SAR/Galileo Return Link Service – System and Operations Perspective

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ABSTRACT

The present paper will provide a detailed overview of the SAR/Galileo Return Link Service, starting from the mission perspective, to the system architecture and operational scenarios envisaged in the Return Link Service, describing also possible utilisation of the Return Link Message. In addition a description of the proposed protocol envisaged for coding the return link message request in the beacon alert message will be presented.

1. INTRODUCTION: THE SAR/GALILEO MISSION

GALILEO will provide a number of services through a combination of capabilities of the core system components and external service facilities. The main services that are planned to be provided by GALILEO are the following: Open Service (OS) implemented through two navigation signals separated in frequency; Safety of Life Service (SoL), which provides global integrity with a defined time to alarm limit; Commercial Service (CS), where encrypted data are available within the open signals to provide a commercial service; Public Regulated Service (PRS), which provides position and timing to specific government-designated users requiring a high continuity of service; and Search and Rescue Services (SAR). GALILEO, which will improve the time to detection and the accuracy of location of distress beacons over the current Search and Rescue services provided by COSPAS-SARSAT. It will also provide an acknowledgement to the user of the receipt of the distress message.

The implementation of the SAR/Galileo service and associated infrastructure is undertaken within the overall context of the Cospas-Sarsat MEOSAR programme.

One of the major innovations brought by GALILEO on the existing search and rescue service provided by Cospas-Sarsat is the capability to provide a Return Link Message to the beacons through the GALILEO navigation signal, acknowledging therefore the reception of the distress message sent by the beacon. The SAR/Galileo return link capability takes advantage of the fact that 406 MHz beacons equipped with a GALILEO navigation receiver will have an inherent 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 SAR payloads on board Galileo satellites are backward compatible with already deployed distress beacons and will detect the distress emissions worldwide. The SAR/Galileo forward link service (space segment and European MEOLUT) is intended to be provided over a *European SAR Coverage Area* defined as the sum of EU Member States (+ Norway and Switzerland) Search and Rescue areas of responsibility.

The SAR/Galileo return service is intended to be provided globally to all registered users equipped with Return Link Enabled Beacons.

2. SAR/GALILEO SERVICE ARCHITECTURE

2.1 System Architecture

Within the scope of the GALILEO FOC program, comprehensive infrastructure will be deployed to support the SAR/Galileo service.

The currently envisaged deployment for the SAR/Galileo FOC architecture is depicted on Figure 1 and includes the following facilities:

- 3 European MEOLUTs in networking configuration:
  - Upgrade of the IOV MEOLUT in Toulouse to full operational MEOLUT

    - 2 new MEOLUT procured and deployed at other location in Europe.

- 1 Return Link Service Provider: the current RSLP prototype is upgraded to an operational RLSP and is connected to the FMCC (nodal MCC for the Central DDR)
- 1 specific centralized facility – MEOLUT Tracking Coordination Facility (MTCF) – is set-up to ensure satellite tracking coordination between the operational MEOLUTs.

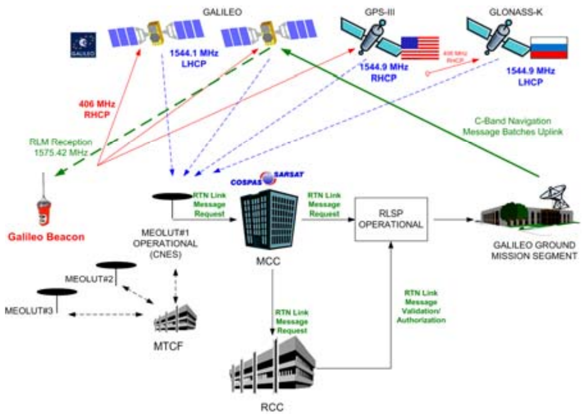

Figure 1: SAR/Galileo System Architecture

The deployed SAR/Galileo ground elements infrastructure will be connected and integrated within the C/S network of MCCs in order to provide support to the overall C/S Search And Rescue programme but also to benefit from the functions provided by the C/S network of MCCs. Therefore it makes sense to assume that the European MEOLUTs should be physically deployed at locations hosting already a C/S MCC.

The Return Link Service Provider will act as the central facility responsible for managing the return link message (RLM) request, originating from the beacons and the return link message to be sent back through the GALILEO system. The RLM requests are received by all the LUT, which can be a MEO-, LEO- or a GEO-LUT, and are forwarded to the Return Link Service Provider through the C/S network. The RLSP interfaces with the GALILEO Ground Mission Segment (GMS) to send the return link messages (RLM).

The Return Link Service Provider interface to the Galileo Ground Mission Segment through two network interfaces allowing Real Time and Non Real Time interface to the Message Generation Facility (MGF) and Service Product Facility (SPF) respectively as shown on Figure 2.

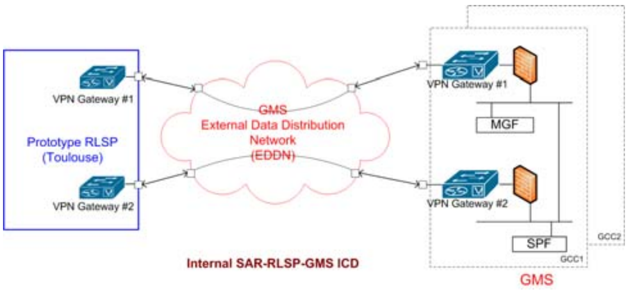

Figure 2: Real Time and Non Real Time Interfaces between the SAR RLSP and the Galileo GMS

The Real Time and Non Real Time interfaces between the RLSP and the GMS will support the following functionalities required for the operations of the Return Link service:

– To start and stop building RLMs on reception of relevant alert data (start if RLM request =1, stop if RLM request =0).
– To control and organise the RLMs flux to Galileo GS. A maximum data rate of 10 bits/s is allowed in each Navigation frame. The flux will be controlled by building a message queue according to a specified criteria (e.g. 1st in/1st out, type of distress, MCC/RCC, etc.).
– To verify “List of Galileo satellites to be used” for each RLM.
– To transmit RLMs with support information to Galileo GS for further transmission to MEOLUTs (e.g. satellite ephemerid, constellation status)
– To make Galileo GS aware to stop sending RLMs.

The infrastructure deployed for SAR/Galileo will be connected and integrated within the Cospas-Sarsat network of MCCs in order to support the overall C/S search and rescue programme, but also to benefit from the dissemination functions provided by the C/S network of MCCs. This is of particular importance in order to provide a means for relaying the Return Link Message request, received by the C/S network from the different LUTs, to the SAR/Galileo return link service provider.

3. SAR/Galileo Return Link Service Operational Concept

3.1 SAR/ Galileo Return Link Operations

From an operational point of view, the return link service of SAR/Galileo is articulated around two distinct steps: (1) Dissemination of the Return Link Message request to the RLSP through the C/S network of MCCs - The return link message request is encoded in the beacon alert message through an agreed coding method of which the current proposal is described in section 3.2; (2) Authorization of the Return Link Message transmission to the dedicated beacon through the GALILEO system. Figure 3 below shows the overall flowchart of the SAR/Galileo Return Link Service operational concept.

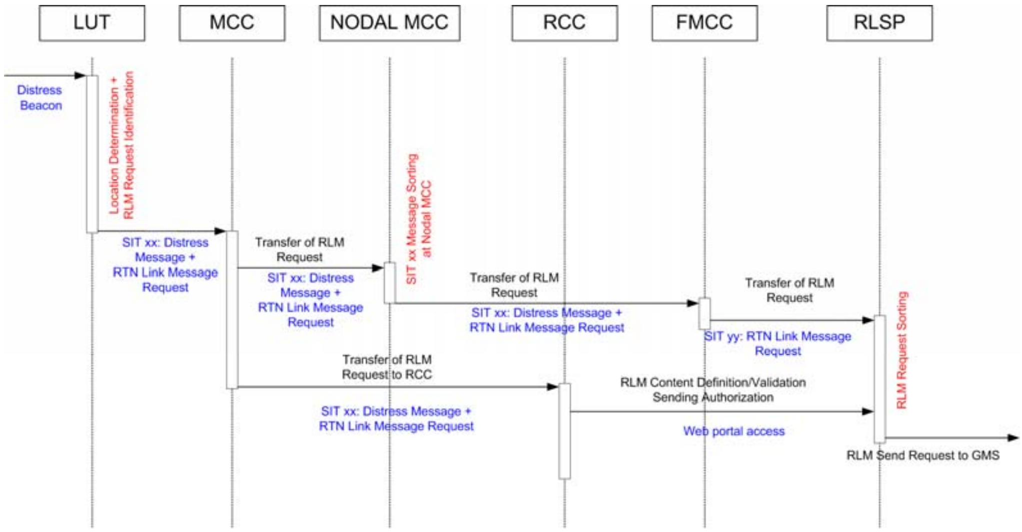

Figure 3: SAR/Galileo Return Link Service Operational Concept

Step 1: RLM Request Identification and Dissemination

At the IOC and FOC stages of the SAR Galileo deployment and MEOSAR System implementation, the identification data in the "SAR Galileo 406 MHz beacon" message will include a protocol code which can identify the 406 MHz transmission as coming from a beacon equipped with a SAR Galileo navigation receiver able to receive and process the SAR Return Link messages sent via the Galileo navigation signal.

This protocol will be fully compatible with the Cospas-Sarsat System and the so-called "SAR Galileo beacons" shall be first processed in the same way as the other Cospas-Sarsat Beacons. However building up a dedicated SIT 185-type would be required for letting the RCCs know that the alert transmitted involves a beacon able to receive the return link messages of the SAR/Galileo return link service.

In addition: the MCC in the Service area of which the confirmed location is situated should send to the French MCC, unique point of contact between the Cospas-Sarsat System and the SAR Galileo Return Link System, specific SIT messages providing the Return Link Service Provider (RLSP) with the Return Link System information included in the beacon message (RLM request, acknowledgment of the RLM receipt etc…). MCC data routing matrix III/A.8 [RD2] should be used for that purpose.

Step 2: Return Link Message Authorization

The second phase of the Return Link Service consists in the actual definition/ validation of the content of the Return Link Message to be sent to the beacon and the authorization of sending. This second phase will be initiated through another interface to the Return Link Service Provider (RLSP), so that Cospas-Sarsat shall not be responsible or involved in the actual authorization of the RTN link message (RLM) sending.

The RLSP will manage a comprehensive data base with the entire population Return Link enabled beacons and their RLM request status.

After notification of a return link message request (phase 1) with an open status (RLM Requested) the RCCs shall directly interface with the RLSP in order to validate or define the content of the RLM and to authorize the actual transmission of the RLM to beacons which have an open return link message request status. The RLSP will be then be responsible to transmit the RLM to the beacon (through the Galileo system) till the RLM Request status for that beacon is cancelled by the beacon or after timing out.

3.2 RLM Request Protocol Definition

Operational Protocol

The operational protocol for coding the Return Link Message request within the beacon forward link alert message is still pending approval of the Cospas-Sarsat community. The proposed solution shall provide sixteen newly available protocols for coding 406 MHz beacons optimized for the MEOSAR system operation, including the Galileo RLS-capable beacons.

The 406 MHz Beacons using the Galileo Return Link System will be identifiable by specific protocols based on and compatible with the National Location protocols (C/S T.001 – Annex A (Page A-29) Figure A9: National Location Protocol) The 00 pattern of bits 25 and 26 indicate that the beacon is encoded with one of the new MEOSAR protocols defined by the patterns of bits 37 to 40 (four bits).

Out of the sixteen newly available protocols, a subset of eight is reserved for the beacons having a Galileo Return Link capability:

- Four protocols for Return Link Beacons compatible with the present National Location Protocol.
  Format Code “00” (bits 25-26),
  Protocol codes (bits 37-40) :
  a) RL ELT 1000
  b) RL EPIRB 1010
  c) RL PLB 1011
  d) RL Test 1111
- Four Protocols (TBD) are reserved for future Return Link beacons compatible with the future Cospas-Sarsat Beacons “optimized for operation with the MEOSAR system”.

Test Protocol

In order to be able to validate the SAR/Galileo return link service in "operational-like" scenario, a RLM test user protocol has been defined which will be used for experimentation, demonstration and validation of the return link system developed by Galileo. It is a specific implementation of the standard Test User Protocol. Mission Control Centres (MCCs) will not forward messages coded with this protocol unless specifically requested by the authority conducting the test.

The currently defined beacon message structure (T.001) can be used to implement the basic Return Link Service functionality with minimum adaptations of the message structure (only one bit – the ARF, also known as the “RLM Request”, needs to be incorporated). Hence, for the purpose of demonstrating and validating the Galileo Return Link Service, it is proposed to use an existing user protocol with specific parts of the message dedicated to validating various functions of the RLS.

The structure and definition of the RLM Test Protocol (see [RD1] for more details) includes the following items to be included in the beacon message:

<u>Mandatory item</u>: This bit of information is necessary for the concept of the return link system to operate as envisaged. This one-bit flag indicates whether a return link message (RLM) has been received by this beacon or not.
Acknowledgement/Confirmation-of-Reception Flag (ARF, also known as the RLM-Request) – 1 bit.

0 - a RLM has been received by this beacon since it was activated

1 - no RLM received by this beacon since it was activated

<u>Optional items</u>: These are some of the items which might be considered for a future beacon dedicated to MEOSAR, and which can be used to demonstrate and experiment with various expanded uses of the RLS.

The definitions of the structure of operational message protocols, as they are defined now, do not allow the inclusion of (an) additional bit(s) to communicate item(s) related to the return link. For the demonstration and validation of the RLS service we therefore propose to use the Test User Protocol as defined in C/S T.001, which allows the transmission of arbitrary Test Beacon Data (46 bits) which can be suitably defined to demonstrate the RLM service without disturbance to the operations of the Cospas-Sarsat system or re-defining an operational message protocol structure.

The following bit assignment for the first protected data field (PDF-1) of the Test User Protocol represents a possible structure for an RLM test message:

RLM TEST USER PROTOCOL											
Bits	25	26	27 36	37 39	40 47	48	49	50	51 54	55 85
....	F	1	Country Code	1 1 1	Beacon ID	ARF	RBF	MDF	RRM	[TBD] Test Beacon Data (31 bits)

Proposed Return Link Message (RLM) Test User Protocol for RLS validation

6. TEST USER PROTOCOL					
Bits	25	26	27 36	37 39	40 85
....	F	1	Country Code	1 1 1	Test Beacon Data (46 bits)

Test User Protocol as defined by C/S T.001 (Figure A3)

Figure 4: Implementation of an RLM Test User Protocol within the standard Test User Protocol definition

3.3 Return Link Message Structure on Galileo L1 Signal

Basic Return Link Message Structure

Two types of RLM are defined: short RLMs (80 bits) and long RLMs (160 bits)

Each Return Link Message encapsulated in a SAR data page shall contain the following data:

- Beacon ID (60 bits) as defined in the C/S T.001 document [RD4]
- 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 discern whether the RLM received is addressed to that particular beacon or to some other beacon while the ‘Parameters’ field provides the information that SAR operators (namely the involved RCC) wish to send to the Galileo-equipped beacon.

Two classes of message types have been identified:

- the standard message type, where the first 60 bits are used as per CS T.001 Beacon ID, and
- the 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 specific alternative message (type C) is foreseen for broadcasting into an entire region (not to any specific beacon).

<u>Short-RLMs</u> are used to provide the activated Galileo-equipped beacon with a short acknowledgement.

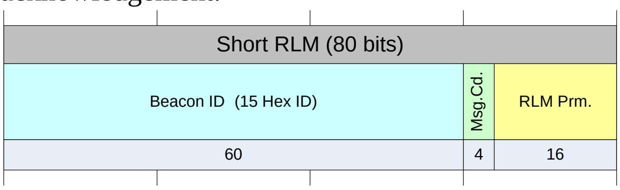

Figure 5: Short RLM structure

<u>Long-RLMs</u> are intended for more complex interactions, for which several parameters may be required.

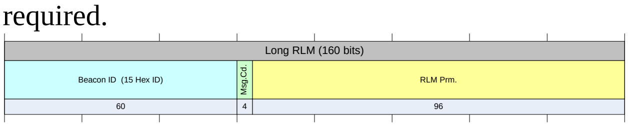

Figure 6: Long RLM structure

Definition of RLM Parameters

The detailed definition of the RLM parameters is still to be consolidated.

One bit, the last one, i.e. 16th in the short-RLM and 96th in the long-RLM, is dedicated for a final parity check. Indeed, even though the navigation data is broadcast with a very robust link margin, the RLM is assembled after a long and segmented reception period in four parts over 8s (short-RLM) or in 8 parts over 16s (long-RLM) within the Galileo L1 open signal. Considering the potentially very unfavourable and dynamically changing conditions, and a final, post-assembly check of the message validity seems appropriate.

The remaining 15 bits on the short message and 95 bits on the long message open up huge possibilities which will need to be associated to further definition of the return link service use cases.

3.4 Definition of the RLM Content

The definition of the content to be included in the RLM will be very dependent on the operational use cases of the Return Link Service. Indeed, besides the generic acknowledgment function, the Return Link Service could also be used for a number of additional use cases such as: automatic activation of a beacon to determine its position, automatic deactivation of a beacon when located in order to improve system capacity, etc…
The consolidation of the uses cases is still on-going and therefore a detailed definition of the content of the RLM cannot be provided at this stage. However, a number of principles can already be defined for the coding of the future content of the RLM.

Automatically generated Long-RLM

A message containing at least the position, intended in addition to the beacon (if it is capable of receiving it) also for general broadcast and reception by stand-by rescue services or nearby ships.

Positional information

It is estimated that using 41 bits would be commensurate with the location accuracy of a single-frequency L1 receiver (15m horizontal).

Total number of bits for location (m+k+2)	41 bits
(full range of lat/lon degrees broken into 2^m, 2^k steps)	
Latitude	20 bits
N/S	1 bit
Decimal degrees (0-90), m bits	19 bits
Angular resolution (step)	1.7E-04 deg
Angular resolution (step)	**0.6 sec**
N-S distance resolution	**19 m**
Longitude	21 bits
E/W	1 bit
Decimal degrees (0-180), k bits	20 bits
Angular resolution (step)	1.7E-04 deg
Angular resolution (step)	**0.6 sec**
E-W distance resolution step at Equator	**19 m**
at 30 deg latitude	*17 m*
at 45 deg latitude	***14 m***
at 65 deg latitude	*8 m*
at 80 deg latitude	*3 m*

Figure 7: Assignment of bits for location in RLM and related resolution step

Note that current Cospas-Sarsat location protocol defines position with an accuracy of 4 seconds, which is equivalent to 127m at Equator (due to a limitation in the number of available bits in the forward message). It is currently considered inadequate for location protocol beacons equipped with GNSS receivers (GPS L1 receivers have been used with 406MHz beacons and have been on the market for a number of years now)

Text message RLM coding

Freely generated Text Messages could be included as a special Long RLM. These could be encoded with the Modified-Baudot code. This is currently used by Cospas-Sarsat for Beacon ID coding, as it provides a better performance than ASCII (6 bits instead of 8 per character) for coding text messages. Up to 15-character messages could be transferred in a single Long-RLM.

RCC-ID

MMSI Maritime Mobile Service Identity (49 bits). An MMSI is a unique ID of each RCC. This ID allows a vessel taking the decision to start rescue operations, to contact the RCC of the RLM origin by usual maritime means (radio-telephone, fax, etc….) for purpose of rescue effort coordination.

Radius of search area

Radius of area searched in km (2-3 bits). The radius of search area is defined by the RCC, is coded and corresponds to a set radius (of e.g. 50, 100, 200 Nq).

General broadcast

Some categories of long-RLMs are to be processed primarily by Galileo Navigation receivers aboard ships (in case of maritime services) or other units in the relative vicinity of the distress, making them aware of the distress. Such units could be requested to participate to rescue operations under RCC coordination. The considered navigation receivers are to be always powered and active, decoding and displaying the received RLMs.

For this purpose, a specific Message code (for some RCC-related RLMs) may enable processing by Galileo receivers not embedded in SAR beacons. The RLM is visualised (distress beacon location + RCC-ID) only if the current position of the vessel (or other unit) is inside the radius of search area around the Beacon location. This is in order to avoid disturbance to boats far from the distress and hence not concerned by the implied request for assistance.

4. SAR/GALILEO RETURN LINK SERVICE VALIDATION PLAN

The SAR/Galileo Service implementation plan is presented on Figure 8 where relations are shown between the Cospas-Sarsat MEOSAR phases, the Galileo procurement activities and SAR/Galileo demonstrations activities.

The SAR/Galileo Return Link Service will be validated during the IOV and D&E phases of the Cospas-Sarsat MEOSAR Implementation Plan, following an incremental approach in order to take into account the constraints linked to the schedule of the Galileo infrastructure deployment but also constraints on the definition/implementation of the interfaces between the SAR/Galileo system and Cospas-Sarsat required for the operations of the Return Link Service (RLS):

- Availability of the SAR/Galileo MEOLUT and RLSP prototypes by mid 2009
- Deployment of Galileo IOV infrastructure by end of 2010
- Definition of the SAR/Galileo – C/S interfaces and validation with C/S network emulator (CSNE) by the end of 2010
- Implementation of the SAR/Galileo Return Link Service with selected MCC(s) partner(s) i.e. Detection by the C/S System and dissemination of the Return Link Service beacon information to the RLSP by the end of 2011.

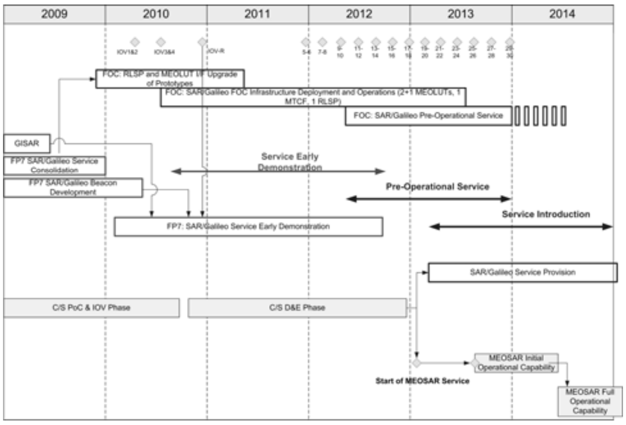

Figure 8: SAR/Galileo Service Implementation Plan

The SAR/Galileo Return Link Service Validation will follow and incremental approach articulated around 3 main phases:

1. Partial Return Link Demonstration in MEOSAR IOV Phase (within GISAR Project)
2. Full Return Link Demonstration in MEOSAR IOV Phase (within the Galileo IOV Validation Campaign)
3. Full End-to-End Return Link Service Demonstration in MEOSAR D&E Phase (within the Galileo FOC deployment programme)

4.1 Partial Return Link Service Demonstration in IOV Phase

The partial return link demonstration will be performed with the current SAR/Galileo MEOLUT and RLSP prototypes developed in the frame of the EU FP6 (6th Framework Programme) GISAR project and with the signals available from the DASS-POC satellites. Interfaces MEOLUT-C/S and C/S-RLSP will be emulated with the use of the Cospas-Sarsat Network Emulator (CSNE), emulating the interaction between the SAR/Galileo system and Cospas-Sarsat network.

Due to the unavailability at that time of the Galileo Ground Mission Segment, the Ground Mission Segment Emulator will service for the validation of the RLSP interface towards the Galileo core infrastructure.

Due to the unavailability of the Galileo IOV satellite, it will not be possible to relay the Return Link Message to the Galileo beacon (or pseudo Galileo beacon), and therefore the demonstration of the return link can only be partial.

The proposed architecture of the Return Link Service partial demonstration is depicted on Figure 9.

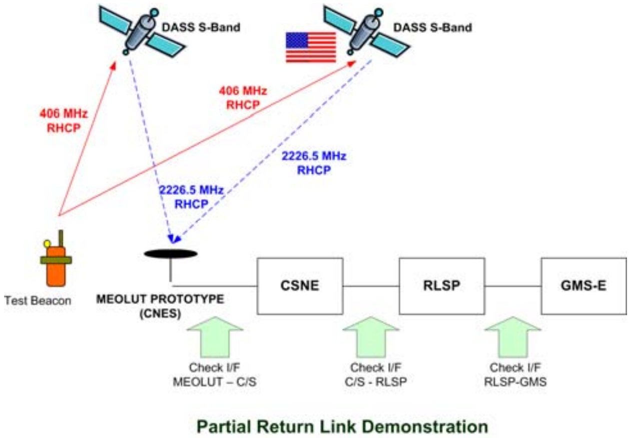

Figure 9: Phase 1 – Partial Return Link Demonstration

4.2 Full Return Link Service Demonstration in MEOSAR IOV Phase

The first full return link demonstration will be performed with the current SAR/Galileo MEOLUT and RLSP prototypes developed in the frame of the FP6 GISAR project and the Galileo IOV satellites (4 satellites).

The SAR/Galileo MEOLUT and RLSP prototype will be upgraded to reflect the latest evolutions brought in the interface definition between the SAR/Galileo component and the Cospas-Sarsat network. However at this stage the interfaces MEOLUT-C/S and C/S-RLSP will continue to be emulated with the use of the Cospas-Sarsat Network Emulator (CSNE) before being replaced in a later phase by a MCC (FMCC).

The deployed IOV Galileo infrastructure will be used to transmit the return link message back to the SAR/Galileo beacon. (or pseudo beacon in case the new beacon developments are not ready yet).

The proposed architecture of the Return Link Service full demonstration in MEOSAR IOV phase is depicted on Figure 10.

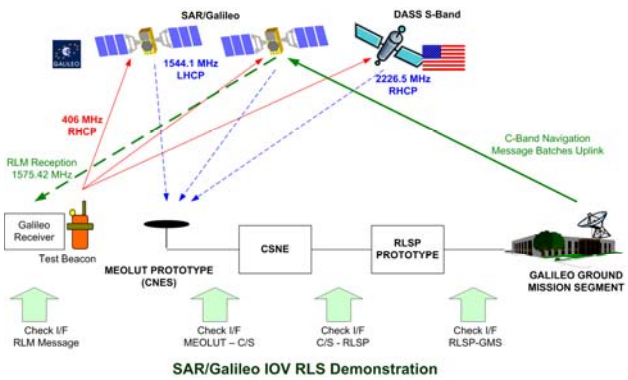

Figure 10: Phase 2 – Full Return Link Service Demonstration in MEOSAR IOV Phase

4.3 Full End–to–End Return Link Service Demonstration in MEOSAR D&E Phase

The full end-to-end return link demonstration will be performed with the operational SAR/Galileo MEOLUT and RLSP developed in the frame of the Galileo FOC programme and the Galileo IOV satellites (+ eventually the available newly deployed FOC satellites).

The Cospas-Sarsat Network Emulator (CSNE) used in the previous phase is replaced by the MCC on which the changes should be performed to implement the dissemination procedure described in Section 2. MCC upgrade should take into account the modifications for:

- Updated MEOLUT-MCC interface for Return Link Service beacon information [RLM request]
- Updated MCC-RLSP interface for Return Link Service beacon information [RLM request]
- Updated MCC-RCC interface for Return Link Service beacon information [RLM request]

A specific operational interface between the RCC and RLSP will also be deployed and validated.

The proposed architecture of the Return Link Service end-to-end demonstration in MEOSAR D&E phase is depicted on Figure 11.

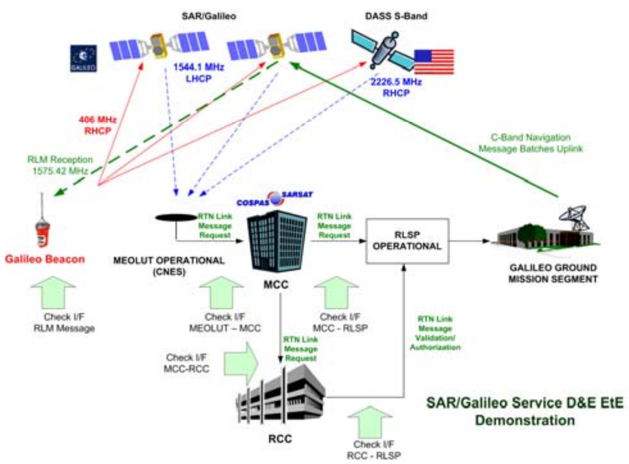

Figure 11: Phase 3 – Full Return Link Service Demonstration in MEOSAR D&E Phase

5. CONCLUSIONS

The present paper has provided a comprehensive description of the SAR/Galileo Return Link Service from a system and an operational perspective. SAR/Galileo return link service will open up the door to a new range of applications in the field of search and rescue. Obviously a number of aspects linked to the Use Cases definition of the return link service still need to be consolidated before details of the return link message can be finalized. In addition the involvement of the Cospas-Sarsat community will be of crucial importance in the validation of the RLS in particular to finalize the coding protocol and dissemination procedure of the return link message requests from the MEOLUT to the RLSP.

The procurement of the SAR/Galileo infrastructure will be started by the end of 2009 within the Galileo FOC programme in order to build up gradually the infrastructure by the end of 2013.
Finally, it has to be noted that EC is also initiating the development of the new types of beacons with return link capability, which will be used during the demonstration and evaluation test campaigns.

6. REFERENCES

[RD1] Cospas-Sarsat MEOSAR Implementation Plan – R.12, Issue 1.4, October 2008

[RD2] Cospas-Sarsat Data Distribution Plan – A.001, Issue 4.11, October 2008

[RD3] Galileo Open Service Signal In Space ICD, Draft

[RD4] Specification for 406 MHz Cospas-Sarsat Beacons – T.001, Issue 3.9, October 2008.