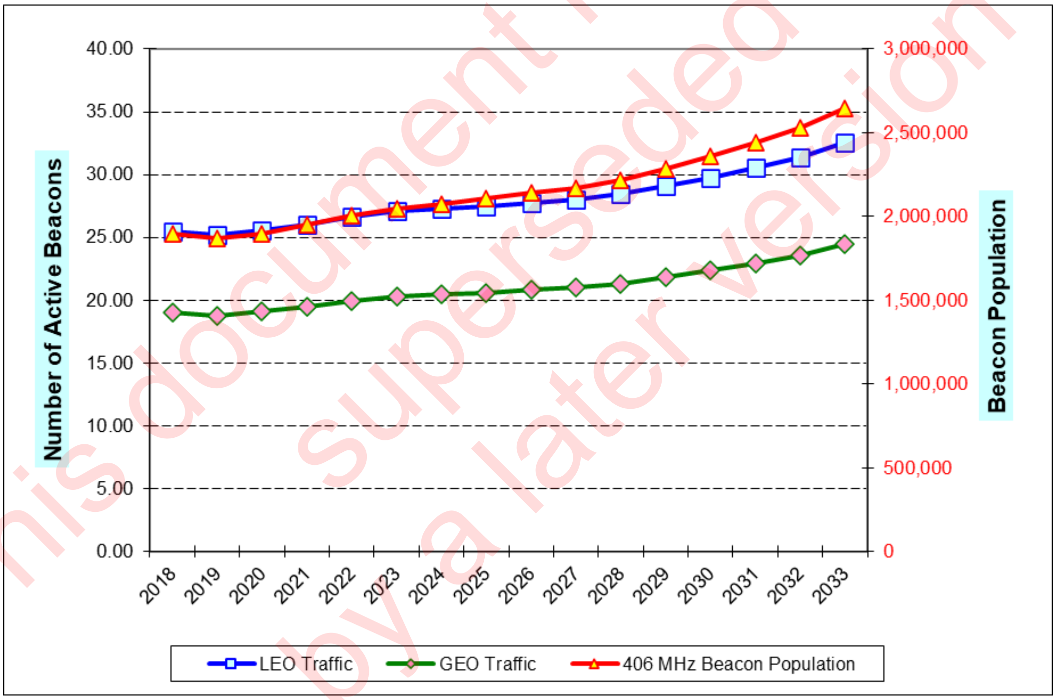


Table G.1: Ten-Year Forecast of Beacon Message Traffic

(2024 Model Parameters based on 2023 population and traffic data)

2023 DATA			ELT	EPIRB	PLB	ALL	ELT	EPIRB	PLB	ALL	ELT	EPIRB	PLB	ALL
			2023	2023	2023	2023	2028	2028	2028	2028	2033	2033	2033	2033
Beacon Population (end of year)	P		248,848	939,731	818,003	2,006,582	281,392	970,426	916,627	2,168,446	338,609	1,075,193	1,113,529	2,527,3
Annual Rate of Activation	Ra		4.81%	1.82%	0.84%		4.81%	1.82%	0.84%		4.81%	1.82%	0.84%	
Average Duration of Transmissions	D		49	238	98		49	238	98		49	238	98	
			4.46538E-06	8.22782E-06	1.55681E-06		4.47761E-06	8.25036E-06	1.56108E-06		4.47761E-06	8.25036E-06	1.56108E-06	
Number of Active Beacons	**NAB = P x (Ra/365) x (D/1440)**		1.11	7.75	1.28	10.14	1.26	8.01	1.43	10.70	1.52	8.87	1.74	12
LEOSAR System														
Ratio of coverage	**R leo**		0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0
Density Factor	**Df (leo)**		5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	
Peak-Time Factor	**Rt**		4	4	4	4	4	4	4	4	4	4	4	
Peak Number of Active Beacons	PNAB / P = (Ra/365) x (D/1440) x Rleo x Df(leo)		6.62662E-06	1.22101E-05	2.31031E-06		6.64478E-06	1.22435E-05	2.31664E-06		6.64478E-06	1.22435E-05	2.31664E-06	
in LEO Visibility Area	**PNAB = P x (Ra/365) x (D/1440) x Rleo x Df(le**		1.65	11.51	1.90	15.05	1.87	11.88	2.12	15.87	2.25	13.16	2.58	17
Population for Self-Test Tr. Observed (2017)		1,878,886												
Observed Self-Test Traffic (2016/ LEO / USA) = OSTT		1.5600												
Average Self Test Traffic	ASTT = OSTT / Rleo / Df(le	4.2												
Self-Test Peak-Time Factor	STPT	4.0												
Self Test Ratio	STR = ASTT x STPT / P	8.952E-06												
Self-Test Peak Traffic (leo)	**STT = P x STR x Rleo x Df(leo)**					6.66				7.20				8
Test Beacons	**TB (leo)**					2				2				
System Beacons	**SB (leo)**					3				3				
TOTAL LEOSAR TRAFFIC	**LEO Traffic = TB (leo) + SB (leo) + STT + PNAB**					**26.72**				**28.08**				**31**
GEOSAR System														
Ratio of coverage	Rgeo		0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0
Density Factor	Dfgeo		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	
Peak-Time Factor	Rt		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Peak Number of Active Beacons	PNAB / P = (Ra/365) x (D/1440) x Rgeo x Dfgeo		5.62638E-06	1.03671E-05	1.96159E-06		5.64179E-06	1.03955E-05	1.96696E-06		5.64179E-06	1.03955E-05	1.96696E-06	
in GEO Visibility Area	**PNAB = P x (Ra/365) x (D/1440) x Rgeo x Dfg**		1.40	9.77	1.61	12.78	1.59	10.09	1.80	13.48	1.91	11.18	2.19	15
Population for Self-Test Tr. Observed (2008)		745,451												
Observed Self-Test Traffic (2008 / GEO / France) = OSTT		0.629												
Average Self Test Traffic	ASTT = OSTT / Rgeo / Df(g	1.2												
Self-Test Peak-Time Factor	STPT	2.5												
Self Test Ratio	STR = ASTT x STPT / P	4.185E-06												
Self-Test Peak Traffic (geo)	**STT = P x STR x Rgeo x Dfgeo**					4.23				4.57				5
Test Beacons	**TB (geo)**					3				3				
System Beacons	**SB (geo)**					0				0				
TOTAL GEOSAR TRAFFIC	**GEO Traffic = TB (geo) + SB (geo) + STT + PNAB**					**20.01**				**21.05**				**23**

- END OF ANNEX G -

ANNEX H

COSPAS-SARSAT 406 MHz CHANNEL ASSIGNMENT PLAN

The 406 MHz Channel Assignment Plan summarised in Table H.2 is based on the following:

a. LEOSAR and GEOSAR systems capacities as described at Annexes C and D of the document C/S T.012 "Cospas-Sarsat 406 MHz Frequency Management Plan";

b. a 25% capacity margin is applied to the capacity of channels to provide for the continued production of type approved beacons;

c. a forecast 406 MHz beacon population as presented at Annex F to document C/S T.012; and

d. a 406 MHz message traffic forecast as presented at Annex G to document C/S T.012 and summarised in Table H.1 below, which shows the LEOSAR and GEOSAR capacity requirements (provided as an equivalent number of 406 MHz beacons in the field of view of a LEOSAR or a GEOSAR satellite) and the corresponding channel requirements.

Table H.1: Summary of 406 MHz Beacon Population Forecast, Capacity Requirements and Channel Requirements

(2024 Model Parameters / 2023 Population and Traffic Data)

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Population Forecast (x 1,000)	1,789.3	1,878.9	1,896.6	1,871.0	1,899.7	1,951.2	2,006.6	2,046.1	2,074.6	2,105.5	2,139.3	2,168.4	2,219.4	2,284.4	2,359.7	2,442.3	2,527.3	2,647.2
LEO capacity requirements *	**24.4**	**25.3**	**25.5**	**25.2**	**25.5**	**26.0**	**26.7**	**27.1**	**27.3**	**27.5**	**27.8**	**28.0**	**28.5**	**29.1**	**29.8**	**30.6**	**31.3**	**32.5**
LEO Capacity - channels ABC	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	34	35	36
LEO Capacity - channels ABC-25%	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	24.75	25.5	26.25	27
LEO Capacity - channels ABC-F	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	35
LEO Capacity - channels ABC-F -25%	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	26.25
LEO Capacity - channels ABC-FG	34	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	42
LEO Capacity - channels ABC-FG -25%	25.5	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	31.5
No. of Channels required for LEO	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3	3
GEO capacity requirements *	**18.2**	**18.9**	**19.1**	**18.8**	**19.1**	**19.5**	**20.0**	**20.3**	**20.4**	**20.6**	**20.8**	**21.0**	**21.3**	**21.9**	**22.4**	**23.0**	**23.6**	**24.5**
GEO Capacity - channels AB																		
GEO Capacity - channels ABC																		
GEO Capacity - (BC-25%)**																		
GEO Capacity - channels ABC+F	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
GEO Capacity - (BCF-25%)**	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5
No. of GEO channels required ***	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Channels in use for operational beacons' operation	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG	BC+FG

Notes:
- * Peak number of active beacons in field of view of satellite, based on Annex G traffic model, as updated in March 2023.
- ** 25% margin required for continued production of type approved beacon models
- *** Assuming a single GEOSAR channel capacity of 14 active beacons.
- **** Based on the assignment strategy described in C/S T.012, section 4

Channel A = 406.022 MHz (reserved for system beacons), Channel F = 406.037 MHz (closed for new type approval since 2012)
Channel B = 406.025 MHz (closed for new type approval since 2002) Channel G = 406.040 MHz (closed for new type approval since 2017)
Channel C = 406.028 MHz (closed for new type approval since 2007) Channel J = 406.049 MHz (not open)

Table H.2: Cospas-Sarsat 406 MHz Channel Assignment Table

Chan. #	Centre Freq. (MHz)	Status for Type Approval of New Beacon Models Date open	Date closed	Comments Table approved by the Cospas-Sarsat Council at the CSC-43 Session – October 2009 (see Note 1)
	406.007	Not available		SARP-2 limitation
	406.010	Not available		Doppler shift limitation
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	406.019	Not available		Doppler shift limitation
A	406.022	C/S orbitography / reference		Reserved for System beacons
B	406.025	1982	1 Jan 2002	Open for beacon models submitted for TA before 01/01/02
C	406.028	1 Jan 2000	1 Jan 2007	Open for beacon models submitted for TA before 01/01/07
D	406.031	1 Jan 2016	1 Jul 2025	Open for beacon models submitted for TA before 01/07/25
E	406.034			Reserved, not to be assigned
F	406.037	1 Jan 2004	1 Jan 2012	Open for beacon models submitted for TA before 01/01/12
G	406.040	1 Jan 2010	1 Jan 2017	Open for beacon models submitted for TA before 01/01/17
H	406.043			Reserved, not to be assigned
I	406.046			Reserved, not to be assigned
J	406.049	TBD	TBD	Available for future assignments / New developments
K	406.052	TBD	TBD	Available for future assignments / New developments
L	406.055			Reserved, not to be assigned
M	406.058			Reserved, not to be assigned
N	406.061	TBD	TBD	Available for future assignments / New developments
O	406.064	TBD	TBD	Available for future assignments / New developments
P	406.067			Reserved, not to be assigned
Q	406.070			Reserved, not to be assigned
R	406.073	TBD	TBD	Available for future assignments / New developments
S	406.076	1 Jan 2025	TBD	Open for beacon models submitted for TA after 01/01/25
	406.079	Not available		Doppler shift limitation
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	406.088	Not available		Doppler shift limitation
	406.091	Not available		SARP-2 limitation

Notes:

(1) Planned assignments may change if the Cospas-Sarsat Council determines that the beacon population in an active channel differs from the projected population.

TA Type approval

TBD To be determined

- END OF ANNEX H –

- END OF DOCUMENT –

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