COSPAS-SARSAT 406 MHz MEOSAR IMPLEMENTATION PLAN

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COSPAS SARSAT

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1. INTRODUCTION

1.1 Background

Cospas-Sarsat is an international satellite system for search and rescue (SAR) distress alerting that was established in 1979 by Canada, France, the USA and the former USSR. Since its inception the Cospas-Sarsat Programme has continually expanded and, as of 2003, 37 countries and organisations share in the management of the System.

The System was originally comprised of satellites in Low-altitude Earth Orbit (LEO). The LEO satellites and associated ground receiving stations (hereafter referred to as the LEOSAR system) are compatible with distress beacons operating at either 121.5 MHz or 406 MHz. The LEOSAR system calculates the location of distress beacons using the Doppler effect on the received beacon signals. Because of LEOSAR satellite orbit patterns, there can be delays between beacon activation and the generation of an alert message.

In 1998, following several years of testing, the Cospas-Sarsat Council decided to augment the LEOSAR system by formally incorporating SAR instruments on geostationary satellites for detecting 406 MHz beacons (hereafter referred to as the GEOSAR system). Geostationary satellite footprints are fixed with respect to the Earth's surface, therefore, each satellite provides continuous coverage over the geographic region defined by its footprint. This reduces the detection delays associated with the LEOSAR system. Because of their altitude each GEOSAR satellite provides coverage of a very large area (about one third the surface of the Earth excluding the Polar Regions). However, because of these attributes (i.e. stationary with respect to the Earth and high altitude):

- GEOSAR systems provide location information only if this information is available from an external source (i.e. global navigation receiver in the beacon) and transmitted in the 406 MHz beacon message;
- obstructions blocking the beacon to satellite link cannot be overcome because the satellite is stationary with respect to the beacon; and
- the beacon to satellite to LUT communication link budget is not as robust as the LEOSAR case because of the greater distances involved.

In 2000 the USA, the European Commission (EC) and Russia began consultations with Cospas-Sarsat regarding the feasibility of installing 406 MHz SAR instruments on their respective medium-altitude Earth orbit navigation satellite systems (hereafter referred to as MEOSAR constellations), and incorporating a 406 MHz MEOSAR capability in Cospas-Sarsat. The USA MEOSAR programme is called the Distress Alerting Satellite System (DASS), the European System is called SAR/Galileo, and the Russian programme is referred to as SAR/Glonass.

The initial investigations identified many possible SAR alerting benefits that might be realised from a MEOSAR system, including:

- near instantaneous global coverage with accurate independent location capability,
- robust beacon to satellite communication links, high levels of satellite redundancy and availability,
- resilience against beacon to satellite obstructions, and
- the possible provision for additional (enhanced) SAR services.

In light of this potential, the Cospas-Sarsat Council decided to prepare for the introduction of a MEOSAR capability into the Cospas-Sarsat System, and to develop this implementation plan.

1.2 Purpose and Scope of Document

The plan addresses all matters that impact upon the possible introduction of a 406 MHz MEOSAR capability into the Cospas-Sarsat System, including the compatibility of MEOSAR constellations with each other and with the Cospas-Sarsat System. It includes:

a. a generic description of the MEOSAR system and detailed information specific to the DASS, SAR/Galileo and SAR/Glonass constellations (section 2);

b. definitions for MEOSAR system compatibility and interoperability, and a discussion of the importance of DASS, SAR/Glonass and SAR/Galileo compatibility and interoperability (section 3);

c. the management structure and policies agreed by the Cospas-Sarsat Council for coordinating the development and introduction of MEOSAR components into the Cospas-Sarsat System (section 4);

d. the minimum acceptable MEOSAR search and rescue operational performance requirements for integrating the MEOSAR system into Cospas-Sarsat, and enhanced performance objectives that might also be achievable (section 5);

e. an analysis of technical issues relating to MEOSAR payloads (section 6);

f. a description and status of advanced SAR services that might be provided by a MEOSAR system (section 7);

g. a description of the issues which impact upon the design and architecture of a MEOSAR ground segment (section 8);

h. an overview of MEOSAR system calibration requirements and methods (section 9); and

i. a description of the various MEOSAR implementation and integration phases, i.e. definition and development, proof of concept/in-orbit validation, demonstration and evaluation, etc. (section 10).

This document also serves as a repository for action items relevant to the possible integration of MEOSAR satellite constellations and ground segment equipment into the Cospas-Sarsat System.

1.3 Management and Maintenance of the MEOSAR Implementation Plan (MIP)

In this document the term "MEOSAR provider" designates the USA for DASS, the Russian Federation for SAR/Glonass, and the Galileo Joint Undertaking (GJU) / European Space Agency (ESA) for SAR/Galileo.

Cospas-Sarsat will apply the following principles to the management and maintenance of this document:

a. information and changes to information concerning a specific MEOSAR component will be provided by the respective MEOSAR provider;

b. information and changes to information pertaining to MEOSAR compatibility with Cospas-Sarsat and the interoperability of MEOSAR components will be coordinated and accepted by all MEOSAR providers; and

c. other aspects of MEOSAR system development will be coordinated with the MEOSAR providers.

1.4 Reference Documents

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

b. C/S G.004: 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.009: Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines;

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

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

j. C/S T.012: Cospas-Sarsat 406 MHz Frequency Management Plan;

k. C/S T.014: Cospas-Sarsat Frequency Requirements and Coordination Procedures; and

l. The International Cospas-Sarsat Programme Agreement (1988).

- END OF SECTION 1 -

2. DESCRIPTION OF THE MEOSAR SYSTEM

The MEOSAR system will provide an enhanced distress alerting capability, characterised by:

- near instantaneous global detection and independent locating capability for Cospas-Sarsat 406 MHz distress beacons;
- high levels of space and ground segment redundancy and availability;
- robust beacon to satellite communication links;
- multiple and continuously changing beacon / satellite links, thereby providing flexibility against beacon to satellite obstructions, and resilience to interference; and
- a possible return link to the 406 MHz beacon.

This section provides a general description of a MEOSAR system focusing on the aspects common to the DASS, SAR/Galileo and SAR/Glonass systems, and also presents a description of the characteristics that are unique to each constellation.

2.1 MEOSAR Concept of Operations

Using networks of SAR instruments on satellites and ground processing stations, the MEOSAR system will receive, decode and locate 406 MHz distress beacons throughout the world. All three MEOSAR constellations will be completely compatible with Cospas-Sarsat 406 MHz distress beacons as defined in document C/S T.001 (Cospas-Sarsat beacon specification).

MEOSAR satellites orbit the earth at altitudes of around 20,000 km receiving the signals transmitted by Cospas-Sarsat 406 MHz distress beacons. The satellite downlinks are processed by ground receiving stations, hereafter referred to as MEO system Local User Terminals or MEOLUTs, to provide beacon identification and location information. The distress alert information computed by MEOLUTs is forwarded to Cospas-Sarsat Mission Control Centres (MCCs) for distribution to SAR services.

Each MEOSAR satellite provides visibility of a large portion of the surface of the Earth. Furthermore, because of the large number of satellites in each constellation, and the orbital planes selected, the DASS, SAR/Galileo and SAR/Glonass constellations could individually provide continuous coverage of the entire Earth, subject to the availability of suitably located MEOLUTs. Each of the three MEOSAR constellations could support near instantaneous distress alerting, although a short processing time may be required before an independent location of the distress beacon becomes available. Information specific to the DASS, SAR/Galileo and SAR/Glonass satellite constellations is provided at sections 2.7, 2.8 and 2.9 respectively.

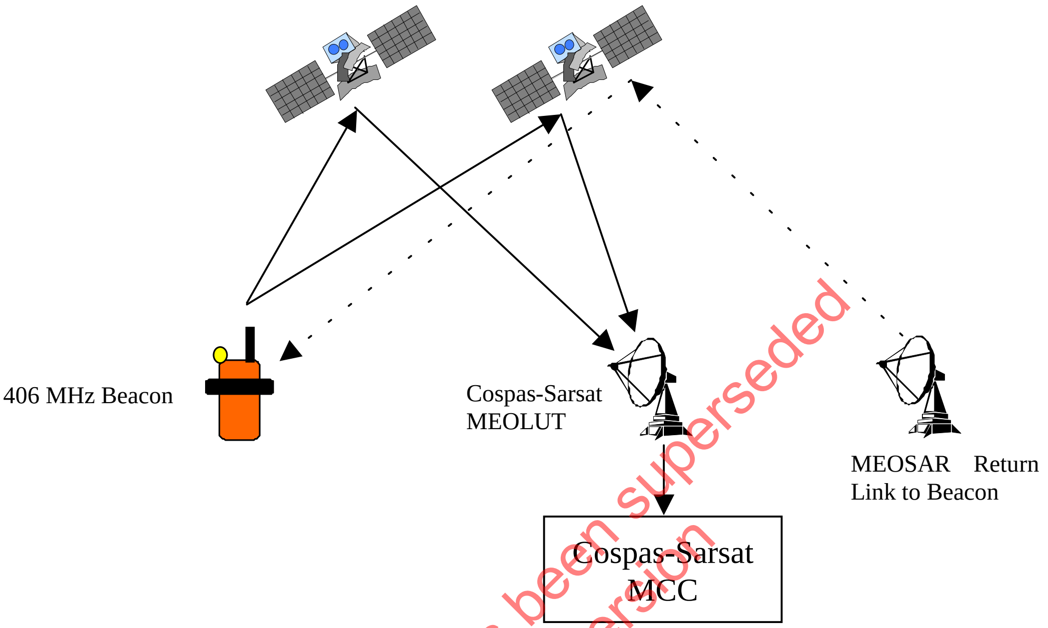


Figure 2.1: MEOSAR System Concept of Operations

In addition to the distress alerting function, MEOSAR providers are investigating the feasibility of providing advanced capabilities, which might include:

- a return link to the beacon to support additional functions; and
- new generation 406 MHz beacons.

The advanced capabilities under consideration are introduced at section 2.6, and are discussed in greater detail at section 7.

2.2 MEOSAR Space Segment

MEOSAR satellites orbit the Earth at altitudes ranging from 19,000 to 24,000 km. The characteristics of the three MEOSAR satellite constellations are summarised at Table 2.1. The primary missions for the satellites used in the three MEOSAR constellations are the Global Positioning System (GPS), Galileo and Glonass global navigation satellite services. As a secondary mission, the SAR payloads will be designed within the constraints imposed by the navigation payloads.

The three MEOSAR satellite constellations will utilise transparent repeater instruments to relay 406 MHz beacon signals, without onboard processing, data storage, or demodulation/remodulation. The DASS, SAR/Galileo and SAR/Glonass payloads will operate with downlinks in the 1544 – 1545 MHz band. A description of the issues that influence the selection of MEOSAR downlinks, and the frequency plan for MEOSAR downlinks are provided at section 6.

Each of the three satellite constellations will require equipment on the ground for satellite / payload control (i.e. sending commands for satellite station keeping, turning instruments on and off, reconfiguring instruments as required, monitoring payload health etc.). This equipment, which is required for satellite housekeeping, is not considered part of the MEOSAR system, and is not discussed further unless specific services for SAR are integrated into these ground stations.

Table 2.1: Characteristics of MEOSAR Satellite Constellations

	DASS	SAR/Galileo	SAR/Glonass
Number of satellites: Total Operational In-orbit Spare With MEOSAR Payloads	 27 24 3 All GPS Block III Satellites	 30 27 3 TBD	 24 24 TBD [(3)] All Glonass-K Satellites
Altitude (km)	20,182	23,222	19,140
Period (min)	718	845	676
Orbital Planes: Number of Planes No of Sat. Per Plane [(1)] Plane Inclination (degrees)	 6 4 55º	 3 9 [(2)] 56º	 3 8 64.8º

Notes: 1 Not including spare satellites
2 Plus one spare in each plane
3 TBD - To Be Determined

2.3 MEOSAR Ground Segment

A detailed discussion of issues pertaining to the MEOSAR system ground segment is presented at section 8. As depicted at Figure 2.1, the MEOSAR ground segment will be comprised of Cospas-Sarsat MCCs, MEOLUTs and possibly ground control stations for return link functions. The specification for Cospas-Sarsat MCCs is provided in Cospas-Sarsat System document C/S A.005. Changes to these requirements may be needed to address specific characteristics of the MEOSAR system.

The technical requirements for a Cospas-Sarsat MEOLUT will be developed during the definition and development phase of the DASS, SAR/Galileo and SAR/Glonass programmes. From a programmatic perspective, the provision of MEOLUTs will be an individual national responsibility. MEOSAR satellite providers will make their satellite downlinks available internationally for processing by MEOLUTs operated by Cospas-Sarsat Ground Segment Operators. However, MEOSAR providers will not be responsible for providing all the MEOLUTs necessary to support global coverage. Noting that the three MEOSAR constellations are expected to be interoperable as defined in section 3, it is envisaged that MEOLUTs will have the capability to receive and process the downlinks of all three MEOSAR satellite constellations.

Depending on the decisions taken in respect of providing the advanced SAR services (sections 2.6 and 7 refer), there may also be a requirement for MEOSAR providers to develop and install ground facilities to implement these additional functions.

2.4 MEOSAR Link Budget

The performance of the MEOSAR system and, therefore, the overall design of the MEOSAR space and ground segment are strongly affected by the beacon to satellite to MEOLUT link budget. A sample MEOSAR single path link budget depicting a nominal case situation is provided at Annex J. In order to assess the anticipated performance of the DASS, SAR/Galileo and SAR/Glonass components, typical link budgets are required for each.

Action Item 2.1*: MEOSAR providers should develop link budgets for their respective MEOSAR satellite constellations for inclusion in future revisions of this document. The link budgets should conform to the assumptions and format adopted for the sample link budget provided at Annex J.*

2.5 MEOSAR 406 MHz Beacon Location Accuracy and Responsiveness

The MEOSAR system will provide independent distress beacon location information using a combination of Time Difference of Arrival (TDOA) and Frequency Difference of Arrival (FDOA) techniques. MEOLUTs calculate the beacon location by measuring and processing the time and frequency differences of the same beacon burst relayed by different satellites. In theory, a minimum of two simultaneous satellite receptions is required for MEOLUTs to locate beacons using TDOA/FDOA techniques (document EWG-1/2002/3/2). However, current performance evaluations are based on a minimum of 3 satellites relaying each beacon burst.

MEOSAR location accuracy is affected by many factors including the number of time and frequency measurements available at the MEOLUT for a particular beacon burst, the accuracy of the time and frequency measurements, and the geometry between the beacon and the satellites.

The time required for a MEOSAR system to produce independent location information is also affected by several factors, the most significant being the length of time required for multiple satellites to provide simultaneous visibility of the beacon and a MEOLUT. A more thorough description of the MEOSAR independent location capability and the various factors that impact upon location performance is provided at section 5.

Because the MEOSAR system will be completely compatible with all Cospas-Sarsat 406 MHz beacon message protocols, it will also provide location information available from the message content of location protocol beacons. In such instances location information could be provided without the need for TDOA/FDOA processing, and could be available even if only one satellite provided simultaneous visibility of the beacon and the MEOLUT.

2.6 Advanced Capabilities

Since the MEOSAR system is being developed using new concepts, the opportunity exists to incorporate additional functions and/or capabilities that might benefit SAR services. The options being considered include:

- a return link to the beacon that might possibly be used to acknowledge reception of a distress alert, and/or control beacon transmissions; and
- support for a new generation of 406 MHz beacons that might provide a superior link budget, improved message content, and support more accurate time-tagging by MEOLUTs.

A more detailed discussion of possible additional capabilities is provided at section 7.

2.7 DASS

2.7.1 DASS System Architecture

The DASS system will include:

- 406 MHz repeaters on all 24 satellites of the GPS system, plus the 3 satellites designated as in-orbit spares; and
- Cospas-Sarsat MEOLUTs located throughout the world as required to provide global coverage.

A decision has not been made regarding a DASS return link service as described in section 2.6 above. If the decision is made to provide a return link, an additional ground segment component would be required to provide and manage return link transmissions.

GPS satellites orbit the Earth at altitudes of 20,182 km. The constellation of 24 satellites is distributed in 6 different orbital planes, equally spaced in longitude. With this constellation every point on the Earth is visible by at least 4 satellites at all times, with a minimum elevation angle of 5°.

2.7.2 DASS SAR Payload

The DASS SAR payload will include a transponder that will relay the signals transmitted by 406 MHz distress beacons. The technical characteristics of the transponders are provided at Annex B. Operational DASS transponders are expected to use downlinks in the 1544 – 1545 MHz band; however, the proof of concept / in-orbit validation phases of DASS implementation will be conducted using transponders with S-band downlinks.

A decision has not yet been made concerning the use of return link services on DASS; therefore, the associated payload requirements to implement this function are not addressed in this document.

2.8 SAR/Galileo

2.8.1 SAR/Galileo System Architecture

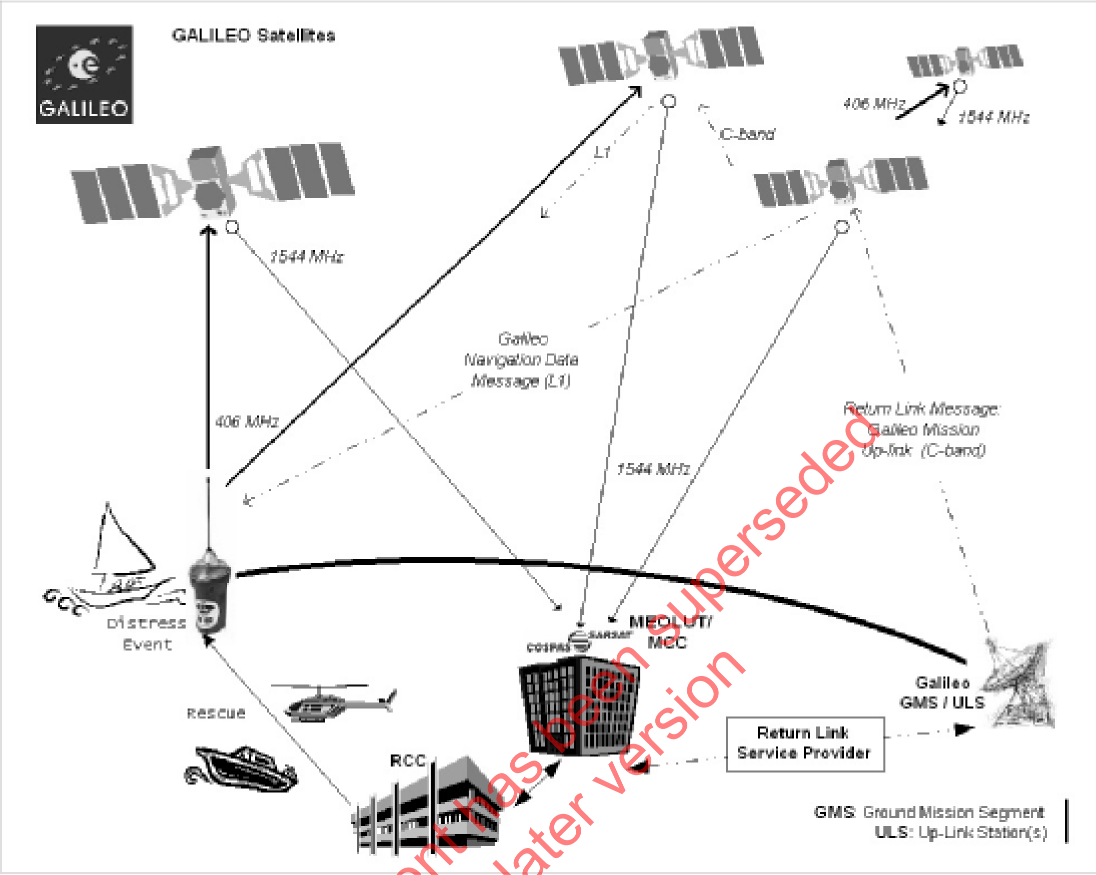
The SAR/Galileo system will consist of:

- 406 MHz repeaters on TBD* satellites of the Galileo navigation system, plus the TBC [3] satellites designated as in-orbit spares;
- Cospas-Sarsat MEOLUTs located throughout the world as required to provide global coverage; and
- a Return Link Service Provider (RLSP) interfacing to the Galileo ground segment for uploading return link messages to Galileo satellites.

Galileo satellites will orbit the Earth at an altitude of approximately 23,200 km. The constellation of 27 satellites will be distributed in 3 planes equally spaced in longitude. With this constellation every point on the Earth will be in visibility of at least 6 satellites at all times with a minimum elevation angle of 5° (document MEOSAR-1/2004/Inf.2). As indicated at Figure 2.2, the SAR/Galileo return link function will be integrated into the Galileo mission uplink, which will operate at C-band.

* Note: Subject to confirmation on the number of payloads needed to meet the Cospas-Sarsat MEOSAR mission objectives.

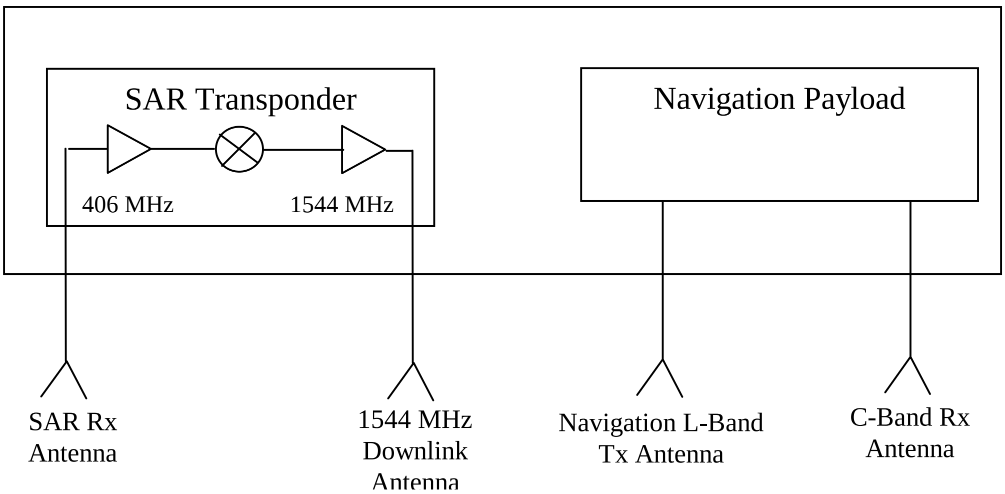
Figure 2.2: SAR/Galileo System Concept



2.8.2 SAR/Galileo Payload

The SAR payload, depicted at Figure 2.3, consists of the forward link 406 MHz receive antenna, transponder and a 1544 MHz transmit antenna, and a return link for SAR-related acknowledgements and other messages. In terms of hardware, the return link is part of the Galileo ground mission segment (GMS) and navigation payload. The technical characteristics of the forward link transponder are provided at Annex C.

Figure 2.3: SAR/Galileo Payload Functions



2.8.3 SAR/Galileo Return Link Functions

SAR/Galileo will provide the advanced services for SAR described at section 2.6

The detailed operational and technical requirements for these functions have not yet been defined.

2.9 SAR/Glonass

2.9.1 SAR/Glonass System Architecture

The SAR/Glonass system will consist of:

- 406 MHz repeaters on all satellites of the Glonass-K navigation system; and
- Cospas-Sarsat MEOLUTs located throughout the world as required to provide global coverage.

Glonass satellites orbit the Earth at altitudes of 19,140 km. The constellation of Glonass satellites is distributed in 3 different orbital planes, equally spaced in longitude. With this constellation every point on the Earth is in visibility of at least 4 satellites with an elevation angle greater than 5 degrees at all times.

A decision has not yet been made regarding whether SAR/Glonass would also provide a return link service to the beacon as described in section 2.6. If so, an additional ground segment component would be required to provide and manage return link transmissions.

2.9.2 SAR/Glonass SAR Payload

The SAR/Glonass payload will include a transparent 406 MHz repeater to relay the signals transmitted by 406 MHz distress beacons. A technical description of the SAR/Glonass 406 MHz repeater is provided at Annex D.

Action Item 2.2: *MEOSAR providers should update, as necessary, the information concerning the design, performance, and functionality of their system.*

- END OF SECTION 2 -

3. MEOSAR COMPATIBILITY AND INTEROPERABILITY

This section defines the concept of MEOSAR system compatibility with the existing Cospas-Sarsat System that includes LEOSAR and GEOSAR components, and the concept of "interoperability" of the three MEOSAR satellite constellations with Cospas-Sarsat MEOLUTs.

3.1 System Compatibility and Interoperability Concepts

As a minimum, the MEOSAR system must ensure compatibility with the existing Cospas-Sarsat LEOSAR and GEOSAR systems, and also compatibility with each other, i.e. they should not impact on the operation of the existing systems, or of other MEOSAR constellations that might operate in the same frequency bands. In addition, a MEOSAR system must be able to process 406 MHz beacons that meet Cospas-Sarsat requirements for operation in the LEOSAR and GEOSAR systems.

Moreover, there are clear benefits to ensuring that Cospas-Sarsat MEOLUTs will be capable of processing the downlink signals of all MEOSAR constellations.

The International Cospas-Sarsat Programme Agreement was established to ensure the continuity of the international cooperation that resulted in the implementation of an international satellite distress alerting system using a variety of space and ground segment components. Although slight differences exist between the satellite payloads in the LEOSAR system, they are basically interoperable, i.e. the same ground segment architecture allows for a local user terminal (LUT) to track, receive and process data from both satellite series. Similarly, although the performance characteristics of the various satellite payloads in the GEOSAR system are different, GEOLUTs must satisfy a common set of performance criteria that ensures consistent distress alerting performance. The advantages of interoperable systems include:

a. a robust ground segment providing redundancy and allowing quicker detection and location of distress beacons;

b. a more efficient management of the System that results from a consistent set of performance requirements for the space and ground segment components;

c. reduced costs of establishing LUTs through competition and economies of scale; and

d. an encouragement for other States to contribute additional ground segment equipment to the "joint" system, and consequently a reinforcement of the international acceptance of the interoperable systems.

The same considerations apply to a MEOSAR system, and a basic objective of 406 MHz MEOSAR providers is to ensure that as far as practical, all MEOSAR components are interoperable with each other.

3.2 Definition of MEOSAR System Compatibility and Interoperability

3.2.1 Compatibility:

The MEOSAR system is capable of orderly and efficient integration and operation with the Cospas-Sarsat System. The MEOSAR constellations are able to coexist on a non-interfering basis with each other and with the existing Cospas-Sarsat System.

3.2.2 Interoperability:

The components of the MEOSAR system conform to a common architecture and comply with agreed performance standards. A set of similar satellite downlink characteristics allows MEOLUTs to track satellites and process signals from interoperable MEOSAR constellations.

3.3 MEOSAR Compatibility and Interoperability Requirements

The Cospas-Sarsat requirements in respect of MEOSAR compatibility are addressed in section 5, except for the detailed technical analysis concerning frequency coordination and Cospas-Sarsat frequency protection requirements which are detailed in document C/S T.014.

The requirements for MEOSAR interoperability are addressed at section 6 (MEOSAR payloads) and section 8 (MEOSAR Ground Segment).

- END OF SECTION 3 –

4. PROGRAMME MANAGEMENT AND COORDINATION

This section describes the management structure and policies agreed by the Cospas-Sarsat Council for coordinating the development and introduction of a 406 MHz MEOSAR system into the operational Cospas-Sarsat System.

The principles that govern the management of the Cospas-Sarsat Programme and the responsibilities of Participants for the provision and operation of ground and space segment components of the Cospas-Sarsat System are defined in the International Cospas-Sarsat Programme Agreement (ICSPA). Because Russia and the USA are Parties to the ICSPA, the development and the integration of their MEOSAR satellite constellations into the Cospas-Sarsat System can be accommodated within the framework established by the ICSPA, as an enhancement to the existing Cospas-Sarsat System, and managed by the Cospas-Sarsat Council through the existing management structure (i.e. Council, Joint Committee, Task Groups, Experts Working Groups, etc.). However, because the EC/ESA are not parties to the ICSPA, a specific management structure is required for coordinating the development and integration activities for SAR/Galileo.

It is expected that a formal agreement between Cospas-Sarsat and the appropriate authority responsible for the development of the SAR/Galileo system would provide the required management structure for the development and integration of SAR/Galileo into the Cospas-Sarsat System.

4.1 Development and Integration of the MEOSAR System

Section 10 of this document describes the procedures agreed amongst Cospas-Sarsat Parties and MEOSAR Providers for the development, proof of concept, demonstration and evaluation phases of MEOSAR programmes, and the integration of an operational MEOSAR system into the Cospas-Sarsat System. During the development, proof of concept, and the demonstration and evaluation phases of the MEOSAR system (i.e. prior to the Council decision to accept the MEOSAR system as an enhancement to Cospas-Sarsat in an initial operational capability), significant changes to the management structure of the Cospas-Sarsat Programme should be avoided, as the primary objective of the Council remains that of ensuring the continuous availability of reliable, efficient and dependable satellite alerting capabilities based on the LEOSAR and GEOSAR satellite systems, in accordance with the Parties’ commitments under the ICSPA.

Therefore, during the development, demonstration and evaluation phases, the coordination amongst MEOSAR Providers and Cospas-Sarsat Participants should be effected through the Council, taking the opportunity of regular Cospas-Sarsat meetings or during special experts’ meetings established by the Council on an ad hoc basis.

However, as noted above, the organisation responsible for the management of SAR/Galileo is not a Party to the ICSPA. Therefore, the Cospas-Sarsat Council would need to enter into a specific agreement with the SAR/Galileo management organisation that:

a. identifies the organisations responsible for the development, testing and operation of SAR/Galileo;

b. delineates the authorities and scope of responsibilities of these organisations in respect of the coordination of SAR/Galileo integration into the Cospas-Sarsat system;

c. defines the role, responsibilities, and authority of the Cospas-Sarsat Council and its subsidiary organs (i.e. Joint Committee, Experts Working Groups, etc.) in respect of the development and integration of SAR/Galileo into Cospas-Sarsat; and

d. defines the procedures for progressing operational, technical and management issues that impact upon MEOSAR development and integration into the Cospas-Sarsat System, including the documentation of decisions, recommendations and actions agreed between Cospas-Sarsat and SAR/Galileo.

In addition, the MEOSAR Providers have stated that they do not intend to fund, procure and operate the complete ground segment required to provide global coverage. Such a complete ground segment providing global coverage will encompass a number of ground receiving/processing stations (MEOLUTs) established world-wide.

Furthermore, as described in section 3 of this document, there are significant advantages to establishing MEOLUTs that operate simultaneously with several MEOSAR satellite systems. Since the development of such ground processing capabilities for MEOSAR distress alerting will also have to be coordinated with Cospas-Sarsat, it would be advantageous to envisage that:

- the development, testing and operation of MEOLUTs should be coordinated by Cospas-Sarsat in the framework of the existing ICSPA;

- a common set of performance requirements should be agreed by Cospas-Sarsat, taking into account the design and capabilities of each MEOSAR constellation; and

- all MEOLUTs would be required to undergo commissioning testing before being authorised to input distress alert information into the Cospas-Sarsat System.

As is the case with the Cospas-Sarsat LEOSAR and GEOSAR systems, the formal process of MEOLUT commissioning testing and reporting would be the responsibility of the respective MEOLUT provider, and the Cospas-Sarsat Council would have final authority to approve the commissioning of a MEOLUT into the Cospas-Sarsat System.

Annex H summarises the guidance provided above, and further details the work plan to be undertaken during the development and integration of the MEOSAR system.

4.2 Institutional / Management Structure for the Operational MEOSAR System

Upon the completion of the MEOSAR development, proof of concept, demonstration and evaluation phases, the MEOSAR system could become an essential component of the operational Cospas-Sarsat System. However, in the absence of any operational experience of the MEOSAR system's performance, it would be premature to speculate on the long-term impact of the introduction of an operational MEOSAR system on the existing LEOSAR and GEOSAR components of Cospas-Sarsat.

The possible institutional evolution of the Cospas-Sarsat Programme and the future roles and responsibilities of MEOSAR space segment and/or ground segment providers will have to be considered in parallel with the development and implementation of MEOSAR capabilities. In the future there will be a requirement to define a stable and comprehensive management framework for the Cospas-Sarsat Programme that will ensure the continuity and availability of 406 MHz satellite alerting services to users worldwide, and address, as required, the provision and operation of the MEOSAR system.

- END OF SECTION 4 -

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5. COSPAS-SARSAT REQUIREMENTS FOR A MEOSAR SYSTEM

5.1 Fundamental MEOSAR Requirements

The primary goal of the proposed MEOSAR system is to provide a reliable distress alerting service for 406 MHz beacons that would enhance the services provided by Cospas-Sarsat LEOSAR and GEOSAR systems. Furthermore, to be incorporated into the Cospas-Sarsat System, MEOSAR system components should be provided and managed in accordance with the principles that govern the Cospas-Sarsat Programme. These guiding principles impose the following requirements.

a. MEOSAR services should be provided free of charge to the end user in distress.

b. the MEOSAR system should not generate harmful interference to the Cospas-Sarsat LEOSAR and GEOSAR systems.

c. the MEOSAR system should be completely compatible with Cospas-Sarsat 406 MHz distress beacons.

d. MEOSAR downlinks should be openly accessible and free of charge to Cospas-Sarsat Ground Segment Providers worldwide.

e. the MEOSAR system must achieve minimum performance levels agreed by the Cospas-Sarsat Council.

5.2 Minimum MEOSAR Performance Levels for Cospas-Sarsat Compatibility

To study the feasibility of providing a MEOSAR capability, MEOSAR space segment providers needed baseline performance requirements against which different designs could be evaluated. Furthermore, Cospas-Sarsat was sensitive to the view that, prior to making the significant investment needed to develop their contributions, MEOSAR providers would need a mechanism and criteria for assessing whether their planned contributions would be compatible with, and would enhance, the Cospas-Sarsat System.

In response to the above, Cospas-Sarsat established, in cooperation with the MEOSAR providers, minimum MEOSAR system performance requirements for compatibility with the Cospas-Sarsat System. These minimum requirements, provided at Annex E, duplicate the key performance levels provided by the Cospas-Sarsat LEOSAR and GEOSAR systems.

The reason for basing minimum MEOSAR requirements on existing Cospas-Sarsat performance levels is that, although a MEOSAR system will have the potential to provide superior performance in many aspects, insufficient information is available at this stage to define specific performance levels that could be achieved practically. However, if the MEOSAR system replicated current LEOSAR and GEOSAR performance, it would benefit the System, and, therefore, should be accepted as part of Cospas-Sarsat.

5.3 Enhanced MEOSAR Performance Objectives

Because of the coverage provided by MEOSAR satellites and the number of satellites in each MEOSAR constellation, the MEOSAR system has the potential to provide performance that exceeds the minimum requirements established above. Cospas-Sarsat and MEOSAR providers agreed that MEOSAR performance should not be limited to those defined for Cospas-Sarsat compatibility, rather, every effort should be made to develop a system that provides the maximum benefits to SAR services. The following sections summarise analyses in respect of achievable MEOSAR performance in key areas.

Action Item 5.1: *MEOSAR providers are invited to conduct analysis to identify performance levels that can be achieved practically. The analysis should particularly investigate the beacon to satellite and satellite to MEOLUT link budgets, and their impact on various aspects of overall MEOSAR system performance.*

5.3.1 Detection Probability

The Cospas-Sarsat LEOSAR system has less than full-Earth visibility at any time due to the limited number of satellites on orbit. Beacons outside a satellite's coverage area can therefore not be immediately detected, but must continue to transmit until a satellite passes overhead. GEOSAR satellites, though visible nearly everywhere in the Earth's mid-latitude regions, can be blocked from a beacon's view by terrain features. MEOSAR systems, due to their large numbers of satellites, changing orbital positions and large fields of view, can significantly reduce or eliminate these limitations and can increase a beacon's probability of detection.

5.3.2 Independent Location Probability

TBD

5.3.3 Independent Location Accuracy

Unlike the Cospas-Sarsat LEOSAR system, which produces independent Doppler locations from a single pass of a single satellite, MEOSAR beacon location algorithms require the beacon transmission to be simultaneously repeated by multiple satellites. The MEOSAR independent location determination performance is affected by the geometry of the satellites in visibility of the beacon, and the number of satellites that simultaneously repeat the beacon transmission.

Preliminary studies conducted by the USA (EWG-1/2002/3/2) concluded that a complete DASS constellation would provide instantaneous visibility by at least 3 satellites anywhere on the surface of the Earth. Furthermore, assuming a suitable ground segment, DASS would provide independent location information from a single 406 MHz beacon burst accurate to within 6.1 km 95% of the time. In addition, subsequent beacon transmissions could be used to refine the location and an accuracy of 1 km could be achievable within [TBD] minutes after a beacon started transmitting.

Action Item 5.2: *MEOSAR providers are invited to conduct analysis to identify anticipated MEOSAR location determination performance in respect of location accuracy and time to produce location information, and to propose options for optimising MEOSAR location determination performance.*

5.3.4 Error Ellipse

TBD

5.3.5 Sensitivity

TBD

5.3.6 Availability

A study conducted by the USA assessing the impact of satellite failures concluded that a MEOSAR system would continue to perform well even if the constellations became reduced. The analysis showed that, assuming only DASS satellites in orbit and with the highly unlikely loss of six satellites randomly selected from a nominal constellation, beacons would still have immediate visibility to 3 or more DASS satellites 99.5% of the time, and the independent location capability would still be provided with only a minor reduction in accuracy.

The availability of MEOSAR services would be further enhanced for a MEOSAR system comprised of satellite constellations fully interoperable with all Cospas-Sarsat MEOLUTs. Table 5.1 provides the expected performance for different availability scenarios of DASS and SAR/Galileo satellite constellations, assuming a global ground segment of MEOLUTs capable of processing both constellations.

Table 5.1: Performance of Combined DASS and SAR/Galileo Constellations

Combined DASS - SAR/Galileo Scenario	Immediate 3 Satellite Visibility (%)	Single Burst Location Accuracy (95th percentile)
24 Randomly Selected DASS - SAR/Galileo Satellites	99.8	7.4 km
48 Randomly Selected DASS - SAR/Galileo Satellites	100	4.1 km

5.3.7 Coverage

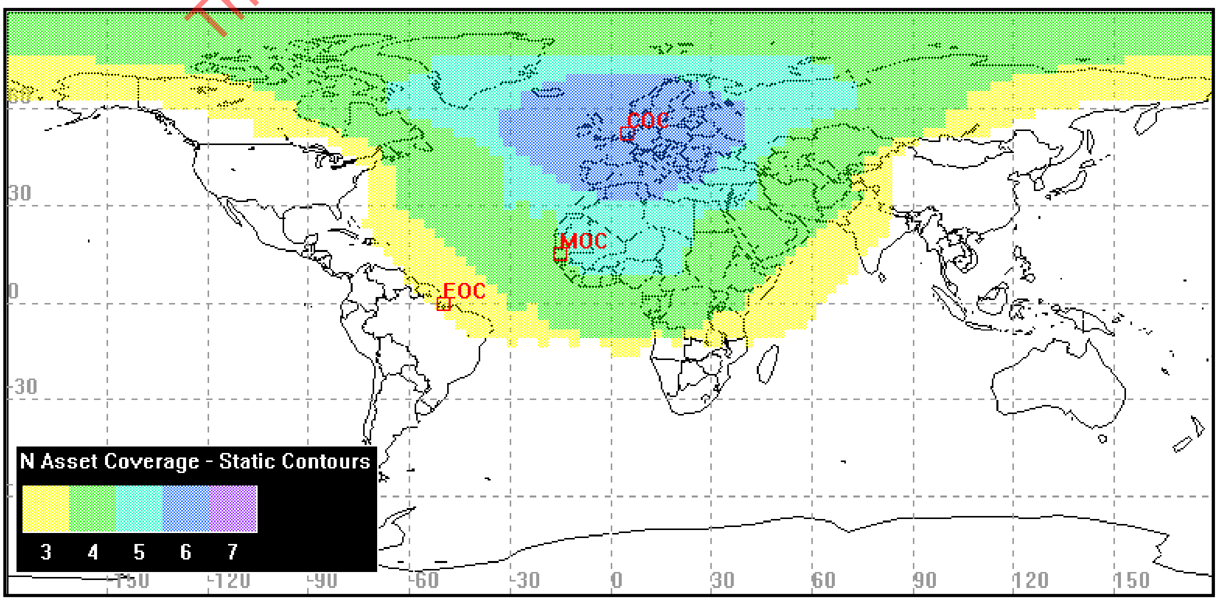
The MEOSAR requirement for global coverage duplicates the performance of the Cospas-Sarsat LEOSAR system, which provides complete global coverage (including the polar regions) for 406 MHz distress beacons. The LEOSAR system achieves this performance using satellite on-board processing of beacon messages and data storage. In effect, because of the onboard memory the LEOSAR system could provide global coverage with a single satellite and a single LEOLUT, but with excessive delay.

The coverage provided by the MEOSAR system will be determined by the availability of a suitable MEOLUT ground segment. The coverage provided with a single MEOLUT is dependent upon the minimum number of satellites that need to achieve simultaneous visibility of both the beacon and the MEOLUT to allow for independent location determination with the required accuracy. Figure 5.1 depicts the nominal coverage for a stand-alone MEOLUT tracking SAR/Galileo satellites.

To achieve global coverage as soon as possible, MEOSAR providers are investigating various possibilities for ground segment architecture and MEOLUT design, including:

- networking MEOLUTs to enable them to share beacon burst time and frequency measurement data with each other; and
- the space and ground segment requirements necessary for Cospas-Sarsat MEOLUTs to receive and process the downlink signals from all MEOSAR satellite constellations.

Figure 5.1: Coverage Area of a Single Stand-alone MEOLUT (non-networked MEOLUT)



The contours depicted in Figure 5.1 show continuous coverage by at least "N" satellites with mutual visibility of the beacon and the MEOLUT. The edge of coverage limits depicted in the figure correspond to 5º beacon-to-satellite and 15º MEOLUT-to-satellite elevation angles.

5.3.8 Capacity

The MEOSAR capacity requirement to support a population of more than 3.8 million beacons is based upon the projected beacon population growth and the channel assignment strategy adopted by Cospas-Sarsat for optimising the capacity of the LEOSAR and GEOSAR systems.

Because a MEOSAR system requires multiple simultaneous beacon, satellite and MEOLUT visibility, the model for calculating MEOSAR capacity is likely to be different from either the LEOSAR or GEOSAR system models. Furthermore, in light of the relationship between capacity and channel assignment strategies, an optimum channel assignment strategy that would accommodate LEOSAR, GEOSAR and MEOSAR systems is needed.

System capacity is defined as the number of 406 MHz distress beacons operating simultaneously that can be successfully processed to provide a beacon geolocation, under nominal conditions. As the number of simultaneous beacon transmissions increases, so does the incidence of interfering collisions between transmitted signals. Such collisions tend to increase the time required for the system to locate a beacon. To minimize the incidence of interfering collisions between transmitted signals and to improve system capacity, the 406-406.1 MHz band has been divided into approximately twenty-five 3 KHz channels in which Cospas-Sarsat attempts to control the number of beacons operating in each channel.

Preliminary capacity studies indicate that the MEOSAR system will provide a large capacity that will adequately support the projected beacon population growth.

Action Item 5.3: *MEOSAR providers and Cospas-Sarsat are invited to develop a MEOSAR capacity model, and proposals for a 406 MHz channel assignment strategy that accommodates LEOSAR, GEOSAR and MEOSAR requirements.*

5.3.9 Interferer Processing

Studies conducted by the USA indicate that a MEOSAR system should be able to locate 406 MHz interfering emitters using the same general techniques used to locate distress beacons. Preliminary analyses indicate that it should be possible to automatically locate narrow band signals to accuracies similar to beacons. However, it may be necessary to store and use off-line techniques for locating wide band signals (EWG-1/2002/3/1).

The impact of possible interference to a MEOSAR system from wind profiler radars operating near the 406 MHz band will have to be considered. The adverse impact of these radars to the Cospas-Sarsat LEOSAR system has been addressed by turning the radars off when LEOSAR satellites are overhead. The radars do not affect the GEOSAR systems because GEOLUTs use directional antennas that are always pointed at a single stationary satellite, therefore, they are not impacted by the highly directional transmissions from wind profiler radars. Because of the number of MEOSAR satellites and their orbital positions, the scheduling techniques adopted for the LEOSAR system will not be possible with a complete MEOSAR constellation.

Action Item 5.4: *Cospas-Sarsat Participants are invited to:*

a. *investigate whether their respective Administrations operate, or have knowledge of other Administrations which operate wind profiler radars at 404.3 MHz, and report their findings to the Council; and*

b. *request administrations operating wind profilers at 404.3 MHz to move these radars to the 449 MHz frequency band by the year 2005.*

5.3.10 Processing Anomalies

TBD

5.4 Evaluation of MEOSAR Performance

Evaluation of MEOSAR system performance will be made during the demonstration and evaluation (D&E) phase (see section 10 for a description of the scope of the D&E). However, the actual MEOSAR performance will depend upon the availability of complete space and ground segments, which may or may not be in place at the time of the D&E.

The decision to use alerts produced by the MEOSAR system operationally will be dependant upon the performance demonstrated during the D&E. Complete MEOSAR ground and space segments will not be a prerequisite for deciding whether MEOSAR alerts should be distributed within the Cospas-Sarsat Ground Segment, instead the Council will take this decision based upon their assessment of whether distress alerts from an incomplete MEOSAR system would enhance the existing Cospas-Sarsat distress alerting service.

- END OF SECTION 5 -

6. MEOSAR PAYLOADS

This section describes requirements for ensuring that MEOSAR payloads will not generate harmful interference to other systems, and payload requirements for achieving full DASS, SAR/Galileo and SAR/Glonass interoperability.

6.1 MEOSAR Downlinks

The DASS, SAR/Galileo, and SAR/Glonass MEOSAR constellations plan to operate with satellite downlinks in the 1544 – 1545 MHz band. The ITU Radio Regulations allocate the 1544 – 1545 MHz band to the mobile satellite service (MSS), space-to-earth, for distress and safety communications (article 5.356). International agreement to operate systems in this band is achieved by completing the formal frequency coordination process with other administrations that have successfully notified their use of the band to the ITU. This process, which establishes whether proposed new systems would generate harmful interference to other "notified" systems, will have to be completed for each MEOSAR satellite constellation. In effect MEOSAR providers will need to design downlinks that support SAR performance requirements, whilst:

a. not generating harmful interference to other authorised users of the band or to other MEOSAR components; and

b. operating in the presence of emissions from the other systems authorised to operate in the band.

Tables 6.1 through 6.3 below summarise the preliminary information provided by the USA, EC/ESA and Russia concerning their respective plans for the DASS, SAR/Galileo and SAR/Glonass MEOSAR downlinks.

The preliminary plan for MEOSAR system use of the 1544 – 1545 MHz band is depicted at Figure 6.1. This plan cannot be finalised until the protection requirements for the other users of the band have been established, the level of interference in the band from existing users has been quantified, and detailed analysis has been conducted to evaluate each proposed MEOSAR component against these criteria.

DASS Payload Downlink Characteristics	
Item	**Description**
Payload type	Direct frequency translation repeater
Downlink frequency	Occupies 200 kHz from 1544.8 to 1545.0 MHz
Downlink EIRP	17.5 dBW
Downlink polarisation	Right Hand Circular Polarisation (RHCP)
Bandwidth relayed	406.0 – 406.1 MHz, possibly reduced by small amount to accommodate MEOSAR Doppler shift

Table 6.1: DASS Payload Downlink Characteristics

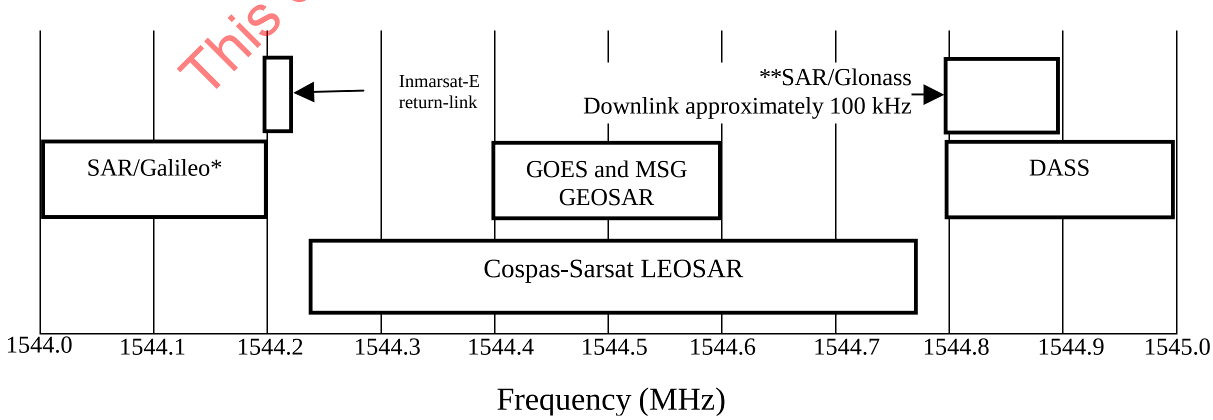
SAR/Galileo Payload Downlink Characteristics	
Item	**Description**
Payload type	Direct frequency translation repeater
Downlink frequency*	Occupies 100 kHz from 1544.0 to 1544.2 MHz
Downlink EIRP	>16.8 dBW over the entire Earth coverage
Downlink polarisation	Left Hand Circular Polarisation (LHCP)
Bandwidth relayed	406.005 – 406.095 MHz (1 dB bandwidth)

Table 6.2: SAR/Galileo Payload Downlink Characteristics

SAR/Glonass Payload Downlink Characteristics	
Item	**Description**
Payload type	Direct frequency translation repeater
Downlink frequency**	Occupies 100 kHz from 1544.8 to 1545.0 MHz
Downlink EIRP	19.0 dBW
Downlink polarisation	Left Hand Circular Polarisation (LHCP)
Bandwidth relayed	406.0 – 406.1 MHz, possibly reduced by small amount to accommodate MEOSAR Doppler shift

Table 6.3: SAR/Glonass Payload Downlink Characteristics

Figure 6.1: 1544 – 1545 MHz Band Plan



Notes: * SAR/Galileo will occupy approximately 100 kHz in the 1544.0 – 1544.2 MHz band.

** Exact location of SAR/Glonass downlink has yet to be determined.

6.2 MEOSAR Interference to Existing Users

The systems listed below have been notified, or are in the process of being notified, to the ITU to operate in the 1544 – 1545 MHz band:

a. Sarsat LEOSAR system;

b. Cospas LEOSAR system;

c. GOES GEOSAR;

d. MSG GEOSAR;

e. Inmarsat-E return link services; and

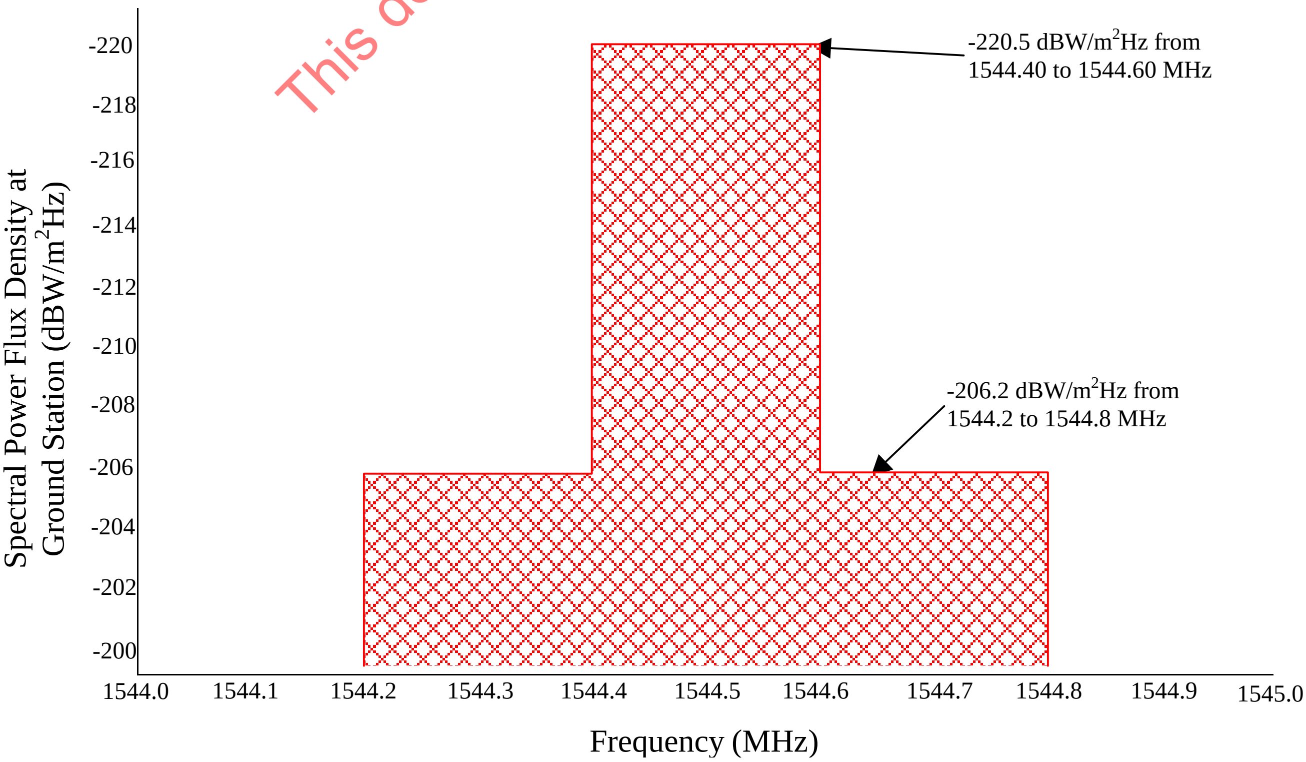
f. Koreasat.

The protection requirements for some of the components of the Cospas-Sarsat systems above are described in the draft Cospas-Sarsat System document C/S T.014 (Cospas-Sarsat frequency protection and coordination requirements). A susceptibility mask for the 1544 – 1545 MHz band based on the information currently available is provided at Figure 6.2.

The 1544 – 1545 MHz protection requirements for the following systems / services are not yet available:

- § Sarsat 121.5 MHz and 243 MHz repeater services;
- § Cospas 121.5 MHz repeater services;
- § Inmarsat-E return link services; and
- § Koreasat.

Figure 6.2: Cospas-Sarsat LEOSAR and GEOSAR Susceptibility Mask for 1544 – 1545 MHz Band



Action Item 6.1: *MEOSAR providers should:*

a. *consider the protection requirements for the other systems that have notified their use of the 1544 – 1545 MHz band when designing their MEOSAR downlinks;*

b. *conduct investigations to identify other systems that have, or will have, started the coordination / notification process with the ITU prior to the respective MEOSAR provider, and consider the protection requirements for such systems when designing MEOSAR downlinks; and*

c. *initiate the formal ITU advance publication, coordination and notification process for their MEOSAR satellite network, in accordance with the procedures described in the Radio Regulations.*

6.3 Interference to MEOSAR Downlinks

In addition to ensuring that the MEOSAR system does not cause interference to other systems, the minimum MEOSAR system performance levels required for compatibility with Cospas-Sarsat must be maintained while operating in the presence of emissions from systems in the 1544 – 1545 MHz band, as well as from other systems operating in adjacent frequency bands.

Specifically, each component of the MEOSAR system must be designed to account for possible emissions in the MEOSAR downlink bands from:

- MEOSAR satellites that operate with downlinks in the band;
- Cospas-Sarsat LEOSAR and GEOSAR satellites;
- other authorised systems using the 1544 – 1545 MHz band; and
- out-of-band emissions from systems operating in adjacent bands.

The level of interference in the MEOSAR downlink band(s) impacts the overall design of a MEOSAR system, and will require trade-offs between payload and MEOLUT design. For example, the impact of interference could be mitigated by using more powerful MEOSAR downlinks. This approach would add to the cost / complexity of the payload and possibly increase the out-of-band emissions. Conversely, interference might be mitigated at the MEOLUT by using more directional antennas and / or more sophisticated signal processing. However, this would impact on MEOLUT cost and complexity.

In view of the above, design decisions taken to mitigate the impact of interference should be considered at a MEOSAR system level taking into account the constraints imposed by both the ground and space segments.

6.3.1 Mutual MEOSAR Interference

Preliminary analysis conducted by ESA (EWG-4/2002/4/2) concluded that it would be feasible for two MEOSAR satellite constellations employing direct frequency translation repeaters to operate without generating harmful interference to each other, if one operates with downlinks in the lower portion of the band between 1544.0 and 1544.2 MHz and the other operates downlinks in the upper portion between 1544.8 and 1545.0 MHz.

With respect to the introduction of a third MEOSAR satellite constellation also employing direct frequency translation repeaters, there is insufficient spectrum available either in the upper or lower portion of the band to assign the third constellation its own allocation.

However, as depicted at Figure 6.1 it might be feasible for DASS and SAR/Glonass to share a portion of the available spectrum between 1544.8 and 1545.0 MHz for their downlinks. In which case the DASS and SAR/Glonass systems could be designed to be viewed by MEOLUTs as a single larger satellite constellation. This might provide MEOLUTs with additional options for selecting satellites, thereby optimising MEOSAR coverage and location determination performance. Additional analysis is required to establish how many DASS and SAR/Glonass MEOSAR satellites can share the upper portion of the band without generating harmful interference to each other. If mutual MEOSAR interference became a problem, it might be necessary to turn-off some DASS and SAR/Glonass MEOSAR payloads, in effect making them in-orbit spares.

Since the primary role for all the satellites under consideration are the navigation missions, replacement satellites might not be launched for the sole purpose of restoring the constellation of MEOSAR payloads. Consequently, the availability of in-orbit spares would be highly beneficial. If such an approach were adopted, a process for determining which MEOSAR payloads would be turned-off will be required.

Action Item 6.2: *MEOSAR providers should study the issue of how many DASS and SAR/Glonass MEOSAR repeaters could be accommodated in the upper portion of the band without generating harmful interference to each other.*

6.3.2 Interference to the MEOSAR System from LEOSAR Satellites

Although the useful signal from Sarsat LEOSAR downlinks is contained within the 1544.5 ± 300 MHz band, Sarsat LEOSAR satellites transmit energy beyond this range, into the bands being considered for MEOSAR downlinks. The worst-case spurious emission limits from Sarsat repeaters is provided in Figure 3.12 of document C/S T.003 (LEOSAR payload description).

6.3.3 Interference to MEOSAR System from GEOSAR Satellites

Similar to the LEOSAR situation described above, the GOES and MSG GEOSAR systems also transmit energy into the bands being considered for MEOSAR downlinks. Spectrum plots for the GOES and MSG downlinks are provided in document C/S T.011 (GEOSAR payload description).

6.3.4 Interference to MEOSAR System Downlinks from Other Systems

In addition to the LEOSAR and GEOSAR systems operated by Cospas-Sarsat, the MEOSAR system must also be designed to accommodate downlink interference originating from Inmarsat-E return link transmissions, Koreasat, and interference spilling over from systems operating outside the 1544 – 1545 MHz band.

In consideration of the Koreasat system, a detailed description of its transmissions in the band was requested from the Korean Administration. However, a letter from the Korean Director of Frequency Division and Radio & Broadcasting Bureau advised that Koreasat was still in the planning stages and detailed information could not yet be provided.

A USA study (EWG-2/2003/4/12-Rev.1) that quantified possible interference in the 1544 – 1545 MHz band from geostationary satellites in the Mobile Satellite Service based upon information provided in filings with the ITU, indicated that the interference levels could exceed the Cospas-Sarsat susceptibility mask provided at Figure 6.2. However, the interference levels presented in the USA study represent the most pessimistic case, since a large number of the systems filed with the ITU will likely never become operational, and for those that do, many will utilise lower EIRP than advertised for their downlinks. Additionally, the study did not consider that beacon signals will be relayed by multiple satellites and will be received by multiple MEOLUTs at different locations. Therefore, even if one MEOLUT is degraded by out-of-band interference, the other MEOLUTs might remain unaffected and the overall system performance impact will be minimal.

Action Item 6.3: *The Secretariat should forward any information regarding Koreasat downlink provided by Korea to the MEOSAR providers.*

Action Item 6.4: *MEOSAR providers should:*

a. *establish susceptibility / protection requirements for their MEOSAR downlinks; and*

b. *consider the possible interference from other systems, including inter MEOSAR satellite constellation interference, when designing their downlinks, and confirm whether the minimum performance required for compatibility with Cospas-Sarsat would still be satisfied while operating in the presence of interference from these systems.*

6.4 Payload Characteristics for MEOSAR Constellations Interoperability

Cospas-Sarsat and MEOSAR providers have agreed that it was highly desirable for MEOLUTs to have the capability to receive and process the downlink signals from multiple MEOSAR satellite constellations. Such a capability would provide options for selecting the optimum satellites for a given coverage, and would enhance MEOSAR system redundancy.

In evaluating payload requirements for interoperability MEOSAR providers considered the impact upon satellite complexity and cost, the available resources on the satellite (e.g. weight and power), MEOSAR performance requirements for compatibility with Cospas-Sarsat, and the impact that payload designs would have on MEOLUT cost and complexity. Based upon these considerations MEOSAR providers and Cospas-Sarsat agreed the MEOSAR payload characteristics for interoperability provided at Annex F.

The most significant payload characteristics that impact upon MEOSAR interoperability are:

- modulation of the downlinks;
- downlink frequency;
- downlink EIRP;
- downlink polarisation;
- repeater bandwidth;
- repeater receiver G/T;
- repeater dynamic range;
- repeater linearity; and
- group delay.

6.4.1 Modulation of the Downlink Signal

The decision by the USA, Russia, and the EC/ESA to use direct frequency translation repeaters for their MEOSAR satellite payloads simplifies the development of MEOLUTs capable of receiving and processing the signals from all MEOSAR constellations.

6.4.2 Downlink Frequency

MEOSAR satellite constellations need not have the exact same downlink frequencies to enable MEOLUTs to process their downlinks. Analysis conducted by ESA (EWG-4/2002/4/1) concluded that it might be preferable to maintain some frequency diversity since this would increase the robustness of the whole system. However, it is important that the downlink frequencies be close enough to each other to minimise the cost of MEOLUT receivers.

The frequency separation resulting from the DASS and SAR/Glonass MEOSAR repeater downlinks operating in the upper portion and the SAR/Galileo downlinks in the lower portion of the 1544 – 1545 MHz band will not impede the development of MEOLUTs capable of receiving and processing the repeater downlinks from the three MEOSAR satellite constellations.

6.4.3 MEOSAR Downlink EIRP

Analysis conducted by ESA regarding the impact of MEOSAR downlink power (EWG-4/2002/4/1) concluded that the power spectral density received by MEOLUTs directly impacts upon Time of Arrival (TOA) measurement accuracy and, therefore, MEOSAR location accuracy. In addition the value of the MEOSAR downlink EIRP drives requirements in respect of MEOLUT antenna options.

MEOSAR providers agreed that to ensure interoperability, MEOSAR downlink EIRPs should exceed 15 dBW for all MEOLUT to satellite elevation angles above 5°.

6.4.4 Downlink Polarisation

The selection of a downlink polarisation should take into consideration:

a. the protection requirements for Cospas-Sarsat LEOSAR and GEOSAR systems;

b. the possible impact on MEOSAR system interoperability; and

c. constraints imposed by the primary navigation mission.

Since the LEOSAR and GEOSAR systems have downlinks with opposite circular polarisation, it is not possible to select a MEOSAR downlink polarisation that optimises protection to both the LEOSAR and GEOSAR systems.

From the perspective of MEOSAR interoperability, adopting a common downlink polarisation for all MEOSAR space segments would simplify the design of Cospas-Sarsat MEOLUTs. However, having different downlink polarisations could be accommodated in MEOLUT designs without imposing substantive additional requirements.

Finally, the SAR mission is a secondary mission accommodated on satellites that are supporting a primary navigation mission. The constraints imposed by the navigation mission may guide the decision in respect of the MEOSAR downlink polarisation. For example, since the MEOSAR downlink antenna may also be used by the navigation payload, the decision on its polarisation may be dictated by the navigation payload requirements.

The preliminary design for DASS is to operate with RHCP downlinks, whereas SAR/Galileo and SAR/Glonass plan to operate LHCP downlinks.

6.4.5 Repeater Bandwidth

Ideally MEOSAR payloads should be capable of relaying the entire 406.0 – 406.1 MHz bandwidth allocated by the ITU for 406 MHz distress beacons, whilst not relaying any out-of-band signals. This would provide Cospas-Sarsat the greatest flexibility for opening 406 MHz channels and maximise MEOSAR system capacity. However, in practice MEOSAR payload bandwidth must take into account:

a. the possible interference from other Systems operating in the adjacent bands, which could be received in the 406.0 – 406.1 MHz band due to the combined effect of Doppler and inadequate transmitter filtering characteristics; and

b. the practical limitations of MEOSAR payload 406 MHz filter characteristics.

In view of the above, MEOSAR providers and Cospas-Sarsat agreed that the 406 MHz 10 dB pass-band must be less than 100 kHz, centred at 406.05 MHz, and that the 1 dB pass-band must exceed 90 kHz.

6.4.6 Repeater Receiver G/T

Analysis conducted by France (MEOSAR-1/2004/5/3) concluded that, assuming practical satellite receiver and receive antenna performance characteristics, the overall MEOSAR link budget was 5 times more susceptible to degradations in the uplink than the downlink. In view of this, the satellite receiver subsystem G/T is a critical characteristic for both MEOSAR performance and interoperability.

MEOSAR providers and Cospas-Sarsat agreed that a repeater G/T value of -17.7 dB/K or greater would enable the development of a fully interoperable MEOSAR system that satisfied the performance requirements for compatibility with Cospas-Sarsat.

6.4.7 System Dynamic Range and Automatic Gain Control (AGC) Characteristics

The repeater dynamic range and AGC characteristics determine the MEOSAR system's ability to adequately accommodate interference and varying beacon message traffic loads. MEOSAR providers agreed that the repeater instantaneous linear range (not including AGC) should meet or exceed 30 dB, and that the ratio of power from a relayed beacon to intermodulation products should be greater than 30 dB when the repeater is operating beyond its linear range.

To accommodate possible interference in the 406 MHz band all repeaters should include an AGC mode with a range of at least 30 dB. Additional study is required to identify suitable AGC attack time and decay time specifications, and to determine whether AGC attack and delay time values must be standardised for interoperability.

6.4.8 Group Delay

Repeater group delay characteristics impact upon MEOLUT time-tagging accuracy and, consequently, MEOSAR independent location accuracy performance. To ensure that minimum performance requirements are satisfied regardless of the satellite constellation relaying the beacon signal, MEOSAR providers agreed that repeater group delay should be less than 10 µS with a stability within that range of 500 nanoseconds.

6.4.9 Compatibility of Preliminary MEOSAR Payload Designs

The feasibility of operating one, two or three of the planned MEOSAR constellations with downlinks in the 1544 – 1545 MHz band cannot be assessed reliably until the characteristics of each MEOSAR payload have been established, and analysis has been conducted to determine expected MEOSAR performance and the impact each MEOSAR satellite constellation would have upon the other authorised users of the band.

Action Item 6.5: *MEOSAR providers should conduct analyses for inclusion in future revisions of this document, to refine the MEOSAR payload requirements provided at Annex F for enabling MEOLUTs to receive and process the downlink signals from multiple MEOSAR satellite constellations.*

- END OF SECTION 6 –

7. ADVANCED MEOSAR SYSTEM CAPABILITIES

MEOSAR providers are investigating the feasibility of advanced capabilities that might enhance the overall effectiveness of SAR operations. The additional capabilities being considered include:

a. a possible return link to the beacon that could be used to acknowledge reception of distress alerts, and/or control beacon transmissions; and

b. support for beacons with different transmission characteristics that could improve beacon effectiveness and reduce beacon cost.

7.1 MEOSAR Return Link

7.1.1 Return Link Functions

7.1.1.1 Acknowledgement of Detection

The EC has advised that their MEOSAR design includes a return link to 406 MHz beacons that could be used for indicating to the user that the beacon has been detected. Confirmation to the person in distress that their distress alert has been received might improve their morale, thus enhancing their chances of survival.

However, the operational implications for SAR and for the person in distress of an acknowledgment service need to be assessed through trials and testing.

The effectiveness and complexity of an acknowledgement service will be affected by its technical design and operational implementation. Some of the issues that have to be considered include:

a. the role of the Cospas-Sarsat Programme, Cospas-Sarsat MCCs, RCCs and SPOCs in respect of acknowledgement services (e.g., which organisation is responsible for initiating the process that will result in an acknowledgement transmission, should Cospas-Sarsat develop MCC standards for this function, etc.);

b. the role of the MEOSAR provider in coordinating acknowledgement transmissions and managing such services;

c. the role of Cospas-Sarsat in developing beacon specification and type approval requirements for “acknowledgement capable” 406 MHz beacons (i.e. should Cospas-Sarsat involvement be limited to ensuring no adverse impact on the 406 MHz distress alerting function, or should efforts be made to develop requirements for acknowledgement capable beacons that would make them compatible with the acknowledgement service); and

d. the benefits and drawbacks of different acknowledgement concepts (e.g. should return link transmissions be automated or manual).

7.1.1.2 Return Link Control of Beacon Transmissions

A return link to the beacon might also be used to control the transmissions of suitably designed new generation 406 MHz beacons. Examples where such a capability might be useful include:

a. activating beacons on boats and aircraft that have been reported missing;

b. turning off beacon transmissions when the SAR mission has been completed, but where it was not possible or practical to recover and turn off the beacon manually; and

c. changing the repetition rate of the beacon transmissions after the alert has been received and location established without ambiguity, with a view to saving battery power or reducing the beacon message traffic load on the satellite system.

Action Item 7.1: *Cospas-Sarsat Participants should investigate, through trials where possible, the operational benefits and drawbacks that may be associated with distress alert acknowledgement services and return link services that control beacon transmissions.*

Action Item 7.2: *Cospas-Sarsat Participants and MEOSAR providers should conduct analysis to identify suitable options for operating and managing acknowledgement services.*

Action Item 7.3: *Cospas-Sarsat Participants and MEOSAR providers should develop technical proposals for acknowledgement services (including description of the required downlink signals and 406 MHz beacon specification / type approval requirements).*

7.1.2 Forward Link Message Structure for Testing the Return Link Service (RLS)

New 406 MHz beacon signal characteristics and a new message structure are expected to be developed in the future to provide for possible enhanced performance with the MEOSAR system, including the option of full compatibility with the Galileo Return Link Service. However, the structure of operational protocols, as currently defined, does not allow the inclusion of additional bits to transmit information items related to the return link operation.

Until a new operational protocol is defined, the Test User protocol described in document C/S T.001 will be used for the RLS demonstration and validation. This protocol allows the transmission of arbitrary test beacon data (46 bits), which can be defined as required to demonstrate the RLS without disturbing the operation of the Cospas-Sarsat System. Mission Control Centres (MCCs) will not distribute alerts with the RLS Test User protocol, unless specifically requested to do so by the test authority. A future operational use of the RLS will probably require the definition of an entirely new set of protocols.

The following items are foreseen for transmission in the 406 MHz beacon forward link message to support the demonstration of the RLS during the MEOSAR D&E:

<u>Mandatory message item</u>:

- Acknowledgement/Confirmation-of-Reception Flag (ARF) – 1 bit, this flag indicates whether a return link message (RLM) has been received by the beacon (also known as the RLM-Request-Status).
  - 0 = an RLM has been received by the beacon since it was activated
  - 1 = no RLM was received by the beacon since it was activated

<u>Optional items</u>: items which might be considered for a future 406 MHz MEOSAR beacon with a message structure that would provide additional bits. These items are not essential to the basic RLS concept, but would be useful to demonstrate and experiment with various expanded uses of the RLS.

- RLM-Beacon Flag (RBF) – 1 bit, indicates that the beacon is capable of receiving Return Link Messages
  - 0 = this beacon does not receive RLMs
  - 1 = this beacon is capable of receiving RLMs
- Manual-Deactivation Flag (MDF) – 1 bit, indicates that the beacon was manually switched off (beacon switch off effective after sending one last extra message)
  - 0 = normal operation; the beacon was not switched off manually
  - 1 = beacon will switch off after transmission of this last burst as a result of manual action initiating the switch off
- Return-Link-Message-Reply (RRM) – 4 bits, a 16-element look-up table to indicate the type of hazard, etc.

The bit assignment for the first protected data field (PDF-1) of the RLS Test User protocol, shown at Figure 7.1, illustrates the structure of an RLS test message:

Figure 7.1: RLS Test User Protocol

RLM TEST USER PROTOCOL										
Bits	25	26	27 36	37 39	40 47	48	49	50	51 54	55 5
....	F	I	Country Code	I I I	Beacon ID	ARF	RBF	MDF	RRM	[TBD] Test Beacon Data (31 bits)

Note that after each change in PDF-1, the BCH code shall be updated accordingly.

The typical RLS Test User protocol has the following structure:

Bits	Usage
25	F: format flag (short message = 0, long message = 1)
26	P: protocol flag (=1)
27-36	country code
37-39	Test User protocol code (=111)
40-47	test beacon identification (8 bits)
48	ARF: acknowledgement/confirmation-of-reception flag
49	RBF: RLM-beacon flag
50	MDF: manual-deactivation flag
51-54	RRM: return-link-message-reply (4 bits, look-up table)
55-85	other [TBD] test beacon data (31 bits)

7.2 Implementation of the SAR Galileo Return Link

7.2.1 General

The SAR Galileo return link capability takes advantage of the fact that 406 MHz beacons equipped with a Galileo navigation receiver will have an in-built capability to receive the Galileo navigation signal. Therefore, short SAR messages included in the Galileo navigation signal (Galileo Signal-In-Space, SIS) can be received by the beacon. The cost of beacons with the return link capability should not be significantly higher than be cost of existing beacons without this capability which already include a GNSS receiver.

The development of operational navigation receivers for Galileo is outside the scope of the Galileo return link development. However, progress of this development will be closely monitored as the availability of Galileo receivers is a prerequisite to the availability of 406 MHz beacons with a Return link Service (RLS) capability.

Prototype beacons using the Cospas-Sarsat test protocol will be used during the SAR Galileo RLS In Orbit Validation (IOV). The IOV technical objective will be to evaluate the feasibility of the concept by validating a basic RLS function: i.e. answering a beacon Return Link Message (RLM) request with an acknowledgement indicating that the Forward Link Alert Message (FLAM) has been correctly received and processed, and that the distress location was [sent to] [received by] a SAR authority (RCC or SPOC).

Moreover, the RLS IOV should provide necessary inputs for the definition of:

- requirements for operational RLS capable beacons,
- requirements for FLAM processing in the Cospas-Sarsat Ground Segment, and

- procedures for generating a return link message request and its transmission to the Return Link Service Provider (RLSP).

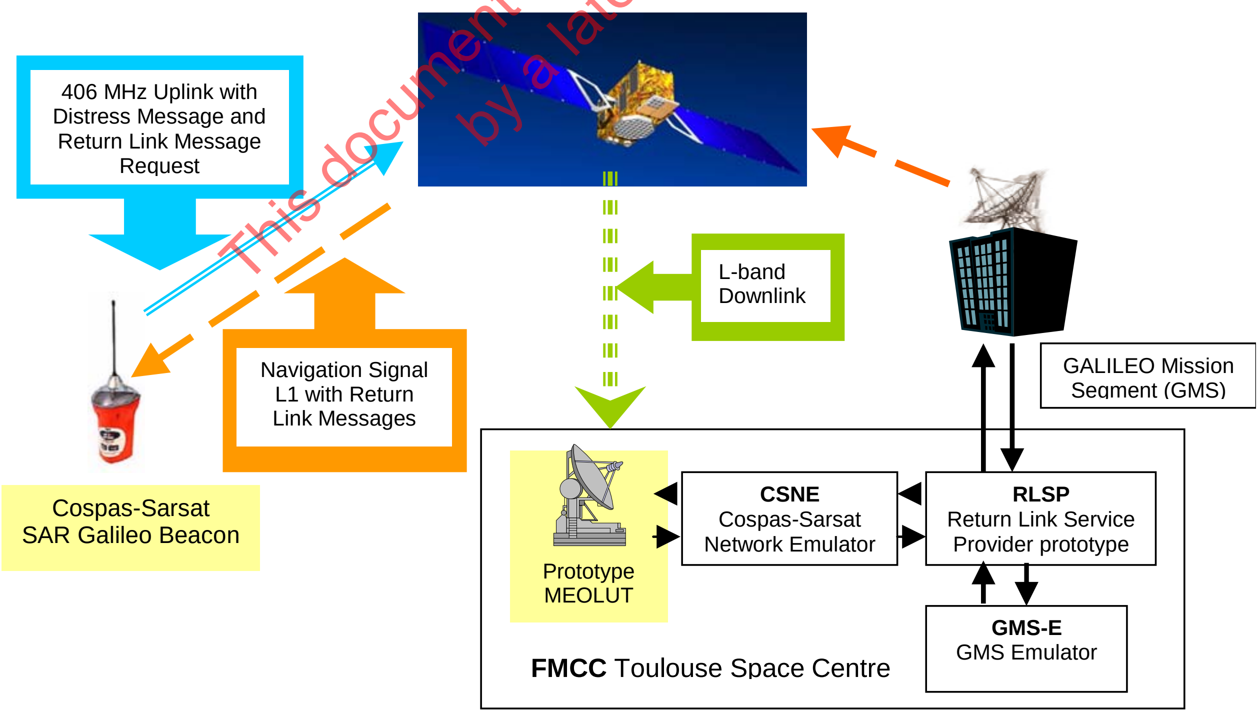
The following sections provide a description of various segments of the Galileo return link system

7.2.2 Galileo System

The space segment and Galileo Mission Segment (GMS) of the Galileo operational system under development will, using the RLSP information, provide the SAR Galileo RLS by broadcasting Return Link Messages (RLMs) to distress beacons on the Galileo navigation signal (Signal-In-Space = SIS). The format of this transmission is presented in section 7.2.7 hereafter.

RLS end-to-end demonstration, i.e. from the transmission by a beacon of a forward link alert message including a RLM request to the reception of the acknowledgment by the same beacon, will be performed with the limited operational capability of the Galileo system during the IOV phase. This will be followed by an initial operational capability (IOC) and, after the full deployment of the Galileo system, by global operation at full operational capability (FOC).

Figure 7.2: Galileo Return Link Service In Orbit Validation Concept



7.2.3 406 MHz Beacons with SAR Galileo RLS Capability

406 MHz beacons with the SAR Galileo RLS capability will meet document C/S T.001 specifications regarding the forward link message transmission. In addition, the design will include a Galileo compatible navigation receiver and a processor able to recover the Return Link Messages (RLMs) included in the Galileo navigation signal. The beacon will identify the specific RLM with its own recipient ID address and react in accordance with the planned actions (see section 7.1.1 of the MIP). Prototypes are available as test equipment for use in the SAR Galileo RLS IOV. Preparation is being made for the development of operational beacons with an RLS capability.

For the Galileo IOV, RLS capable beacons will be coded as described in section 7.1.2 of the MIP i.e. with a Cospas-Sarsat test protocol. MCC(s) participating in the RLS IOV will have the identifications on file and will be able to recognize and transmit the RLM request to the RLS Provider.

Operational beacons compatible with the Cospas-Sarsat System and meeting international requirements (i.e. ETSI, RTCM, RTCA, EUROCAE) must be available before the Return Link Service is declared at Initial Operational Capability (see section 10.4 of the MIP).

Amendments to the Cospas-Sarsat 406 MHz Beacons documentation (documents C/S T.001, C/S T.007 and C/S G.005) are required for allowing the development and type approval of operational 406 MHz beacons with the SAR Galileo RLS capability.

These actions are also to be coordinated with other possible modifications of existing requirements aiming to optimize the performance of beacons used with the MEOSAR system. Possible specification changes include the 406 MHz transmit antenna pattern and the use of new modulation techniques which, together with other possible improvements, would define a new type of uplink message (see section 7.3 of the MIP).

7.2.4 Identification of Return Link Message Requests

For the full implementation of a global SAR Galileo RLS, the Forward Link Alert Messages (FLAMs) received by any of the Cospas-Sarsat LUTs (MEO, GEO and LEO) have to be analysed and the requests for Return Link Messages (RLM requests) have to be identified and forwarded to the SAR Galileo RLSP. The definition and implementation of this task will be done taking into account the full deployment schedule of the Galileo system.

For the SAR Galileo IOV, the FMCC will forward the RLM requests to the experimental RLSP. Some of the tests will also be performed using a Cospas-Sarsat Network Emulator (CSNE) to generate the RLM request, in lieu of the FMCC.

7.2.5 Return Link Service Provider (RLSP)

The RLSP is the unique point of interface between the Galileo Mission Segment (GMS) and the Cospas-Sarsat System. Although mostly devoted to the RLS, the RLSP is in charge of providing Cospas-Sarsat MEOLUT Operators with SAR Galileo System information such as operational functionalities and monitoring status.

The development of an RLSP prototype was completed at the end of 2007 and is planned for installation at the FMCC during the first half of 2008. The objective is to validate the RLSP interfaces:

- with the GMS, by simulation and as a Galileo External Service Provider (ESP) with an operational connection to the GMS;
- with the Cospas-Sarsat System by simulation using a Cospas-Sarsat Network Emulator (CSNE).

This configuration will be maintained for the IOV of the SAR Galileo RLS. The FMCC will take part in the IOV using the GSA/ESA MEOLUT developed by the GISAR consortium. Other MCCs may participate in the RLS IOV using their LEOLUTs, GEOLUTs and experimental MEOLUTs.

7.2.6 Coding a Return Link Message (RLM) Request in the Forward Link Alert Message

To be developed

7.2.7 Return Link Messages (RLMs) in the Galileo Signal-In-Space (SIS)

The Return Link Messages to be received by SAR Galileo Beacons are included in the Galileo navigation signal in space (SIS). A description of the RLM contained in the Galileo SIS is provided in Chapter 4.3.7 "SAR Field Structure" of the "Galileo Open Service Signal In Space Interface Control Document - Draft 1 (OS SIS ICD Draft 1)" which may be accessed at the following web site:

> http://www.gsa.europa.eu/go/galileo/os-sis-icd/galileo-open-service-signal-in-space-interface-control-document

7.2.7.1 Basic RLM Structure

The RLM SAR data is defined in the Galileo Signal-in-Space Interface Control Document (SIS-ICD) as follows:

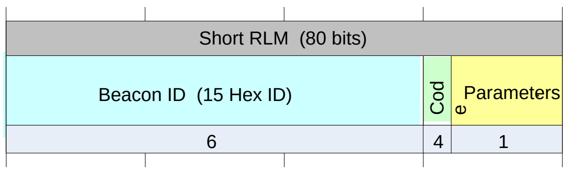
Each RLM shall contain the following data included in the Galileo SIS as defined in chapter 4.3.7 of the SIS ICD document:

- Beacon ID (60 bits): the Cospas-Sarsat 15 Hex characters identification
- Message Code (4 bits)
- Parameters (16 bits for the short RLM, 96 bits for the long RLM)

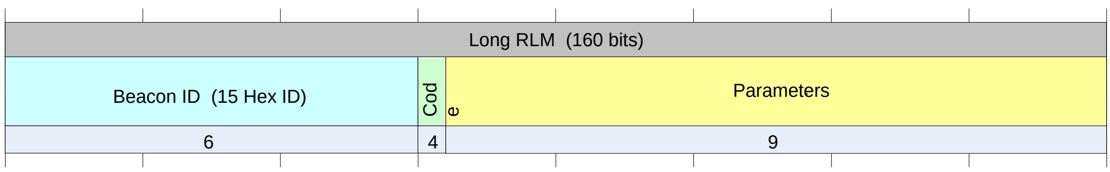
The 'Beacon ID' field is used by the beacon to decide whether it is the intended recipient of the received RLM or this RLM is addressed to some other beacon.

The 'Parameters' field contains information that SAR services wish to send to the Galileo RLS-capable beacon.

Short-RLMs are used to provide the activated beacon with a short acknowledgement or various kinds of commands (e.g. to reduce its transmission rate).



Long-RLMs are intended for more complex commands in which several parameters may be required (e.g. to provide operational information or the coordinates of a location).



RLMs are sent to Galileo RLS-capable beacons (or other dedicated receivers) using the Galileo Open Service. Short RLMs could be primarily associated with automatically generated acknowledgements, while long RLMs might be used for RCC-generated messages relating to operational aspects of the rescue.

7.2.7.2 Definition of the Data Fields

a) 60-bit Beacon ID

This field content is identical to the 60 bit (15 Hexadecimal characters) of the standard beacon identification defined in the C/S T.001 document. It uniquely identifies the beacon to which the RLM is addressed.

The Beacon ID field consists of:
- Protocol Flag (1 bit): 1= User Protocols; 0 = other protocols.
- Country Code (10 bits)
- Beacon Identification (49 bits), as specified in C/S T.001 Annex A, with default bits for National or Standard location protocol beacons.

b) 4-bit Message Code

Two classes of RLMs have been identified:

i. the standard message type, where the first 60 bits are used per the C/S T.001 definition of the beacon identification; and

ii. an alternative message type, where only the 4 message code bits are defined as well as the last (parity) bit, while all the other bits are open for later determination (this may even allow chaining messages into mega-messages, should this ever be needed).

A possible alternative message is foreseen for broadcasting to a specific geographical area or region, not to any specific beacon.

c) RLM Parameters

The detailed definition of the RLM parameters is still open. The last bit of this field, i.e. bit 16 in the short-RLM and bit 96 in the long-RLM, is reserved for a final parity check. The available capacity (15 unassigned bits on the short-RLM; 95 unassigned bits on the long-RLM) can be used for a variety of applications.

Even though the navigation data is broadcast with a very robust link margin, the RLM is assembled after a long segmented reception period, in four segments over 8 seconds for short-RLMs or eight segments over 16 seconds for long-RLMs. Furthermore, the environmental conditions of the reception are potentially very difficult and changing in time. Therefore, a final post-assembly check of the RLM validity using the last parity bit is required.

7.2.7.3 IOV Messages

At this stage of development, for the IOV, only the standard type of the short or long RLM is required for providing an automatic acknowledgement. The short/long message information is included in the SIS format (see the SIS.ICD, Chapter 4.3.7 Table 53). The four bits of the message code define the type of message:

- message code 0000: automatic acknowledgment without significant parameters (15 or 95 bits);
- message code 0001: automatic acknowledgment with significant parameters (15 or 95 bits)

7.3 Improved 406 MHz Beacon Signals

The Cospas-Sarsat 406 MHz beacon specification was originally developed to optimise the detection and Doppler location performance of the LEOSAR system. Because the MEOSAR system will employ different location determination techniques, it might be possible to improve MEOSAR performance by changing the 406 MHz beacon transmission characteristics.

Preliminary studies conducted by France and the USA indicate that changes to the 406 MHz channel coding (e.g. coding for error detection and correction) for improving the processing gain are possible. Improved processing gain would reduce the overall bit error rate, thereby increasing the probability of decoding the beacon message. Another option being considered is possible changes to the content of beacon messages that would enhance MEOSAR system effectiveness, and/or simplify beacon coding requirements.

With respect to possible new 406 MHz beacon modulation waveforms, the Sarsat SARP-3 instruments developed by France will support an additional modulation format called mixed QPSK, also known as MQPSK. The efficient channel coding associated with MQPSK will improve the beacon – satellite – LUT link margin by several dB. Such an improvement might be particularly beneficial for a MEOSAR system, where the greater satellite to ground distances result in a poorer link margin than that provided by LEOSAR systems.

Any new beacon specifications, or changes to existing specifications should be:

a. approved by the Cospas-Sarsat Council and coordinated with international organisations as appropriate;

b. as spectrum efficient as current 406 MHz beacons;

c. supported by extensive analysis and testing; and

d. accompanied with the necessary type approval requirements.

Action Item 7.4: *Cospas-Sarsat and MEOSAR providers should conduct analyses to identify improvements to the 406 MHz beacon specification for the MEOSAR system. The following points should be specifically addressed:*

a. changes in the channel coding (e.g. convolutional coding);

b. the impact that new beacon specifications would have on System capacity;

c. new modulation techniques to improve TDOA/FDOA performance;

d. improvements to the message format;

e. additional encoded data requested by SAR authorities;

f. general optimisation of beacon parameters;

g. technologies that could reduce the cost of the beacon; and

h. the suitability of the MQPSK modulation for the MEOSAR TDOA time-tagging requirement.

- END OF SECTION 7 -

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8. MEOSAR GROUND SEGMENT

The three MEOSAR programmes each will provide a satellite constellation that will support global coverage, and include the development of prototype MEOLUTs for use in the proof of concept (POC) and demonstration and evaluation (D&E) phases. However, none of the programmes will provide all the MEOLUTs necessary for global coverage. Instead, the provision of MEOLUTs will be a national responsibility, and the programmatic requirements and responsibilities for providing and operating MEOLUTs will have to be formulated during the development and proof of concept phases of the MEOSAR programmes.

8.1 MEOSAR Ground Segment Concept and Architecture

The MEOSAR ground segment will be comprised of Cospas-Sarsat MEOLUTs, the existing Cospas-Sarsat MCC network, and possibly ground control stations for implementing return link functions. The principal function of the MEOLUT is to receive and process satellite downlinks, calculate 406 MHz beacon locations, and forward this information to the MCC associated with the MEOLUT. The MCC network will perform the same basic functions for MEOSAR alerts as they currently provide for LEOSAR and GEOSAR alerts (e.g. distribute alerts to other MCCs or SAR points of contact as per the Cospas-Sarsat Data Distribution Plan, validate alert data, filter-out redundant data, etc.).

Unlike LEOLUTs which track a single satellite at a time and derive Doppler location information from a single satellite pass, a MEOSAR system requires multiple simultaneous time and frequency measurements to calculate beacon locations to the required accuracy. MEOSAR location accuracy is also affected by the beacon / satellite geometry. As a consequence, the probability of providing independent location information and the accuracy of the location data would decrease when the distance of a beacon to the MEOLUT increases. Specifically, ambiguity resolution could become problematic at the edge of a MEOLUT coverage area. Two approaches can be used to mitigate these potential problems:

- design MEOLUTs that can track as many satellites as possible, i.e. satellites from all available constellations; and/or

- design MEOLUTs that operate as a network, i.e. MEOLUTs that can exchange beacon burst time and frequency measurements with adjacent MEOLUTs.

The terminology applicable to the various MEOSAR ground segment concepts and possible architectures is provided at Annex A to this document.

8.1.1 Stand Alone MEOLUTs

MEOLUTs with the capability of simultaneously receiving and processing the downlinks of multiple MEOSAR satellites will provide a stand-alone beacon location capability that extends to a radius of around 6,000 to 7,000 kilometres centred on the LUT. The number of stand alone MEOLUTs that would be required to achieve complete coverage depends on a number of factors such as:

- the number of operational satellites available in orbit;
- MEOSAR system performance requirements;
- operational requirements in terms of redundancy; and
- the actual geographical location of the MEOLUTs.

Studies show that a minimum of six MEOLUTs suitably situated around the world would provide for global MEOSAR coverage.

8.1.2 Networked MEOLUTs

The basic advantages of a network of MEOLUTs include:

- increased coverage due to geographically dispersed MEOLUTs sharing data in order to increase the input to location processing algorithms;
- increased fault tolerance and backup capability; and
- reducing or eliminating regions with reduced location accuracy, as the computed location accuracy decreases when distance to the MEOLUT increases.

MEOLUT networking is expected to be essential during the pre-operational phase of the MEOSAR system, when the limited number of satellites will directly impact the capability of MEOLUTs to locate beacons. With complete MEOSAR constellations in a fully operational MEOSAR system, MEOLUT networking would still be beneficial. A network of MEOLUTs would augment the coverage of individual MEOLUTs, providing for the location of beacons at the fringe of the coverage area.

The networking requirements will probably be different in a pre-operational system, where all data should be made available to all MEOLUTs, and in an operational MEOSAR system where MEOLUTs would request burst data as necessary to perform the location of a particular beacon.

However, a number of issues need to be addressed before implementing MEOLUT networks on an operational basis, including:

- programmatic issues concerning IT security; and
- operational and technical issues related to the provision of reliable communications and increased requirements for measurement calibrations.

8.1.3 Optimum Ground Segment Architecture

Further studies are needed to determine an optimum MEOSAR Ground Segment architecture that would ensure the required performance in terms of availability and location accuracy. The optimum architecture will depend on a number of factors concerning space and ground segment design that have not yet been finalised, including:

- the feasibility of MEOLUTs simultaneously tracking the satellites of multiple MEOSAR constellations; and
- the feasibility of MEOLUTs sharing measurement data in real or near real-time.

Assuming the feasibility of MEOLUT networks, and noting that it would be difficult to define an architecture and data exchange formats applicable to both the pre-operational and the operational phases of the MEOSAR system, the following principles and standards should be used in the development of MEOLUT networks:

a) the approach used in the earlier phases of the system should remain flexible to allow for the evolution towards an operational status and should not limit system capabilities or preclude future enhancements;

b) the networking architecture should use the hybrid concept illustrated at Annex L, to include distributed data servers networked in accordance with any one of the two options depicted at Annex L;

c) the local implementation of MEOSAR data servers should remain the prerogative of the MEOLUT operator, taking into account local infrastructures and practices, particularly with regard to IT security constraints;

d) burst data should be stored on the data servers in the format specified at Annex L and the exchange of burst data should be made using the message definitions and data contents provided at Annex M.

8.1.4 International Networks

Sharing MEOLUT measurements internationally would raise several policy, management, technical, and operational issues requiring further study.

At present, each Cospas-Sarsat administration is responsible for the operation and performance of its own ground segment equipment. If raw and / or semi-processed MEOLUT data were shared internationally, then the performance of MEOLUTs would be affected by the performance of equipment operated by other administrations. In view of this, further analysis is required in respect of:

- the suitability and implications of networking MEOLUTs internationally;

- procedures for sharing data internationally; and
- specifications and commissioning requirements for sharing MEOLUT data.

8.2 MEOLUT Requirements

The main role of a MEOLUT is to track MEOSAR satellite(s), measure the time and frequency of beacon bursts relayed by MEOSAR satellites, possibly interface with other MEOLUTs to obtain additional beacon burst time and frequency measurements, calculate the location of 406 MHz beacons, and provide distress alert messages from active 406 MHz beacons to the MEOLUT's associated MCC.

8.2.1 Satellite Tracking

It is desirable that MEOLUTs be capable of simultaneously tracking and processing the downlinks from all satellites in a given MEOSAR constellation that are in the MEOLUT's field of view. This would minimise its reliance on other MEOLUTs for providing beacon burst time and frequency measurements, and provide options in selecting satellites with the best geometry to the beacon for location processing. Depending on MEOSAR downlink design options, it is likely that MEOLUT cost and complexity will increase as a function of the number of satellites they are capable of tracking and processing simultaneously.

Analysis should be carried-out to determine an appropriate MEOLUT requirement in respect of the number of satellites that MEOLUTs should be capable of simultaneously tracking, taking into account MEOLUT costs, complexity, and performance.

8.2.2 Tracking Satellites from Different MEOSAR Constellations

Separate studies conducted by the USA and ESA (EWG-2/2003/4/4 and EWG-2/2003/4/13-Rev.1 respectively) clearly show that there are benefits to providing MEOLUTs that are capable of receiving and processing the downlinks of MEOSAR satellites from different constellations. These benefits include:

a. improved MEOSAR system redundancy;

b. the possibility of reducing the time required to deploy a MEOSAR space segment that provides permanent global coverage;

c. an improvement to the location accuracy on the first beacon burst from over 6 km 95% of the time in the case of a single constellation, to about 4 km 95% of the time when MEOLUTs have access to two complete MEOSAR satellite constellations; and

d. an increase in MEOLUT local coverage area from a 6,000 km radius for SAR/Galileo system alone to approximately 7,000 km for combined DASS – SAR/Galileo constellations.

The feasibility of implementing a MEOSAR system comprised of fully interoperable satellite constellations is dependant upon the decisions taken by MEOSAR providers for the downlinks of their respective systems. The degree of interoperability achieved between the three MEOSAR constellations will also impact MEOLUT cost and complexity.

8.2.3 MEOLUT RF Chain

As discussed at section 5.3.3, MEOSAR independent location accuracy performance is dependent upon the accuracy of the measurements of beacon burst time and frequency by the MEOLUT, which in turn are affected by the beacon carrier to noise density ratio available at the MEOLUT processor. Further analysis is needed to identify MEOLUT antenna and receiver requirements necessary to achieve the desired MEOSAR system performance.

8.2.4 Suppressing Redundant Information

MEOLUTs will be capable of calculating beacon location information from a single beacon burst that has been relayed by multiple MEOSAR satellites. Therefore, in view of the coverage available from a MEOSAR system, it is possible that MEOLUTs might produce new beacon location information every time a beacon transmits a burst, resulting in over 70 solutions per beacon per hour. Because of the large number of solutions that will be available for each active beacon, procedures will be required for determining which solutions should be forwarded to the MCC, and which solutions should be suppressed at the MEOLUT.

It may be feasible to send every alert message to the MCC, in which case it would be an MCC function to determine whether specific alert messages should be distributed further. Conversely, if it is possible to establish criteria for estimating the accuracy of specific solutions at the MEOLUT, it might be preferable to incorporate features in the MEOLUT to suppress redundant solutions.

8.2.5 Beacon Message Processing

The LEOLUT and GEOLUT specifications (C/S T.002 and C/S T.009) include requirements for validating and confirming the content of beacon messages. The validation and confirmation procedures have been developed to provide confidence that beacon message information provided by LUTs is reliable. Although the LEOLUT and GEOLUT procedures differ, they are both based on receiving beacon information from a single satellite. Since MEOLUT processing is based on obtaining beacon information from multiple satellites, a different validation and confirmation process might be required.

In a MEOLUT network, only burst data corresponding to valid beacon messages should be placed on the MEOSAR data servers for exchange among MEOLUTs.

8.2.6 Burst Time and Frequency Measurement Data

The accuracy of location data computed by a MEOLUT is dependent upon the accuracy of the time and frequency measurements performed for each MEOSAR beacon event (see the definition of a MEOSAR Beacon Event at Annex A). A uniform convention should be used by all MEOLUTs for burst time and frequency measurements. In particular, burst frequency data should be provided with reference to the same burst time defined in accordance with the agreed burst timing convention.

Burst data formats and contents to be made available to networked MEOLUTs are defined at Annex L and M to this document. Networked MEOLUTs should be capable of exchanging these data on request via MEO data servers as described at Annex L, using the SIT message formats described at Annex M to this document.

8.2.7 Interferer Processing

As described at section 5, studies conducted by the USA indicate that a MEOSAR system should be able to locate 406 MHz interferers. However, additional study is required to identify specific MEOLUT interferer location determination techniques most suitable to the transmission characteristics of the interference signal.

8.2.8 Data Channels

MEOLUTs should be capable of receiving and processing the entire bandwidth of the MEOSAR satellite downlinks.

Action Item 8.1: *Cospas-Sarsat and MEOSAR providers should conduct analysis on the feasibility of developing MEOLUTs and identifying the associated LUT technical characteristics necessary for simultaneously receiving and processing the downlinks from:*

a. multiple MEOSAR satellites from the same MEOSAR constellation; and

b. multiple MEOSAR satellites from different MEOSAR constellations.

Action Item 8.2: *Cospas-Sarsat and MEOSAR providers should conduct analysis and propose options for a MEOLUT ground segment architecture. The analysis should specifically address advantages and disadvantages of networking MEOLUTs, propose options for sharing MEOLUT beacon burst data measurements with other MEOLUTs, and* *identify specification and commissioning requirements for the MEOLUT data sharing function.*

Action Item 8.3: *Cospas-Sarsat and MEOSAR providers should conduct analysis and propose MEOLUT functional, technical and commissioning requirements, that ensure that MEOLUTs will be capable of providing a service that satisfies the performance requirements identified at section 5.*

- END OF SECTION 8 -

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9. MEOSAR SYSTEM CALIBRATION

To perform reliable TDOA / FDOA measurements and location processing, MEOLUTs require reliable and timely calibration data. The calibration information needed, and the update frequency, is affected by many factors including:

a. variations in MEOSAR payload technical characteristics from satellite to satellite;

b. the rate of change of payload characteristics over long, medium and short time periods;

c. the ground segment architecture (e.g. standalone MEOLUTs or MEOLUTs which share time and frequency measurements); and

d. bias errors introduced at the MEOLUT.

There are a number of options that might be suitable for obtaining calibration information, including:

- specialised processing of periodic transmissions from reference beacons;
- data from onboard satellite telemetry; and
- tests performed locally at individual MEOLUTs which might not necessarily involve the processing of signals relayed by MEOSAR satellites.

9.1 Satellite Payload Calibration

TBD

9.2 Signal Path Delay

TBD

9.3 MEOLUT Time Measurement Calibration

TBD

9.4 MEOLUT Frequency Measurement Calibration

TBD

Action Item 9.1: *MEOSAR providers should conduct studies and trials to identify:*

a. *what calibration information will be required to support Cospas-Sarsat performance requirements;*

b. *the required update frequency of calibration information; and*

c. *the most appropriate methods for obtaining and distributing calibration information.*

-END OF SECTION 9-

10. PROCEDURES FOR MEOSAR INTRODUCTION INTO COSPAS-SARSAT

Prior to distributing distress alert data from LEOSAR and GEOSAR systems to SAR services, extensive demonstration and evaluation (D&E) programmes were conducted by Cospas-Sarsat. Specifically the LEOSAR D&E Report was approved by the Cospas-Sarsat Coordinating Group (CSCG) in 1984 before declaring the LEOSAR system operational. Similarly the Cospas-Sarsat Council at its 21st Session in October 1998 adopted the GEOSAR D&E Report before incorporating GEOSAR elements into the Cospas-Sarsat System. In accordance with the same principles that were followed for the LEOSAR and GEOSAR systems, a MEOSAR system will have to undergo an extensive test and evaluation period to validate its performance prior to its data being used operationally.

The MEOSAR system should be implemented in several phases to clearly delineate development and implementation activities. The various activities can be summarised in the five phases described below. The time estimates for the various stages are not definitive and can overlap to show that some activities will occur concurrently. For example, it may be possible to start using operational data prior to having all satellites in orbit operating in their final configuration. In most cases, activities in each stage will have to be successfully completed before substantial work can be initiated in the following stage.

10.1 Definition and Development Phase

During this phase MEOSAR providers and Cospas-Sarsat focus on identifying MEOSAR system functional and performance requirements, as well as matters relating to MEOSAR / Cospas-Sarsat compatibility. MEOSAR providers also refine the high-level functional and performance requirements into more detailed technical specifications suitable for building MEOSAR space segment and prototype ground segment equipment.

Work should also start in developing Cospas-Sarsat specification and commissioning requirements for all MEOSAR components, although these specifications and commissioning standards will continue to be enhanced during subsequent programme phases and will not be finalised until the D&E results have been analysed.

The coordination of MEOSAR performance requirements and system characteristics required to ensure the compatibility and interoperability is conducted under the ICSPA during the definition and development phase.

MEOSAR satellites in orbit with SAR capability are not required during this phase. However, after completion of the requirements analysis and design, MEOSAR providers should develop prototype ground stations to be used during the proof-of-concept, and the demonstration and evaluation phases. Cospas-Sarsat Participants should be kept informed of the development efforts undertaken by the MEOSAR providers, and system specifications should be shared with interested Participants, as appropriate.

Ground Segment operators, other than MEOSAR providers, could be invited to participate in the development of the MEOSAR ground segment. However, Ground Segment operators and User States are not required to participate during this phase. More importantly, the development of the MEOSAR system should not detract Cospas-Sarsat Participants from upgrading their existing LEOSAR and GEOSAR ground segment equipment as these systems will continue to be the primary distress alerting source for the foreseeable future.

10.2 Proof of Concept / In-orbit Validation Phase

The proof-of-concept (POC) / in-orbit validation phase, hereafter referred to only as the proof-of-concept phase, of MEOSAR programmes will assess the basic capabilities of the MEOSAR system and establish preliminary performance levels that will be used to focus the scope and content of the MEOSAR D&E phase. This is the first test stage.

The proof-of-concept phase will focus on confirming the capabilities of the MEOSAR space and ground segments. Proof-of-concept testing will include as a minimum:

a. confirmation of the ability to reliably receive and process emergency beacon signals (i.e., confirm the performance of the link from the beacon to the satellite and the ground station);

b. an evaluation of location processing algorithms;

c. an assessment of the performance of detection and location processing with degraded system components (e.g., less than four satellites in view, malfunctioning beacons, etc.); and

d. the confirmation of the ground segment architecture (e.g., tracking satellites with receive only phased-array antennas).

During the POC phase, MEOSAR providers continue co-coordinating with Cospas-Sarsat on compatibility and interoperability issues under the auspices of the ICSPA. While DASS and SAR/GLONASS can be viewed as “enhancements” to the existing LEOSAR and GEOSAR systems, a specific arrangement should be established with the SAR/Galileo management organisation to formalise the relationship with the Cospas-Sarsat Programme.

The number of satellites required to conduct the proof-of-concept will depend on the orbital planes of the available MEOSAR satellites. At least three to four satellites will need to be in view of the ground station and the beacon to confirm the detection and location processing performance.

The primary ground stations to be used during the proof-of-concept phase will be the prototype stations developed during the previous phase. A global ground segment is not envisioned during this phase. However, if other Cospas-Sarsat Participants have established MEOSAR ground segment equipment, they should be invited to participate in the proof-of-concept trials. There will be no distribution of operational distress alert data to SAR services during the proof-of-concept phase.

Successful completion of the proof-of-concept phase will initiate the transition to the demonstration and evaluation phase.

10.3 Demonstration and Evaluation Phase (D&E)

The demonstration and evaluation phase will focus on characterising the technical and operational performance of the MEOSAR system, evaluating the operational effectiveness and the benefits to SAR services, and providing a basis for a Cospas-Sarsat Council decision on the use of the MEOSAR system operationally. This assessment of MEOSAR system performance is required for national and international organizations (e.g., ICAO and IMO which mandate the use of beacons and accept distress alerting systems, ITU which regulates the use of the frequency bands, and Cospas-Sarsat Participants that provide and use the new alerting system) to accept the MEOSAR system as an alerting source.

Typical demonstration and evaluation periods in Cospas-Sarsat span a number of years. A thorough evaluation is particularly important as the MEOSAR system could significantly alter the Cospas-Sarsat System architecture in the long term. Therefore, although the demonstration and evaluation period for the GEOSAR systems was limited to two years (the MSG system is also expected to undergo a demonstration and evaluation period of two years), the importance of the MEOSAR D&E, combined with the development of new specifications and System documentation, might require extending the D&E period to more than two years.

Sufficient MEOSAR capability in terms of space and ground segment will be required to adequately characterise the system and confirm its benefits. During this phase all minimum MEOSAR performance parameters required for compatibility with Cospas-Sarsat, with the possible exception of global coverage, will be evaluated. Operational data should be provided to the Cospas-Sarsat network for analysis, however, data should not be transmitted to SAR services until the Council decides that the MEOSAR system has reached its initial operational capability (IOC). In light of the different characteristics of each MEOSAR constellation, a specific D&E plan may have to be developed for each. The plan should provide guidelines for conducting the demonstration and evaluation in a standard manner, collecting a set of results on an agreed basis, and establishing a process for translating the results into a set of recommendations.

MEOSAR technical performance parameters to be evaluated include, but are not limited to:

- detection probability including processing threshold and system margin;

- message transfer time between activation of the beacon and availability of the first valid message;
- capacity of the system;
- impact of interference on detection probability;
- location accuracy and location error prediction;
- reliability/sensitivity (i.e. BER);
- availability of system;
- coverage provided by ground stations that are not networked; and
- system anomalies.

In addition, if MEOLUTs are designed to operate in a network, the performance enhancement provided by the exchange of MEOLUT data, and possible drawbacks, should be assessed. Furthermore, if as planned, MEOLUTs are capable of processing satellites from several constellations, a specific evaluation of the performance achieved with the combined processing capability should also be performed.

Operational performance parameters to be evaluated include, but are not limited to:

- location accuracy of operational beacons;
- potential time advantage of MEOSAR system over the existing System;
- degree to which the MEOSAR system complements the existing System;
- volume of distress alert traffic in the Cospas-Sarsat Ground Segment and impact on communication networks; and
- direct and indirect benefits of the MEOSAR system.

In addition to technical and operational testing, Cospas-Sarsat will have to develop distribution procedures for MEOSAR distress alert data, and specifications and commissioning requirements for MEOLUTs. Therefore, all Cospas-Sarsat Participants should be invited to participate in the D&E. The detailed description of the technical and operational testing to be performed during the D&E and the procedure applicable for the distribution of alert data and the collection of test data will be provided in a MEOSAR D&E Plan to be approved by the Cospas-Sarsat Council. Successful completion of demonstration and evaluation activities should form the basis for a Council decision on the operational use of the MEOSAR system.

A minimum of six MEOSAR satellites is required to start the demonstration and evaluation. Although initial technical characterizations can be completed without a full constellation, 12 to 24 satellites will be required to characterize the operational performance (the exact number to be determined during proof-of-concept).

International activities during this phase continue to fall under the ICSPA. However, the Cospas-Sarsat Parties should begin an evaluation of the ICSPA to address long term issues associated with the integration of the MEOSAR system.

Cospas-Sarsat Participants should be encouraged, as possible, to implement MEOLUTs to participate in the demonstration and evaluation. Additional ground stations will be required for the MEOSAR system to reach Full Operational Capability.

The primary ground stations to be used during the demonstration and evaluation phase will be the prototype ground stations developed by the MEOSAR providers. Distress alert data from these MEOLUTs should be transmitted to the associated Cospas-Sarsat MCC where it will be collected and made available for analysis. Data should also be exchanged among Cospas-Sarsat Participants for their evaluation. However, MEOSAR alert data should not normally be transmitted to SAR services unless special arrangements are made. In order for data to be exchanged among Cospas-Sarsat Participants, changes may be required to the existing Cospas-Sarsat Data Distribution Plan and the Standard Interface Description documents. Other Cospas-Sarsat documentation will also have to be reviewed and updated, as necessary.

To terminate the D&E phase the Cospas-Sarsat Council will have to adopt a D&E Report that provides official results of the evaluation, including the MEOSAR system performance data.

10.4 Initial Operational Capability (IOC)

Initial operational capability is a declaration by MEOSAR satellite providers and Cospas-Sarsat that, prior to full deployment, alert data from the MEOSAR system can be used operationally. The MEOSAR system need not necessarily provide global coverage during the IOC phase. This could be due to an incomplete satellite constellation or an incomplete ground segment. However, MEOSAR distress alert data will have already been proven to be reliable, and, therefore, should be provided to SAR services for their use.

To declare the MEOSAR system (or a combination of MEOSAR constellations) at IOC, the Cospas-Sarsat Council should:

a. approve the specification and commissioning requirements for MEOSAR space and ground segments;

b. declare the MEOSAR space segment and at least one MEOLUT as commissioned;

c. make a formal decision concerning whether alert data from the MEOSAR system can be distributed to SAR services and inform the appropriate international bodies of its decision; and

d. amend the Cospas-Sarsat documentation as appropriate and undertake action to also reflect the transition to IOC in national and international organisations' documentation as required.

The number of satellites required to operate in IOC will be determined during the demonstration and evaluation phase. However, it is expected that a minimum of [TBD] satellites will be needed.

Although all Cospas-Sarsat activities would continue to fall under the ICSPA, the Cospas-Sarsat Parties should begin the development of a follow-on international agreement, as necessary.

All Cospas-Sarsat Participants should be involved during the IOC phase and encouraged to implement MEOLUTs as required to complete the MEOSAR system global coverage.

10.5 Full Operational Capability (FOC)

Full operational capability is a declaration by Cospas-Sarsat that the MEOSAR system should be considered fully operational. At FOC the MEOSAR system should satisfy all requirements defined by Cospas-Sarsat. This implies that sufficient space and ground segment components have been commissioned in accordance with Cospas-Sarsat requirements.

Before the MEOSAR system is declared at FOC the appropriate programmatic commitments must be in place. Specifically, agreements must have been completed which commit MEOSAR space segment providers to the long-term provision of MEOSAR space segment capabilities.

The number of satellites required to reach FOC is the minimum number of satellites that provide the required level of performance (e.g. availability). In addition, a ground segment that provides global coverage is necessary (this could be four to six strategically located ground stations).

It should be noted that at FOC the MEOSAR system should provide near-instantaneous alerting and locating services for existing 406 MHz beacons, therefore, it could be assumed that the MEOSAR system could become the primary alerting source for 406 MHz beacons.

10.6 MEOSAR Implementation Schedule

Each MEOSAR constellation will be implemented in accordance with the plans developed by the respective MEOSAR space segment provider. The tentative schedules for the DASS, SAR/Galileo and SAR/Glonass components, and the overall definition, POC, D&E, IOC and FOC phases are provided at Annex I.

Action Item 10.1: *Cospas-Sarsat and MEOSAR providers should develop proposals for the content and implementation of MEOSAR Demonstration and Evaluation Programmes.*

Action Item 10.2: *Cospas-Sarsat and MEOSAR providers should develop proposals in respect of MEOSAR system requirements necessary for progressing to IOC.*

Action Item 10.3: *MEOSAR providers should update the implementation schedules for their MEOSAR constellations.*

- END OF SECTION 10 -

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ANNEXES TO COSPAS-SARSAT 406 MHz MEOSAR IMPLEMENTATION PLAN

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ANNEX A

LIST OF ABBREVIATIONS, ACRONYMS AND DEFINITIONS

A.1 ABBREVIATIONS AND ACRONYMS

C/No	Carrier to noise density ratio
C/S R.0##	Cospas-Sarsat System document in the R (Reports / Plans) series
C/S T.0##	Cospas-Sarsat System document in the T (technical) series
CSCG	Cospas-Sarsat Coordinating Group (superseded by the Cospas-Sarsat Council)
D&E	Demonstration and Evaluation test
DASS	Distress Alerting Satellite System
EC	European Commission
EIRP	Effective Isotropically Radiated Power
ESA	European Space Agency.
EWG	Cospas-Sarsat Experts Working Group
FDOA	Frequency Difference Of Arrival
FLAM	Forward Link Alert Message
FOA	Burst frequency measured at the time of arrival (TOA)
FOC	Full Operational Capability
Galileo	A global navigation satellite system being developed by ESA and the EC
GJU	GALILEO Joint Undertaking
GEOSAR	Geostationary Satellite System for Search and Rescue
Glonass	A global navigation satellite system provided and operated by Russia
GMS	Galileo Mission Segment
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite operated by the USA
GPS	Global Positioning System (global navigation satellite system operated by the USA)
ICSPA	International Cospas-Sarsat Programme Agreement
IOC	Initial Operational Capability
IOV	In-Orbit Validation
ITU	International Telecommunication Union
JC	Joint Committee
kHz	kilohertz
LEOSAR	Low-altitude Earth Orbiting satellite System for Search and Rescue
LHCP	Left Hand Circular Polarisation
LUT	Local Users Terminal (ground station in the Cospas-Sarsat System for tracking and processing the downlink of search and rescue satellites)

MCC	Mission Control Centre (control centre in the Cospas-Sarsat System for distributing Cospas-Sarsat SAR distress alert messages)
MEOLUT	LUT in the MEOSAR system
MEOSAR	Medium-altitude Earth Orbiting satellite System for Search and Rescue
MHz	Megahertz
MIP	MEOSAR Implementation Plan
MQPSK	Mixed Quaternary Phase-Shift Keying
MSG	Meteosat Second Generation Satellite
MSS	Mobile Satellite Service
POC	Proof Of Concept
QPSK	Quaternary Phase-Shift Keying
RCC	Rescue Coordination Centre
RHCP	Right Hand Circular Polarisation
RLM	Return Link Message
RLS	Return Link Service
RLSP	Return Link Service Provider
SAR/Galileo	Search and Rescue distress alerting service supported by the Galileo satellite System
SAR/Glonass	Search and Rescue distress alerting service supported by the Glonass satellite System
SAR	Search and Rescue
SARP	Search and Rescue Processor
SARR	Search and Rescue Repeater
SIS	Signal In Space: navigation signal broadcast by Galileo satellites
SPFD	Spectral Power Flux Density
SPOC	SAR Point Of Contact
STB	Set of Transponded Bursts
TDOA	Time Difference Of Arrival
TG	Task Group
TOA	Time Of Arrival (Beacon burst time of arrival at the MEOSAR satellite)
TT&C	Telemetry, Tracking and Control
XML	Extensible Markup Language

A.2 DEFINITIONS

The following standard terminology should be used for the description of the MEOSAR Ground Segment

MEOLUT

Antennas, hardware and software required to track global navigation satellite system (GNSS) satellites, process and generate locations for 406 MHz distress beacons and distribute resultant alerts to a Mission Control Center (MCC).

Dependent MEOLUT

MEOLUT with one or more antennas, which may or may not be co-located, that must rely on data from another MEOLUT in order to generate distress alerts.

Networked MEOLUT

MEOLUT with multiple antennas, which may or may not be co-located, that can use processed beacon messages from another MEOLUT to generate distress alerts, and distribute processed beacon messages to another MEOLUT, as required.

Stand-Alone MEOLUT.

MEOLUT with multiple antennas, which may or may not be co-located, that does not rely on any other MEOLUT or antenna(s) to generate distress alerts.

MEOSAR Solution

An unambiguous location generated by a MEOLUT from one or more MEOSAR beacon events.

Remote Antenna(s)

Antenna(s) that track global navigation satellite system (GNSS) satellites and recover beacon messages, but do not generate locations for 406 MHz distress beacons. Remote antennas can be used to enhance the capability of a MEOLUT, or can provide additional data to a MEOLUT with insufficient standalone capability. Remote antennas have the same capabilities as collocated antennas, but are geographically separated by a significant distance from the MEOLUT processor.

Beacon Burst

A specific transmission from a beacon compliant with C/S T.001.

A beacon burst can be either short or long and is repeated periodically. The digital message transmitted by the beacon can vary between consecutive beacon bursts, e.g. if the encapsulated beacon location changes. The repetition period is much longer than the burst duration for both short and long beacon bursts.

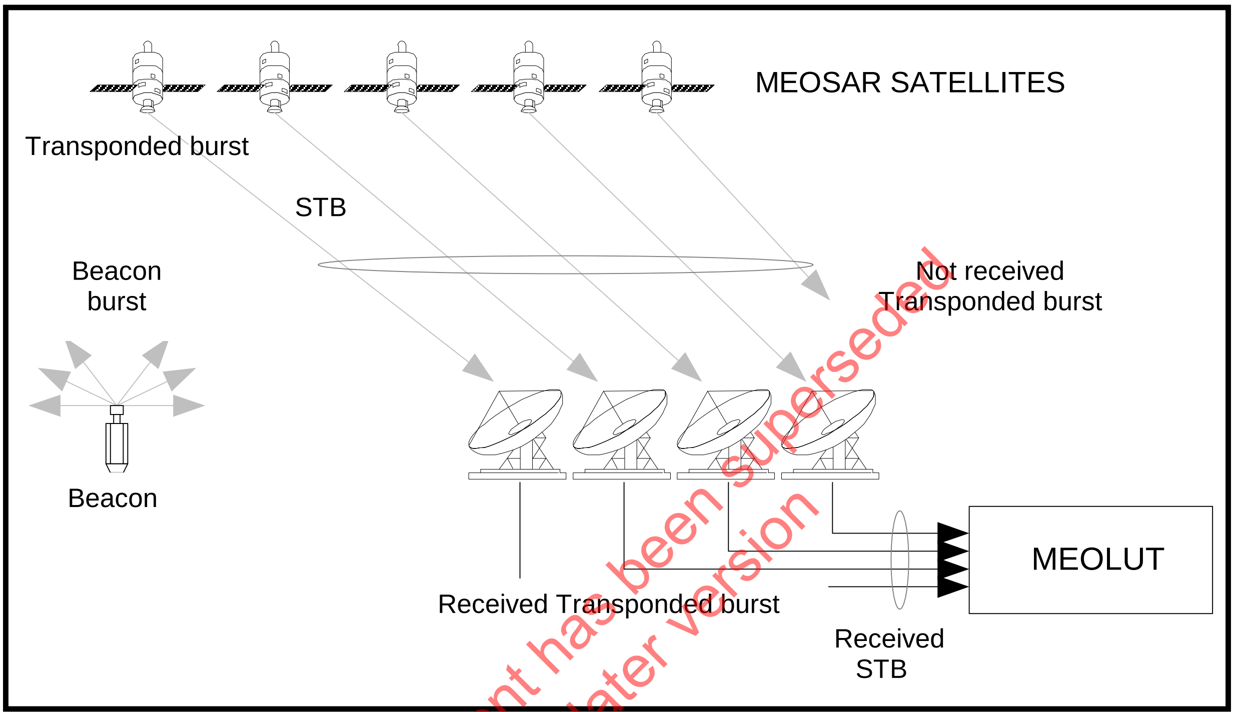

Figure A-1: Proposed MEOSAR terminology

Transponded Burst

A specific beacon burst as relayed by a single MEOSAR satellite.

A transponded burst may or may not be received by a MEOLUT depending on whether the corresponding MEOSAR satellite is also visible from the MEOLUT location and whether a MEOLUT antenna is allocated to that satellite.

Received Transponded Burst

A specific beacon burst as relayed by a single MEOSAR satellite and received through a single MEOLUT antenna.

A received transponded burst is uniquely identified by: beacon ID, time of transmission, satellite ID and antenna ID.

Set of Transponded Bursts (STB)

All transponded bursts corresponding to a single beacon burst (relayed through all MEOSAR satellites within view of the beacon).

The transponder burst in an STB may be received by different MEOLUTs, depending on the location of the beacon and the MEOLUTs and the corresponding satellites in common view.

Received STB

All transponded bursts corresponding to a single beacon burst and received at a given MEOLUT.

The received STB is a subset of the STB for the particular beacon burst. The number of transponded bursts in the received STB is limited by the number of MEOLUT antennas and by the number of satellites in common view of the beacon and the MEOLUT.

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ANNEX B

PRELIMINARY DASS TRANSPONDER CHARACTERISTICS[1]

Parameter	Requirement	Units
Uplink frequency range	406.0 to 406.1	MHz
Nominal input power level at antenna input[2]	-159.0	dBW
Maximum input power level at antenna input [3]	-148.0	dBW
System dynamic range	30	dB
Receive antenna polarization	RHCP	-
Receive antenna gain	10.7	dBiC
System noise temperature	695	K
Receive system G/T	-17.7	dBi/K
Bandpass Characteristic (0.5 dB bandwidth)	100	KHz
Phase linearity (overall in-band)	within ± 10° of linear	Degrees
Group delay	5.8 +/- 0.5	us
Group delay slope	-	-
AGC time constant	[250]	ms
AGC dynamic range	30	dB
Transponder gain (including ant. gains)	165	dB
Transponder linearity (C/I)	-	-
Frequency translation	direct	-
Gain stability	+/- 0.5	dB
Output frequency stability	~1 x 10^{-11}	-
Downlink frequency band	1544.8 to 1545.0	MHz
Downlink antenna polarization	RHCP	-
Maximum transmitter output power	7	dBW
Downlink antenna gain	10.5	dBiC

(1) Final parameters for the DASS L-Band transponder will be supplied at completion of instrument specification and design.

(2) Four simultaneous 406 MHz beacon signals at the antenna input each at –165 dBW.

(3) Ten simultaneous 406 MHz beacon signals at the antenna input each at –165 dBW plus 2 interferers in the band each with 100 Watt EIRP.

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ANNEX C

PRELIMINARY SAR/GALILEO TRANSPONDER CHARACTERISTICS

Parameter	Requirement	Units
Uplink frequency range	406.0 to 406.1	MHz
Receive centre frequency Normal mode Narrowband mode	 406.050 406.043	 MHz
Nominal input power level at antenna	-159.0	dBW
Maximum input power level at antenna	-148.0	dBW
System dynamic range	30.0	dB
Receive antenna polarisation	RHCP	
Receive antenna gain	11.7	dBi min.
Receive antenna G/T At edge of coverage At centre of coverage (assuming Ta = 400K)	 > -16.1 > -14.8	 dB/K
System noise temperature	< 598	K
Bandpass Characteristics: Normal mode (1 dB) > 90 kHz (1 dB) <120 kHz (10 dB) < 170 kHz (45 dB) < 210 kHz (70 dB) Narrowband mode (1 dB) > 50 kHz (1 dB) < 75 kHz (10 dB) < 130 kHz (45 dB) < 160 kHz (70 dB)	 90 50	 kHz
Phase linearity (overall in-band)(1)	/	
Group delay (total turn-around time)	TBD	µs
Group delay uncertainty (with 95% confidence)	< 102	ns
Group delay slope (over any 4kHz in the 1dB band) Normal mode Narrowband mode	 < 11.1 < 10.5	 µs
Transponder gain modes (set by telecommand)	Fixed Gain (FG) / AGC	
AGC time constant	< 80	ms
AGC dynamic range	> 30.0	dB
Transponder gain	>180	dB min
Transponder linearity (C/3I)	>30.0	dBc
Frequency translation, Direct (non-inverting), both modes	+ 1,138.05	MHz
Frequency translation accuracy, within	+/- 2E-11	
Frequency translation stability (over 100 ms), within	+/- 1E-11	

Parameter	Requirement	Units
Gain stability over temperature, frequency and lifetime	2.0	dB pk-pk
Output frequency stability	Derived from navigation clock	[High]
Downlink frequency band	1544.0 to 1544.2	MHz
Downlink centre frequency Normal mode Narrowband mode	1,544.100 1,544.093	MHz
Downlink antenna polarisation	LHCP	
Downlink EIRP (within +/- 12.44 deg off-nadir angle, i.e. full Earth disk)	16.8	dBW
Downlink EIRP (within +/- 12.25 deg off-nadir angle, i.e. 10 deg elevation)	>18.0	dBW
Minimum MTBF	520,833	h

(1) Group delay specified instead.

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ANNEX D

PRELIMINARY SAR/GLONASS TRANSPONDER CHARACTERISTICS

Parameter	Requirement	Units
Uplink frequency range	406.0 to 406.1	MHz
Receive centre frequency Normal mode Narrowband mode	 406.050 406.043	MHz
Nominal input power level at antenna	-162.0	dBW
Maximum input power level at antenna	-	dBW
System dynamic range	30.0	dB
Receive antenna polarisation	RHCP	
Receive antenna gain	10	dBi
Receive antenna G/T At edge of coverage	> -17.7	dB/K
System noise temperature	700	K
Bandpass Characteristics: Normal mode (1 dB) ≥ 90 kHz (1 dB) ≤ 100-120 kHz (10 dB) ≤ 170 kHz (40-45 dB) ≤ 210 kHz (50-70 dB) Narrowband mode (1 dB) > 50 kHz (1 dB) < 75 kHz (10 dB) < 130 kHz (45 dB) < 160 kHz (50-70 dB)	 90 50	 kHz
Phase linearity (overall in-band)(1)	/	
Group delay (total turn-around time)	TBD	µs
Group delay uncertainty (with 95% confidence)	< 100	ns
Group delay slope (over any 4kHz in the 1dB band) Normal mode Narrowband mode	 < 10 < 10	µs
Transponder gain modes (set by telecommand)	AGC	
AGC time constant	< 80	ms
AGC dynamic range	> 30.0	dB
Transponder gain	>175	dB min
Transponder linearity	>30.0	dBc
Frequency translation, direct (non-inverting), both modes	direct	
Frequency translation accuracy, within	+/- 1E-11	
Frequency translation stability (over 100 ms), within	+/- 5E-12	
Gain stability over temperature, frequency and lifetime	2.0	dB pk-pk
Output frequency stability	Derived from navigation clock	[High]
Downlink frequency band	1544.85 to 1544.95	MHz
Downlink centre frequency Normal mode Narrowband mode	1544.900 1544.893	MHz
Downlink antenna polarization	LHCP	
Downlink EIRP (within +/- 14 deg off-nadir angle, i.e. 10 deg elevation)	15-17	dBW

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ANNEX E

MINIMUM PERFORMANCE REQUIREMENTS FOR MEOSAR COMPATIBILITY WITH THE 406 MHz COSPAS-SARSAT SYSTEM

The table provided below defines the minimum performance requirements that should be satisfied by a MEOSAR system at full operational capability (FOC) to ensure compatibility with the existing 406 MHz Cospas-Sarsat satellite system. It is understood that:

a) these minimum requirements should be satisfied under nominal conditions, in particular assuming that the 406 MHz beacon transmissions satisfy the specification of document C/S T.001; and

b) a MEOSAR satellite system at full operational capability may exhibit better performance than the requirements specified below.

The table provides:

- in column 1: the performance parameter that characterises a specific system capability;
- in column 2: the applicable requirement that would ensure compatibility with the existing Cospas-Sarsat 406 MHz system;
- in column 3: the definition of the performance parameter;
- in column 4: applicable comments as necessary; and
- in column 5 the applicable Cospas-Sarsat document reference in respect of the identified requirement.

Performance Parameter	**Requirement**	**Definition**	**Comments**	**Reference**
Detection Probability	99%	The probability of detecting the transmission of a 406 MHz beacon and recovering at the MEOLUT a valid beacon message, within 10 minutes from the first beacon message transmission.	The MEOLUT referred to in the definition is a function, independent of its actual implementation, which may include several distinct physical entities/facilities operating in a network.	Detection probability for a single LEO satellite pass in visibility > 98% (C/S G.003). Detection probability over successive LEOSAR satellite passes > 99%. GEOSAR detection probability > 98% within 10 min. (C/S T.012).
Independent Location Probability	98%	The probability of obtaining at the MEOLUT a 2D location (Lat./Long.), independently of any encoded position data in the 406 MHz beacon message, within 10 minutes from the first beacon message transmission.	Same as above.	Cospas-Sarsat system exercises have demonstrated a Doppler location probability of 98% on a single LEO satellite pass (C/S G.003).
Independent Location Error	P(e < 5 km) > 95%	The system independent location solution should be within 5 km from the actual beacon position 95% of the time.	This requirement applies to all independent location solutions.	C/S T.002 requires 95% of nominal solutions to be within 5 km from the actual position.
Estimated Error (Error Ellipse)	50%	A measure of the accuracy of the calculated independent location expressed as an area that encompasses the actual beacon location 50% of the time.	This requirement applies to all independent location solutions provided by the system.	C/S T.002 defines the requirement for a 50% error ellipse.

Performance Parameter	Requirement	Definition	Comments	Reference
Sensitivity	BER < $5x10^{-5}$	Assuming a nominal background noise temperature of 600^{0}K, the overall link budget should provide a bit error rate better than $5x10^{-5}$ to allow for adequate system performance margins.		This BER is used in the analysis for all repeater based system protection requirements in document C/S T.014.
Availability	99.5%	The system should be available 99.5% of the time over a period of one year. The system is considered to be unavailable when any of the performance requirements listed in this Table cannot be satisfied.	This goal may be achieved through various means, i.e. by providing adequate redundancies and/or high reliability of sub-systems.	C/S A.005 requires a 99.5% availability of Cospas-Sarsat MCCs. The overall System availability is achieved through redundancy of the other sub-systems.
Coverage	Global	The system should satisfy the minimum performance requirements listed in this Table regardless of the beacon position on the Earth.		The existing Cospas-Sarsat LEOSAR system provides global coverage for 406 MHz beacons (C/S G.003).
Capacity	≥ 3.8 M	The system minimum performance requirements should be satisfied assuming a worldwide 406 MHz beacon population of at least 3.8 million.	A 3.8 million worldwide beacon population corresponds to a peak number of active beacons in a MEO satellite visibility area of 150. To be confirmed upon completion of MEOSAR beacon message traffic model.	The existing LEOSAR system has a maximum capacity of 3.8 million beacons when carrier frequencies are spread in accordance with C/S T.012.

Performance Parameter	Requirement	Definition	Comments	Reference
Processing Anomalies	$< 1x10^{-4}$	The system should not produce more than one processing anomaly for every 10,000 alert messages. A processing anomaly is an alert message produced by the system, which should not have been generated, or which provided incorrect information.	MCCs are required to validate alert messages before distribution to SAR services. Processing anomalies may, or may not result in false alerts.	This requirement applies to Cospas-Sarsat LEO and GEO LUTs (C/S T.002 and C/S T.009).

- END OF ANNEX E –

ANNEX F

MEOSAR SPACE SEGMENT INTEROPERABILITY PARAMETERS

Parameter	Requirement	Definition	Comments	Reference
SAR Receive Centre Frequency (normal bandwidth mode)	406.05 MHz			
SAR Receive Bandwidth (normal bandwidth mode)	> 80 kHz (1.0 dB bandwidth) > 90 kHz (3.0 dB bandwidth) < 110 kHz (10 dB bandwidth) < 170 kHz (45 dB bandwidth) < 200 kHz (70 dB bandwidth)	Normal mode must be included on all satellite constellations.	Optimises pass band to reduce the possible impact from out of band interferers. Must satisfy system group delay requirements.	
SAR Receive Centre Frequency (optional additional bandwidth mode)	406.043 MHz			
SAR Receive Bandwidth (optional additional bandwidth mode)	> 50 kHz (1.0 dB bandwidth) < 75 kHz (10 dB bandwidth) < 130 kHz (45 dB bandwidth) < 160 kHz (70 dB bandwidth)		Narrowband option would provide improved C/N, and reduce the susceptibility to interference. The 50 kHz covers channels A through O, which is expected to satisfy capacity requirements through 2025.	C/S T.012 traffic model and 406 MHz Channel Assignment Table.

Parameter	Requirement	Definition	Comments	Reference
Receive System G/T	> -17.7 dB/K	Measured at the input of the LNA. Over the entire Earth coverage area.	Assuming an antenna noise of 400 K.	
Axial Ratio	< 2.5 dB	Over entire Earth coverage area.		
Rx Antenna Polarisation	RHCP			
System Dynamic Range	> 30 dB	The linear range of the transponder, not accounting for AGC.	Will accommodate 10 narrow band signals (interferers or beacon bursts) received at the satellite. A nominal single beacon signal level at the satellite receiver input is approximately -165 dBW.	
AGC Dynamic Range	> 30 dB		Required to accommodate varying noise and interference levels.	
AGC Time Constant	[< 80 ms]			Sarsat LEOSAR AGC performance as documented at Table 3.3 of document C/S T.003.

Parameter	Requirement	Definition	Comments	Reference
SAR Transmit Frequency	SAR/Galileo (1544.0-1544.2 MHz) DASS and SAR/Glonass (1544.8 - 1545.0 MHz)		The exact bandwidth used for the downlink must take into account protection requirements for other instruments that have filed to use the band.	
Transmit EIRP	> 15 dBW	Over entire Earth coverage.		
Downlink Polarisation	Circular		Either RHCP or LHCP.	
SAR Transmit Emission Mask	Must meet Annex I of C/S T.014 and Inmarsat-E protection requirements		Negotiations with Inmarsat will be required to confirm their protection requirements.	Annex I of C/S T.014
Repeater linearity (C/I)	> 30 dBc	Ratio of power to intermodulation products (which occur when the repeater operates beyond its linear range)		
Frequency Translation	Accuracy +/- 2x10^{-11} Short Term Stability (100 ms) < 1x10^{-11}		Synchronisation with the on-board navigation frequency reference provides for a very accurate and stable frequency translation on all MEOSAR satellites. Allows FDOA measurements through different satellites regardless of their constellation.	

Parameter	Requirement	Definition	Comments	Reference
SAR Rx to Tx conversion	Frequency Translation, non-inverted		Rx band is not re-modulated on a downlink carrier Conversion may utilize an intermediate frequency to facilitate translation with minimum loss of gain.	
Group Delay	< 10 µs / 4 kHz		Group delay is a function of bandwidth and filter design. Filter must be designed with group delay characteristics that satisfy the system performance requirements. Group delay parameter is for guidance only and should be considered subsidiary to the Bandwidth requirement.	
Group Delay Stability	< 500 ns		This performance will ensure that group delay has negligible impact on TDOA measurements	

- END OF ANNEX F -

ANNEX G

PRELIMINARY MEOLUT INTEROPERABILITY PARAMETERS

Parameter	Requirement	Definition	Comments	Reference
MEOLUT BER Performance	Suitable to provide BER of 5E-5		Achievable with a G/T of 4 dB/K Update MIP to correct BER discrepancy at Annex E.	
Antenna Polarisation	RHCP and LHCP		DASS will operate with RHCP downlinks, SAR/Galileo with LHCP downlinks and a decision for SAR/Glonass has not yet been finalised.	
MEOLUT System Clock Accuracy	UTC +/- 50 ns			
Time Tagging Accuracy	Standard Deviation within 7 µs	Time tagging accuracy measured at MEOLUT processing threshold using a calibrated input signal fed directly into the MEOLUT.	When processing C/S T.001 signals. Theoretical limit at threshold is 3 µs.	
Frequency Measurement Accuracy	Standard Deviation within 0.1 Hz	Frequency measurement accuracy at MEOLUT processing threshold using a calibrated input signal fed directly into the MEOLUT.	To facilitate the exchange of frequency measurements between MEOLUTs. Theoretical limit at threshold is 0.025 Hz.	
Processing Threshold	34.8 dB - Hz	C/No measured at the demodulator.	C/No that supports a BER of 5E-5.	

Parameter	Requirement	Definition	Comments	Reference
Beacon Modulations Supported	As per C/S T.001		New modulations are being considered to enhance MEOSAR system performance. When and if accepted these will be included in C/S T.001.	

Note: The above MEOLUT interoperability parameters have not been finalised and may be amended as MEOLUT development proceeds.

- END OF ANNEX G -

ANNEX H

WORK PLAN FOR MEOSAR SYSTEM DEVELOPMENT AND INTEGRATION IN RESPECT OF TECHNICAL AND OPERATIONAL MATTERS

This annex presents a work plan overview for the development and integration of the MEOSAR system. The work plan is organized by system data flow; it presents the work required for each process or interface and the Cospas-Sarsat body which should undertake the work effort. The work effort in some cases can be accomplished during a single implementation phase, but in others it can span several phases. The work plan must retain some measure of flexibility to account for the different implementation schedules of the MEOSAR component providers. The work plan overview is graphically depicted at Figure H.1.

H.1 Beacon to Satellite Interface

Because of the use of transparent repeaters planned for the MEOSAR satellite payloads, there are no modifications required to the 406 MHz beacon for its compatibility with the proposed MEOSAR system. However, the possible implementation of advanced capabilities of a return link or enhanced beacon transmissions would require consideration by the Joint Committee and Task Groups as required to study specific needs. Consideration of a return link service should be accomplished as early as possible in the development and proof-of-concept/in-orbit validation phases. Because of the use of spacecraft repeater instruments, enhanced beacon characteristics can be considered at any time.

H.2 Satellite to MEOLUT Interface

The satellite to MEOLUT interface, or the satellite downlink parameters, must be completed in the development phase. To this end, the major parameters for downlink compatibility and interoperability have been agreed among the MEOSAR system providers and are documented in section 6 and Annex F of this document. Issues remaining to be completed should be addressed in specific Experts' Working Groups established by the Council, with the results recorded in this document according to procedures given in section 1.3.

H.3 MEOLUT Processing

The development of MEOLUT processing will initially be accomplished by the respective MEOSAR component providers. The performance of the prototype MEOLUTs will be evaluated during the proof-of-concept/in-orbit validation phase. Further evaluation of the MEOLUTs will be accomplished during the demonstration and evaluation phase, and the MEOSAR D&E Plan should include the necessary test objectives to be measured. These evaluations will contribute to the effort within Cospas-Sarsat to develop new System documents for MEOLUT performance, design guidelines, and commissioning. The development of these documents should be accomplished by the Joint Committee, with Task Groups as necessary, and should be completed and approved by the end of the demonstration and evaluation phase.

H.4 MEOLUT to MCC Interface

There are no explicit actions to be taken in respect of the MEOLUT to MCC interface as Cospas-Sarsat does not create specifications dealing with this nominally technical matter of ground segment provider concern. However, the appropriate body of the Joint Committee should ensure that the necessary data fields to be provided by the MEOLUTs are specified in the operational documents. The Joint Committee should continue to look at changes that need to be made to existing System documents and ensure that the MEOSAR D&E Plan includes the appropriate references to MEOLUT / MCC interface, as necessary.

H.5 MCC Processing

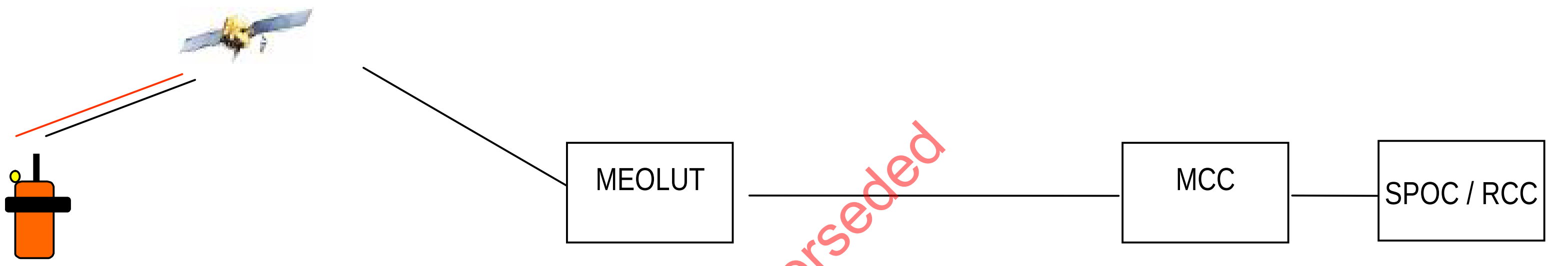
A significant effort is required to determine how MEOSAR alert data will be incorporated into the distress alert information distributed to the SAR services. The amount of modifications necessary in the Cospas-Sarsat MCCs will depend on the operational scenario concept developed for the use of MEOSAR data, and the additional information provided by the MEOSAR system. Extensive modifications will require the convening of a dedicated task group to review the impact on the documents C/S A.001 (DDP) and C/S A.002 (SID), and to recommend the necessary updates. Modification will also be required to ancillary documents such as C/S A.003 (monitoring and reporting), but these may be accomplished within the context of the Joint Committee. The Joint Committee should ensure that the MEOSAR D&E Plan accommodates the necessary objectives to evaluate the MCC performance.

H.6 MCC to RCC/SPOC MEOSAR Alert Data Distribution

The MEOSAR D&E implementation phase offers the opportunity to evaluate the planned data distribution procedures for MEOSAR distress alert data, and the anticipated response procedures for the use of the data by SAR services. The Joint Committee, and possibly a dedicated task group, will need to ensure that the operational procedures and message formats are modified as necessary to optimise the availability of MEOSAR data. This will particularly impact the document C/S A.002 (SID) and other ancillary documents provided for RCC/SPOC edification on the use of Cospas-Sarsat alert data. Cospas-Sarsat will need to coordinate with the appropriate international organizations to ensure that their publications are updated to include the most current description of the System.

H.7 Return Link Service

If a return link service is implemented by any MEOSAR component provider, it will represent a new function that will, in all probability, impact on several, or all, interfaces and processes within the Cospas-Sarsat System, depending on its operational implementation. The return link function may be implemented by entities outside the Cospas-Sarsat System, or may be part of Cospas-Sarsat, but in either case its implementation must be recognised and accommodated by the System. Because it represents an entirely new operational concept, the introduction of a return link process should first be studied in dedicated operational / technical task groups, given adequate guidance by the Council on the scope of their efforts. The impact of a return link service on the processes and interfaces covered in the preceding sections will not be known until an operational scenario is developed by Cospas-Sarsat task groups, in coordination with the MEOSAR component providers and, possibly, national Administrations. Any impact on the Cospas-Sarsat System must be documented in the appropriate System documents. The development of a return link service could impact all phases of MEOSAR system implementation.



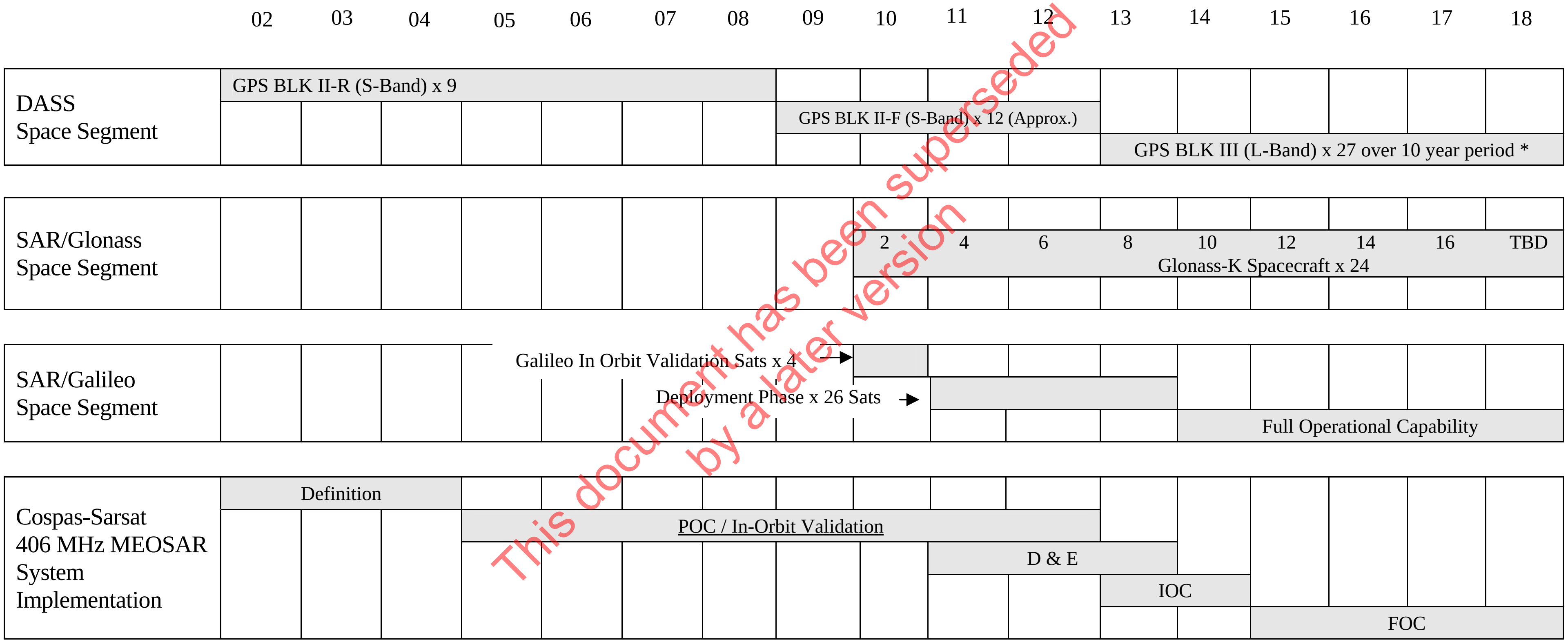
Technical / Operational Matter	Beacon to Satellite Interface	Satellite to MEOLUT Interface	MEOLUT Processing	MEOLUT to MCC Interface	MCC Processing	MCC to SPOC/RCC Alert Distribution
Description	No change to current beacon specifications; review return link service	Development of downlink parameters and issues regarding interoperability	Development of design and performance specifications	Development of specifications	Change to specifications and data distribution	Changes to alert message format and content
Venue	N/A	EWG	JC / TG	JC / TG	JC / TG	JC / TG
System Documentation Affected	N/A	C/S R.012 (MIP)	D&E Plan; New documents; affected System documents	D&E Plan; affected System documents	D&E Plan; C/S A.001; C/S A.002; affected System documents	Affected System documents; documents of international bodies
Return Link	Discussed in JC / TG and may affect several System documents	TBD	TBD	TBD	TBD	TBD

Figure H.1: Summary of Work Plan for Technical and Operational Matters

- END OF ANNEX H –

ANNEX I

TENTATIVE MEOSAR SYSTEM DEVELOPMENT AND INTEGRATION SCHEDULE



* SAR Repeater planned to be included starting between 2013 and 2017.

- END OF ANNEX I -

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ANNEX J

SAMPLE MEOSAR CONSTELLATION LINK BUDGET

System Constants	Units	Value		Comments
Boltzman's Constant	Joules/K	1.38E-23		
Boltzman's Constant	dB(W/m^2Hz)	-228.6		
Satellite Altitude - from earth centre	km	29994.135		23,616 km above earth surface
Earth Radius	km	6378.135		
Parameter	**Units**	**Typical Case**		
Uplink (Beacon to Spacecraft)				
Beacon Transmit Power	dBW	7.00		Beacon spec C/S T.001 para 2.3.2 Nominal power 5 Watts
Beacon Antenna Gain	dB	0.00		Beacon spec T.001 para 2.3.3, approx mid-range case
Elevation	deg	30.0		Typical elev to a MEOSAR satellite
Range	Km	26292		Slant range at 30 degree elevation
Uplink Frequency	MHz	406.050		Middle of beacon operating band
Path Loss	dB	-173.0		
Polarization Loss	dB	-4.5		Linear beacon antenna to elliptical spacecraft antenna
Fading loss	dB	-2.5		Sum of various atmospheric effects
G/T of Satellite Rx Antenna	dB/K	-17.7		Estimated value
Uplink C/No	**dBHz**	**37.9**		
Downlink (Spacecraft to MEOLUT)		Scenario 1	Scenario 2	Two possible scenarios for satellite to MEOLUT link
Satellite Transmit EIRP	dBW	15.0	20.0	Two possible scenarios for satellite
Elevation	deg	30	30	
Range	Km	26292	26292	
Downlink Frequency	MHz	1544.5	1544.5	Mid-band for 1544.0 to 1544.1 MHz
Path Loss	dB	-184.6	-184.6	
Fading Loss	dB	-1.0	-1.0	
Polarization Loss	dB	-1.0	-1.0	LUT antenna will need to match polarization of spacecraft D/L antenna
Power Sharing Loss	dB	-10.0	-10.0	Assume 8 total signals + 1 dB for noise
Ground Station G/T	dB/degK	4.0	-1.0	Two possible scenarios for MEOLUT
Downlink C/No	dBHz	51.0	51.0	
Estimated downlink C/Io	dBHz	51.0	51.0	
Downlink C/(No+Io)	**dBHz**	**48.0**	**48.0**	
Overall C/(No+Io)	**dBHz**	**37.4**	**37.4**	Combined effect of uplink and downlink
Required C/No				
Theoretical Eb/No for required BER	dB	8.8		Theoretical for BPSK at $5x10^{-5}$ BER
Beacon Data Modulation loss (for 1.1rad)	dB	1.0		Due to Bi-phase-L being used in beacon, relative to BPSK
Coding Gain	dB	2.0		from BCH decoding on beacon burst
Processing Gain (on only 1 burst)	dB	0.0		For decoding beacon on 1 burst with no integration
Modem implementation loss	dB	1.0		
Required Eb/No on coded channel	dB	8.8		
Bit rate (at 400 bps)	dBHz	26.0		
Required C/(No+Io)	**dBHz**	**34.8**		
Margin	**dB**	**2.6**		

Summary:

The link budget is calculated for a single burst from a 406 MHz beacon at nominal power (5 W) transmitting to a MEOSAR satellite at a 30 degree elevation angle, and the MEOLUT is viewing that single satellite also at a 30 degree elevation angle. It is assumed that there are a total of 8 signals present simultaneously in the band.

The resultant values for this link budget are:

$(C/N_o)_{up}$ = 37.9 dBHz
$(C/N_o)_{down}$ = 48.0 dBHz (i.e. 10 dB above the $(C/N_o)_{up}$)
$(C/N_o)_{overall}$ = 37.4 dBHz
$(C/N_o)_{required}$ = 34.8 dBHz
Margin = 2.6 dB

This $(C/N_o)_{down}$ can be achieved with a satellite EIRP of 15 to 20 dBW, requiring a MEOLUT antenna G/T greater than 4 or –1 dB/K, respectively.

Based on the assumptions adopted for the link budget calculations, MEOSAR interoperability can be achieved with a MEOLUT G/T of 4 dB/K and MEOSAR satellite downlinks with an EIRP of 15 dBW. Under these conditions MEOSAR system communication links would provide 2.6 dB of margin.

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ANNEX K

LIST OF ACTIONS
FOR THE DEVELOPMENT AND INTEGRATION
OF A MEOSAR SYSTEM INTO COSPAS-SARSAT

Action	Status / Comments
Action Item 2.1: MEOSAR providers should develop link budgets for their respective MEOSAR satellite constellations for inclusion in future revisions of this document. The link budgets should conform to the assumptions and format adopted for the sample link budget provided at Annex J.	Revision provided for SAR/Glonass To be continued
Action Item 2.2: MEOSAR providers should update, as necessary, the information concerning the design, performance, and functionality of their system.	On-going
Action Item 5.1: MEOSAR providers are invited to conduct analysis to identify performance levels that can be achieved practically. The analysis should particularly investigate the beacon to satellite and satellite to MEOLUT link budgets, and their impact on various aspects of overall MEOSAR system performance.	On-going
Action Item 5.2: MEOSAR providers are invited to conduct analysis to identify anticipated MEOSAR location determination performance in respect of location accuracy and time to produce location information, and to propose options for optimising MEOSAR location determination performance.	On-going
Action Item 5.3: MEOSAR providers and Cospas-Sarsat are invited to develop a MEOSAR capacity model, and proposals for a 406 MHz channel assignment strategy that accommodates LEOSAR, GEOSAR and MEOSAR requirements.	Open
Action Item 5.4: Cospas-Sarsat Participants are invited to: a. investigate whether their respective Administrations operate, or have knowledge of other Administrations which operate wind profiler radars at 404.3 MHz, and report their findings to the Council; and b. request administrations operating wind profilers at 404.3 MHz to move these radars to the 449 MHz frequency band.	On-going Modifications of US profiler radar transmitters is in progress with three transmitters modified each year.

Action	Status / Comments
Action Item 6.1: MEOSAR providers should:	
a. consider the protection requirements for the other systems that have notified their use of the 1544 – 1545 MHz band when designing their MEOSAR downlinks;	On-going
b. conduct investigations to identify other systems that have, or will have, started the coordination / notification process with the ITU prior to the respective MEOSAR provider, and consider the protection requirements for such systems when designing MEOSAR downlinks; and	Notification of SAR/Glonass frequencies has been made, Status of notification for SAR/Galileo frequencies to be investigated by France/ESA
c. initiate the formal ITU advance publication, coordination and notification process for their MEOSAR satellite network, in accordance with the procedures described in the Radio Regulations.	
Action Item 6.2: MEOSAR providers should study the issue of how many DASS and SAR/Glonass MEOSAR repeaters could be accommodated in the upper portion of the band without generating harmful interference to each other.	On going
Action Item 6.3: The Secretariat should forward any information regarding Koreasat downlink provided by Korea to the MEOSAR providers.	No information received from Korea
Action Item 6.4: MEOSAR providers should:	Open
a. establish susceptibility / protection requirements for their MEOSAR downlinks; and	
b. consider the possible interference from other systems, including inter MEOSAR satellite constellation interference, when designing their downlinks, and confirm whether the minimum performance required for compatibility with Cospas-Sarsat would still be satisfied while operating in the presence of interference from these systems.	
Action Item 6.5: MEOSAR providers should conduct analyses for inclusion in future revisions of this document, to refine the MEOSAR payload requirements provided at Annex F for enabling MEOLUTs to receive and process the downlink signals from multiple MEOSAR satellite constellations.	Open
Action Item 7.1: Cospas-Sarsat Participants should investigate, through trials where possible, the operational benefits and drawbacks that may be associated with distress alert acknowledgement services and return link services that control beacon transmissions.	Open
Action Item 7.2: Cospas-Sarsat Participants and MEOSAR providers should conduct analysis to identify suitable options for operating and managing acknowledgement services.	Open

Action	Status / Comments
Action Item 7.3: Cospas-Sarsat Participants and MEOSAR providers should develop technical proposals for acknowledgement services (including description of the required downlink signals and 406 MHz beacon specification / type approval requirements).	Open
Action Item 7.4: Cospas-Sarsat and MEOSAR providers should conduct analysis to identify improvements to the 406 MHz beacon specification for the MEOSAR system. The following points should be specifically addressed: a. changes in the channel coding (e.g. convolutional coding); b. the impact that new beacon specifications would have on System capacity; c. new modulation techniques to improve TDOA/FDOA performance; d. improvements to the message format; e. additional encoded data requested by SAR authorities; f. general optimisation of beacon parameters; g. technologies that could reduce the cost of the beacon; and h. the suitability of the MQPSK modulation for the MEOSAR TDOA time-tagging requirement.	Open
Action Item 8.1: Cospas-Sarsat and MEOSAR providers should conduct analysis on the feasibility of developing MEOLUTs and identifying the associated LUT technical characteristics necessary for simultaneously receiving and processing the downlinks from: a. multiple MEOSAR satellites from the same MEOSAR constellation; and b. multiple MEOSAR satellites from different MEOSAR constellations.	Open
Action Item 8.2: Cospas-Sarsat and MEOSAR providers should conduct analysis and propose options for a MEOLUT ground segment architecture. The analysis should specifically address advantages and disadvantages of networking MEOLUTs, propose options for sharing MEOLUT beacon burst data measurements with other MEOLUTs, and identify specification and commissioning requirements for the MEOLUT data sharing function.	Open
Action Item 8.3: Cospas-Sarsat and MEOSAR providers should conduct analysis and propose MEOLUT functional, technical and commissioning requirements, that ensure that MEOLUTs will be capable of providing a service that satisfies the performance requirements identified at section 5.	Open

Action	Status / Comments
Action Item 9.1: MEOSAR providers should conduct studies and trials to identify: a. what calibration information will be required to support Cospas-Sarsat performance requirements; b. the required update frequency of calibration information; and c. the most appropriate methods for obtaining and distributing calibration information.	Open
Action Item 10.1: Cospas-Sarsat and MEOSAR providers should develop proposals for the content and implementation of MEOSAR Demonstration and Evaluation Programmes.	Open
Action Item 10.2: Cospas-Sarsat and MEOSAR providers should develop proposals in respect of MEOSAR system requirements necessary for progressing to IOC.	Open
Action Item 10.3: MEOSAR providers should update the implementation schedules for their MEOSAR constellations.	On-going

- END OF ANNEX K –

ANNEX L

PRELIMINARY MEOLUT NETWORK ARCHITECTURE AND BURST DATA REQUIREMENTS

This Annex illustrates the architecture concept for MEOLUT networking agreed at the Experts Working Group Meeting on MEOLUT interoperability requirements (EWG-2/2006) held in April 2006 in Montreal, Canada.

L.1 OPTIONS FOR MEOSAR DATA SERVER NETWORK IMPLEMENTATION

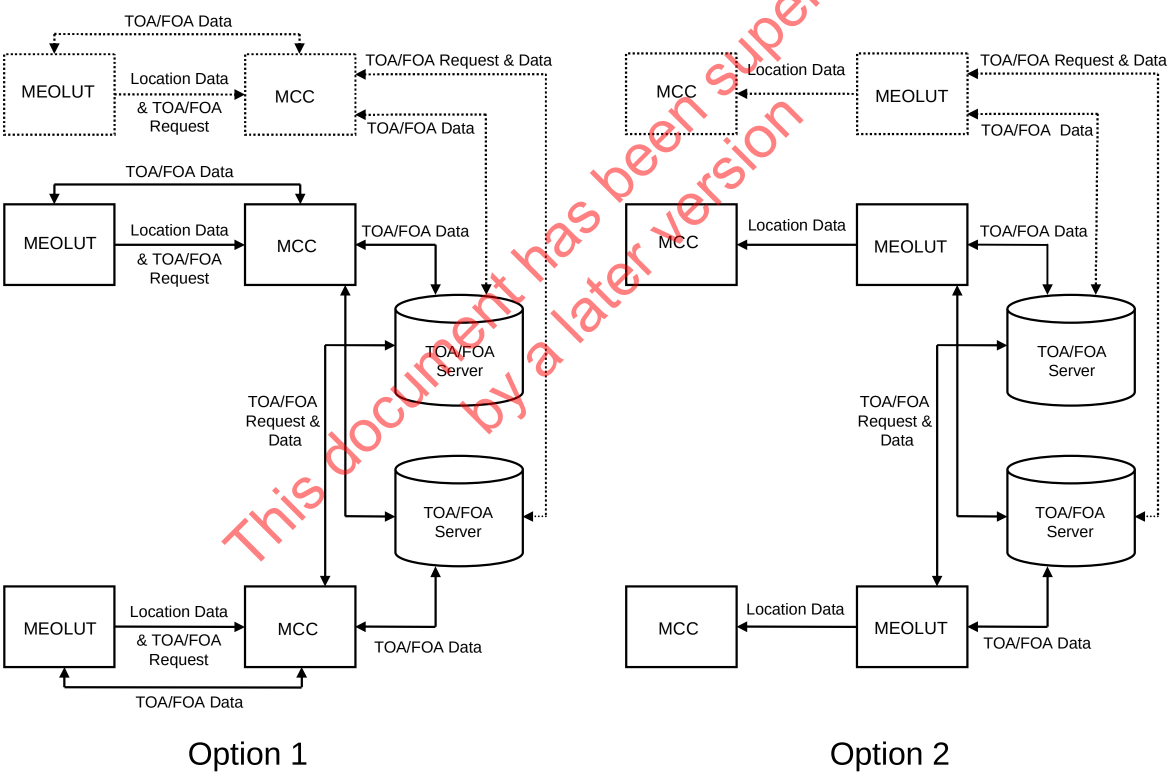

Figure L.1: Overall Architecture of the MEOSAR Data Server Network

L.2 FORMAT OF MEOSAR DATA HOSTED ON MEOSAR DATA SERVERS

L.2.1 Folder structure:

FTP_OUTPUT_FOLDER
- BEACON_ID
  - Text Files
- BEACON_ID
  - Text Files
- BEACON_ID
  - Text Files
- BEACON_ID
  - Text Files
- BEACON_ID
  - Text Files

BEACON_ID as defined by message field 22 in C/S A.002.(SID)

L.2.2 File naming convention:

YY_DDD_HHMM_SS_NNNNNN_AA.txt

Using the Uplink TOA, new message field 67 (C/S A.002).

YY – year
DDD – Julian day
HH – hour
MM – minute
SS – seconds
NNNNNN – fraction of second (micro-seconds)
AA – antenna ID

L.2.3 Example of MEOSAR Beacon Event File

/01614 00000/3668/06 005 1320
/722/0000/01
/323/3668/02/123456789ABCDEF012345600000000
/06 093 1320 20.453613/406.025123456
/0.123456/10000.123/00.0/400.000/FFFF
/LASSIT
/ENDMSG

Each file contains a single TOA/FOA pair, in accordance with the format of data defined for SIT 722 messages (see Annex M)

L.2.4 The server is interrogated for data using Beacon ID and Time using the following general steps:

(1) Log onto the FTP site
(2) Search for folder name with desired Beacon ID
(3) If found, change to that folder
(4) List files within time range using expressions like YY_DDD_HHMM_*.*
(5) Perform FTP “get” on resulting file list
(6) Log off

- END OF ANNEX L -

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ANNEX M

DRAFT DEFINITIONS OF BURST DATA ELEMENTS AND ASSOCIATED MESSAGE FIELDS DESCRIPTIONS

The following definitions and descriptions of data elements and message fields are provided in accordance with the conventions / standards and formats used to define MCC interfaces in the document C/S A.002 (SID), Annexes B and C. However, these definitions will not be included in the Cospas-Sarsat System Document C/S A.002 (SID) at this stage.

New message fields 67 to 76, which are specific to MEOSAR burst data, are described per the format used in Table B.1 of the SID and defined as per Appendix B.1 of Annex B to the SID.

New SIT message format are defined for the exchange of burst data between networked MEOLUTs, i.e. SIT number:

- o 721 to request burst data; and
- o 722 to provide the requested data.

These new SIT formats and contents are described as per Annex C, Table C.4 and Appendix C.1 of the SID.

In addition, during the POC/IOV phase, MEOSAR providers may, as an option, evaluate on a bilateral basis the exchange of data between MEOLUTs using the XML protocol as defined at Appendix M.1 to Annex M in Figure M.1 (MEOSAR XML Schema) . A sample SIT 722 message in the XML format is provided as illustration in Figure M.2

Note: In this Annex, existing text in the document C/S A.002 (SID) is in normal fonts, deletions are shown as ~~strike out~~ fonts and additions are in italic fonts.

TABLE B.1 TO ANNEX B OF C/S A.002 (SID)

MESSAGE FIELDS DESCRIPTION

MF#	NAME	CONTENT	CHARACTER TEXT
2	REPORTING ~~MCC~~ *FACILITY*	(SEE TABLE II/A.1 in C/S A.001)	nnnn
6	SPACECRAFT ID	SARSAT = 001 -> 099 COSPAS = 101 -> 199 GOES = 201 -> 220 LUCH-M = 221 -> 240 INSAT-2, INSAT-3 = 241 -> 260 MSG = 261 -> 280 *GPS = 300 -> 399*[1] *Galileo = 400 -> 499* *GLONASS = 500 -> 599* (See Annex II/F in C/S A.001 for spacecraft status)	nnn
67	*UPLINK TOA*	*YEAR = 00 -> 99* *DAY(JULIAN) = 001 -> 366* *UTC - HRS = 00 -> 23* *MINS = 00 -> 59* *SECS = 00.000000 -> 59.999999*	*nn* *nnn* *nnnn* *nn.nnnnnn*
68	*UPLINK FOA (MHz)*	*406.000000000 -> 406.100000000*	*nnn.nnnnnnnnn*
69	*TIME OFFSET (sec)*	*0.000000 -> 9.999999* *DEFAULT VALUE = 0.000000*	*n.nnnnnn*
70	*FREQUENCY OFFSET (Hz)*	*-90000.000 -> +90000.000* *DEFAULT VALUE = +99999.999*	*snnnnn.nnn*
71	*ANTENNA ID*	*(SEE TABLE II/TBD in C/S A.001)* *DEFAULT VALUE = 00*	*nn*
72	*C/N_0 (dBHz)*	*00.0 -> 99.9* *DEFAULT VALUE = 00.0*	*nn.n*
73	*REQUEST TIME WINDOW (sec)*	*000.000000 -> 999.999999* *DEFAULT VALUE = 000.000000*	*nnn.nnnnnn*
74	*NUMBER OF DATA BLOCKS*	*01 -> 99*	*nn*
75	*BIT RATE*	*000.000 -> 999.999* *DEFAULT VALUE = 000.000*	*nnn.nnn*
76	*SPARE DATA*	*FFFF* *DEFAULT VALUE = 0000*	*hhhh*

1. *For MEOSAR satellites the sequence within the range correspond to the Pseudo Random Noise (PRN) number for the spacecraft (e.g., GPS PRN 23 would be 323).*

APPENDIX B.1 TO ANNEX B OF C/S A.002 (SID)

MESSAGE FIELDS DEFINITION

MF #	Message Fields Definition

2. Reporting ~~MCC~~ *Facility*

The identification code corresponding to the ~~MCC~~ *facility (e.g., MCC, LUT)* sending the current message.

67. Uplink TOA[*]

Time that the burst is received at the satellite as calculated by the MEOLUT. The time reference point (anchor) of a 406 MHz SAR burst is the end of the 24th bit in the message Preamble. The end of the 24^{th} bit is defined as the mid point of the 50% phase crossing (i.e. "zero-crossing") of the mid-transitions of the 24^{th} and 25^{th} bit.

68. Time Offset [*]

This is the calculated difference in time between the reception of the beacon burst at the satellite and the ground station. Adding this offset to the Uplink TOA provides the time the burst was received at the ground station.

69. Uplink FOA

Burst frequency measured at the time of the Uplink TOA.

70. Frequency Offset

This is the calculated difference of the burst frequency received by the satellite and the ground station. Adding this offset to the Uplink FOA provides the frequency of the burst as received at the ground station. If the offset is set to the default value, the Uplink FOA refers to the frequency measured at the ground station (i.e. offset is included). The intended use of the default value pertains to "antenna only" installations that may not have the capacity to compute this offset.

[*] *If the offset is set to the default value, the Uplink TOA refers to the time the end of bit 24 was received at the ground station (i.e. offset is included). The intended use of the default value pertains to "antenna only" installations that may not have the capacity to compute this offset.*

71. Antenna ID

The identification code corresponding to the individual antenna associated with the ground station that originally provided the burst data being reported in the SIT message.

72. C/N_0

The Carrier over Noise Density of the detected burst as determined by the ground station.

73. Request Time Window

The time frame for which burst data is requested. Specifically, this number of seconds should be added to and subtracted from the time reference in the request to determine the start and end time (Uplink TOA) for bursts to be included in the response. If the default value is received, a window of +/- [5.0] seconds should be applied.

74. Number of Data Blocks

The number of data blocks in this SIT format.

75. Bit Rate

The number of bits per second as measured by the ground station.

76. Spare Data

This field consists of four hexadecimal characters as place holders for additional information.

TABLE C.4 TO ANNEX C OF C/S A.002 (SID)

MESSAGE CONTENT
FOR
MEOSAR DATA MESSAGES

MESSAGE FORMAT	*MF #*	*TITLE*	*SIT NUMBERS 721*	*722*
MESSAGE (1)	*1*	*MESSAGE NUMBER*	*A*	*A*
HEADER	*2*	*REPORTING FACILITY*	*A*	*A*
(2)	*3*	*MESSAGE TRANSMIT TIME*	*A*	*A*
SIT	*4*	*SIT*	*A*	*A*
HEADER	*5*	*SIT DESTINATION*	*A*	*A*
	74	*NUMBER OF DATA BLOCKS*	*A*	*A*
	6	*SPACECRAFT ID*	.	*A*
	11	*SOURCE ID*	.	*A*
	71	*ANTENNA ID*	.	*X*
	22	*BEACON ID*	*A*	.
	23	*406 MESSAGE*	.	*A*
	67	*UPLINK TOA*	*A*	*A*
DATA	*68*	*UPLINK FOA*	.	*A*
	69	*TIME OFFSET*	.	*X*
	70	*FREQUENCY OFFSET*	.	*X*
	72	*C/N_0*	.	*X*
	73	*REQUEST TIME WINDOW*	*X*	.
	75	*BIT RATE*	.	*X*
	76	*SPARE DATA*	.	*X*
		REPEAT MF #s 6 TO 76 AS REQUIRED, BY MF # 74	*A*	*A*
SIT TRAILER	*42*	*ENDSIT*	*A*	*A*
MSG TRAILER	*43*	*ENDMSG*	*A*	*A*

Note 1: *"A" - indicates actual values.*
"X" - indicates default values are allowed.
Note 2: *The underline "__" is an indication where the New Line (NL) code is to be inserted.*

APPENDIX C.1 TO ANNEX C OF C/S A.002 (SID)

SAMPLE MESSAGES

SAMPLE MESSAGE FOR SIT 721

FORMAT FRAMES	*MF#*	*CONTENT*
HEADER		*(as per communication network requirements if any)*
	1,2,3	*/01614 00000/3169/80 005 1750*
	4,5,74	*/721/3668/02*
	22	*/123456789ABCDEF*
	67,73	*/80 005 1700 20.000000/000.000000*
INFO	*22*	*/23456789ABCDEF0*
	67,73	*/80 005 1700 20.000000/000.000000*
	42	*/LASSIT*
	43	*/ENDMSG*
TRAILER		*(as per communication network requirements if any)*

SAMPLE MESSAGE FOR

SIT 722

FORMAT FRAMES	*MF#*	*CONTENT*
HEADER		*(as per communication network requirements if any)*
	1,2,3	*/01614 00000/3668/80 005 1750*
	4,5,74	*/722/3169/02*
	6,11,71,23	*/323/3668/02/123456789ABCDEF012345600000000*
	67,68	*/80 005 1700 20.000000/406.025123456*
	69,70,72,75,76	*/0.123456/+10000.123/00.0/400.000/FFFF*
INFO	*6,11,71,23*	*/318/3668/02/23456789ABCDEF0123456700000000*
	67,69	*/80 005 1700 20.000000/406.025123456*
	68,70,72,75,76	*/0.123456/+10000.123/00.0/400.000/FFFF*
	42	*/LASSIT*
	43	*/ENDMSG*
TRAILER		*(as per communication network requirements if any)*

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APPENDIX M.1 TO ANNEX M

The data contained in the SIT messages can easily be described by the Schema below for packet data and packet request messages. One XML Schema document can be copied to any number of users for immediate use by any of the third-party XML parsers.

Figure M.1: MEOSAR XML Schema

```
<?xml version="1.0"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns="urn:packet-schema"
 elementFormDefault="qualified"
 targetNamespace="urn:packet-schema">
 <xsd:element name="Packet">
  <xsd:complexType>
   <xsd:all>
    <!-- Beacon code -->
    <xsd:element name="MsgNum" type="xsd:positiveInteger" />
    <xsd:element name="MsgOrig" type="xsd:positiveInteger" />
    <xsd:element name="SIT" type="xsd:positiveInteger" />
    <xsd:element name="TxTime" type="xsd:dateTime" />
    <xsd:element name="Beacon30">
     <xsd:simpleType>
      <xsd:restriction base="xsd:string">
       <xsd:pattern value="[0-9A-F]{30}" />
      </xsd:restriction>
     </xsd:simpleType>
    </xsd:element>
    <xsd:element name="GS" type="xsd:positiveInteger" />
    <xsd:element name="SatID" type="xsd:positiveInteger" />
    <xsd:element name="TOA" type="xsd:dateTime" />
    <xsd:element name="FOA" type="xsd:decimal" />
    <xsd:element name="TimeOffset" type="xsd:decimal" />
    <xsd:element name="FreqOffset" type="xsd:decimal" />
    <xsd:element name="AntID" type="xsd:positiveInteger" />
    <xsd:element name="CN0" type="xsd:decimal" />
    <xsd:element name="RqTimeWndw" type="xsd:decimal" />
    <xsd:element name="NumBcks" type="xsd:positiveInteger" />
    <xsd:element name="BitRate" type="xsd:decimal" />
   </xsd:all>
  </xsd:complexType>
 </xsd:element>
</xsd:schema>
```

Figure M.2: Sample SIT 722 in XML format

```
<?xml version="1.0" encoding="utf-8"?>
<Packet>
<MsgNum>00020</MsgNum>
<SIT>722</SIT>
<TxTime>2007-12-21T21:04:27</TxTime>
<Beacon30>4E04E98EBAC9A68AB880D000000000</Beacon30>
  <GS>1</GS>
  <TOA>2007-12-21T21:03:21.673114657</TOA>
  <FOA>29313.0467</FOA>
  <SatID>28874</SatID>
  <CN0>41.56188</CN0>
</Packet>
```


- END OF ANNEX M -

- END OF DOCUMENT -

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