SAR/Galileo
A contribution to COSPAS-SARSAT MEOSAR

Eric Bouton

31/08/2022

Contents

Galileo Services

Open Service (OS)

- Navigation service available world wide
- Interoperable with other satellite systems
- Free of charge

High Accuracy Service (HAS)

- OS Horizontal accuracy < 2 m (Dual Frequency, 95%)
- HAS Horizontal accuracy < 0.2 m (95%)

OSNMA (testing phase)

- verifies the authenticity of the received navigation data
- Key applications: digital tachography, transport of goods fleet management, etc.

Public Regulated Service (PRS)

- Navigation service for Governmental users
- Robust and encrypted signals

Search and Rescue (SAR)

- European contribution to Cospas-Sarsat
- Free of charge
- Worldwide coverage
- 2 Services: ALERT & Acknowledgement (RLS)

SAR: A Galileo service

The EU Council of December 2004 confirmed the main characteristics of the Galileo system and the services it will offer.

The GALLILEO Search and Rescue service (**SAR/Galileo**) was defined as one of the Galileo services, as follows …

- The Galileo system shall provide a Search and Rescue service by performing the detection and localization of Cospas-Sarsat 406 MHz beacons ⇨ **SAR/Galileo ALERT Service** (aka Forward Link Service).
- The SAR/Galileo service shall provide a return link capability to distress beacons
  ⇨ **SAR/Galileo Acknowledgement Service** (aka Return Link Service).
- The GALILEO SAR mission shall be an integral component of **Cospas-Sarsat MEOSAR** initiative.
- SAR/Galileo shall be capable of contributing to a **self-standing** SAR service, not crucially relying on other GNSS constellations.

The Return Link Service is a novel SAR initiative by GALILEO.

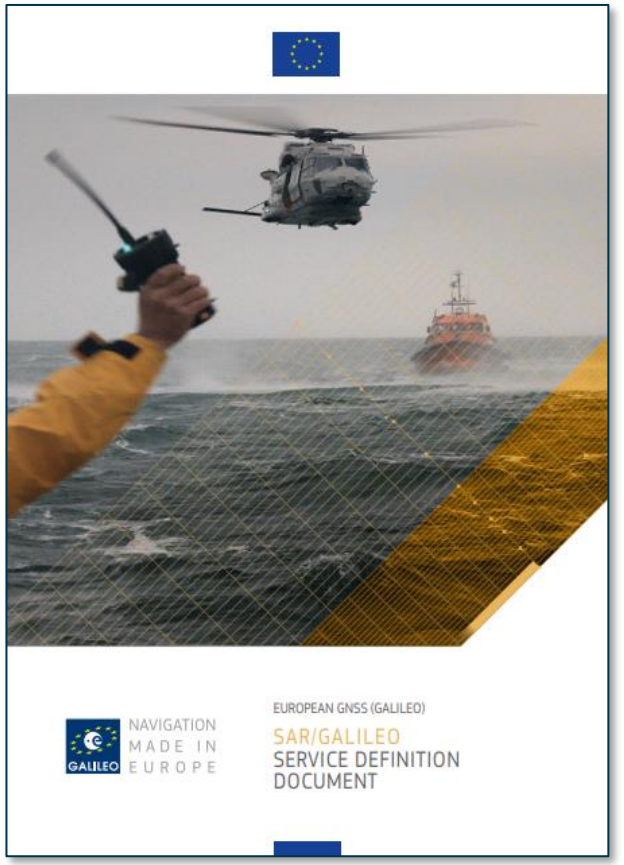
Initial Services Provision – Alert Service

2016 DECEMBER						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Search and Rescue (SAR/Galileo)
European Contribution to C/S

- Alert Service (FL)
- Return Link Service (Ackn.)

Galileo Search and Rescue SDD
Service Definition Document
Initial Service: Version 1.0, December 2016
Enhanced Service: 2.0, January 2020



Initial Services Provision – Acknowledgement Service

JANUARY 2020

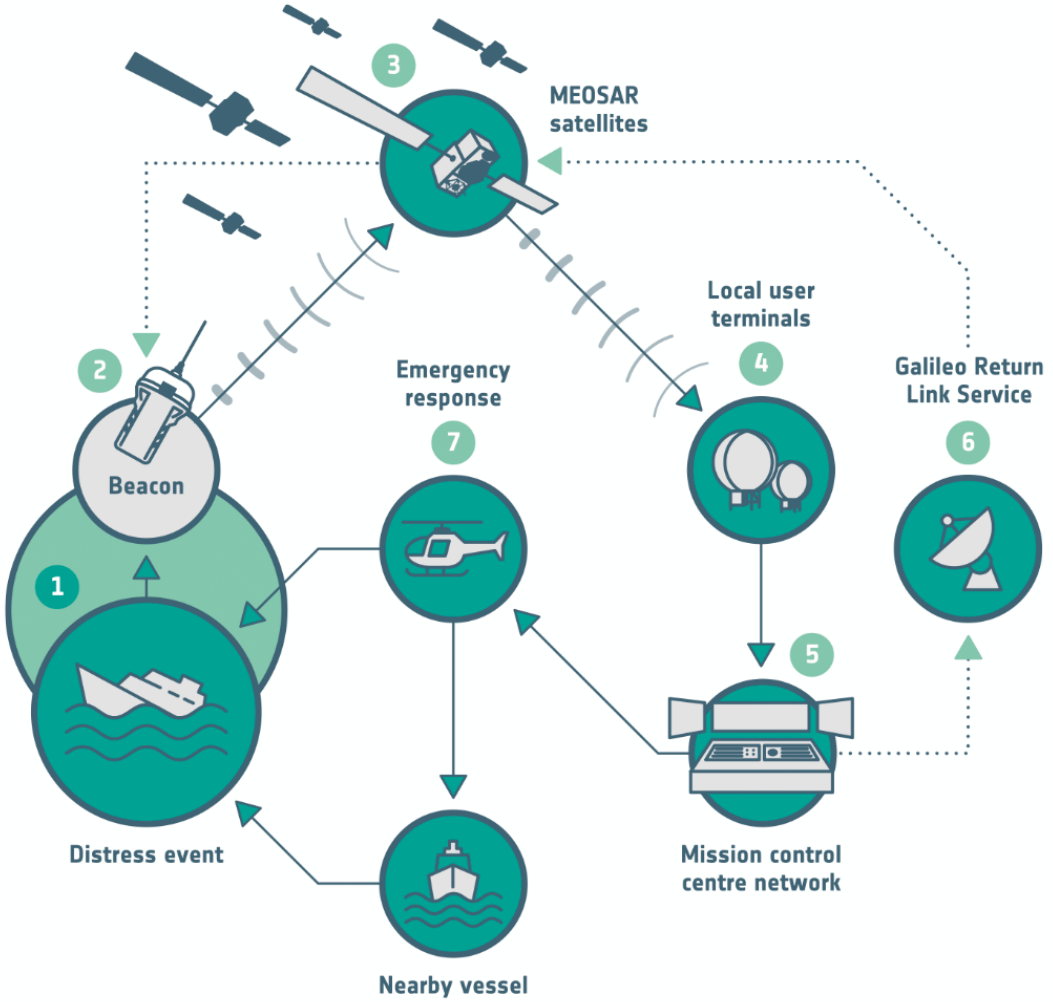
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Search and Rescue (SAR/Galileo)
European Contribution to C/S

- Alert Service (FL)
- Return Link Service (Ackn.)

SAR/Galileo Forward and Return Link Service

SAR/Galileo is a major contributor to the COSPAS-SARSAT system



The SAR/Galileo **Forward Link Service (FLS)** detects and locates distress alerts worldwide and passes this information to associated Mission Control Centres (MCC), which in turn inform national Rescue Coordination Centres (RCC).

The **Return Link Service** (RLS), available only through Galileo and declared in FOC by C/S, provides an automatic message is sent to the beacon **acknowledging** that the localisation of the alert has been confirmed by the Cospas-Sarsat system.

1. An accident at sea, in the air or on land.
2. Ships, planes, hikers or drivers in remote areas can carry these radio transmitters, which can be activated in a life-threatening emergency, sending a **distress alert message.**
3. The Cospas-Sarsat MEOSAR system, involving satellites of international partners and with worldwide coverage, provides fast detection and location services. A distress signal can be picked up and relayed by several MEOSAR satellites within seconds.
4. Cospas-Sarsat's local user terminals receive the signal and rapidly share the data with a mission control centre network.
5. The mission control centre network meanwhile processes the data and channels it to a national rescue coordination centre and also to the Galileo Return Link Service Provider.
6. This service quickly transmits a signal, via Galileo satellites, back to the beacon that made the distress call. **This lets the user know their message has been received**.
7. Local emergency services are alerted. Sometimes it is also possible to alert nearby vessels at sea.

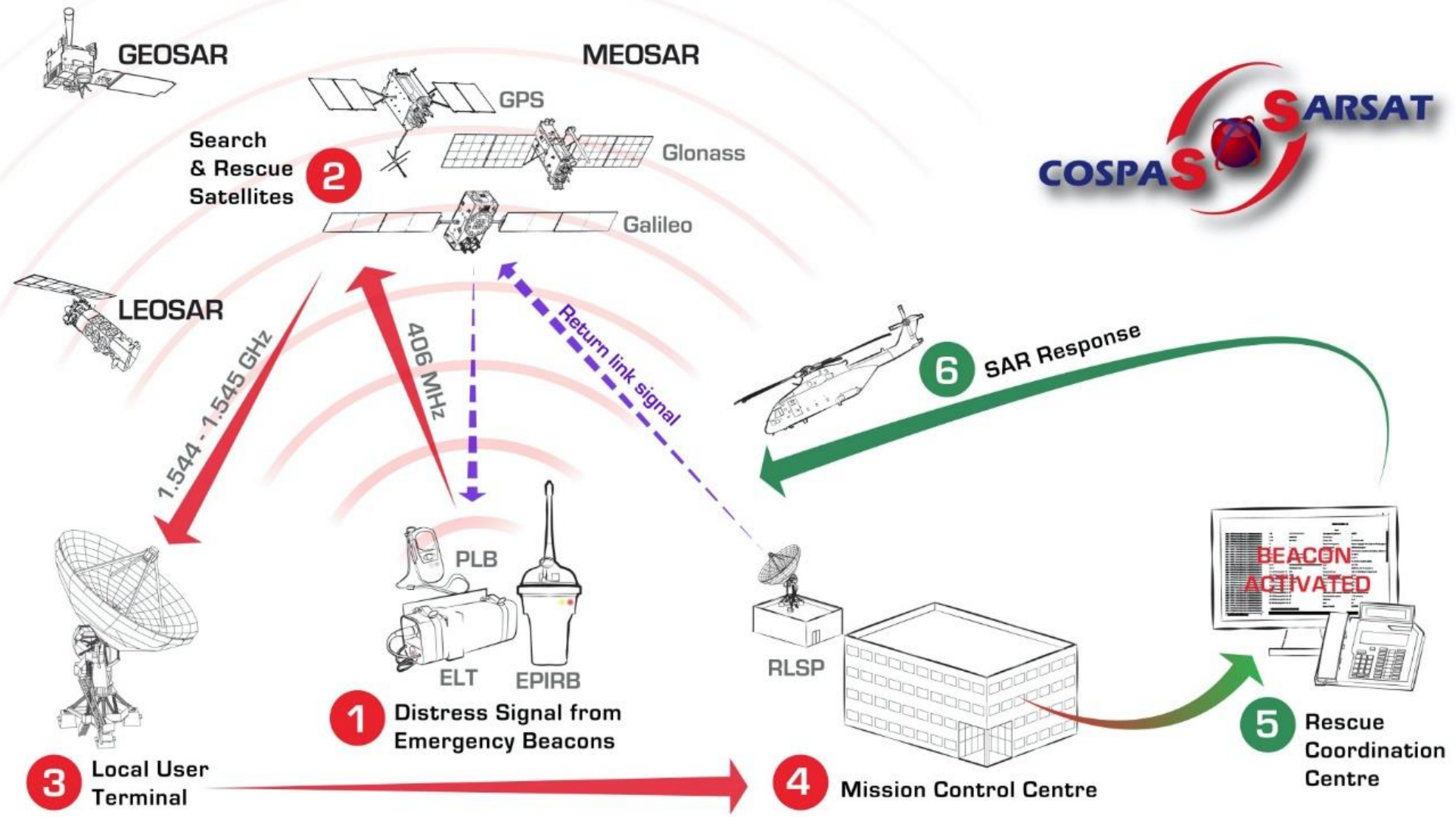
In 2020, alert and location data provided by the Cospas-Sarsat System assisted SAR forces in **951 '406-MHz' events**, helping them to **rescue 2278 persons.**

Synergy of Satellite Navigation and Search & Rescue

Orbits: Optimised for Tri-lateration

- Same satellites can be used to:
  - Receive signals from beacons
  - Transmit signals to receivers in beacons
- Receivers in beacons can be used to:
  - Determine own (beacon) position
  - Receive SAR-related messages (RLS messages)

MEOSAR


GEOSAR
MEOSAR
GPS
Glonass
Galileo
Search
& Rescue
Satellites
2
LEOSAR
COSPAS SARSAT
1.544 - 1.545 GHz
406 MHz
Return link signal
6
SAR Response
PLB
ELT
EPIRB
1
Distress Signal from
Emergency Beacons
RLSP
BEACON
ACTIVATED
3
Local User
Terminal
4
Mission Control Centre
5
Rescue
Coordination
Centre

SAR/Galileo Service – part of MEOSAR

COSPAS-SARSAT MEOSAR system advantages

- **MEOSAR : Based on interoperable transparent SAR instruments on board**
  - Galileo, GPS, Glonass and BDS satellites – the 4 GNSS constellations

- **MEOSAR : A major evolution of the COSPAS-SARSAT system**
  - Significant performance improvement with regards to LEO and GEO
  - Near-instantaneous worldwide detection
  - Improved location accuracy
  - Significantly reduced effect of terrain/wreckage or sea-state obstructions
  - Extensive redundancy both in Space and Ground Segments
  - Acknowledgement of reception and localization of alert
  - [Future introduction of new, second generation beacons – enabled by MEOSAR]

MEOSAR advantages for the SAR community

Goal: To facilitate fast and reliable ALERTING (informing) Rescue Coordination Centres that there is an EMERGENCY and where it is LOCATED.

Faster detection and better

ALERT localization accuracy.

Acknowledgement of receipt

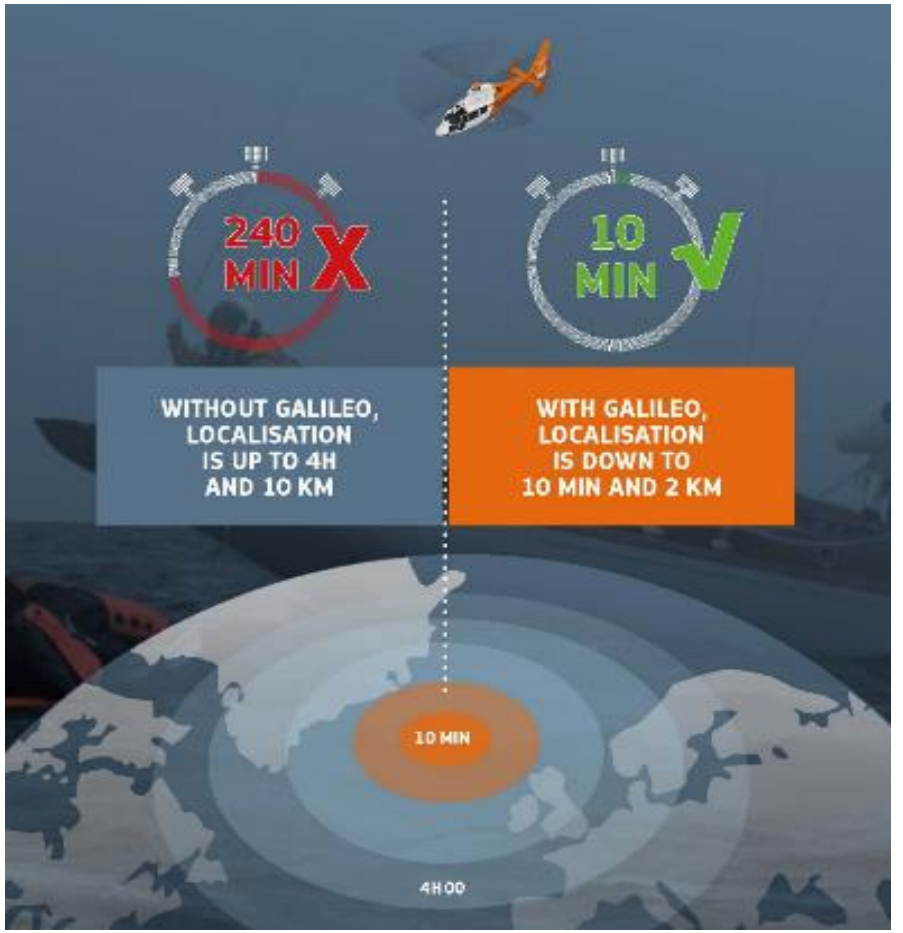
=

Improved effectiveness of rescue operations

=

Improved psychological state and will of persons in distress

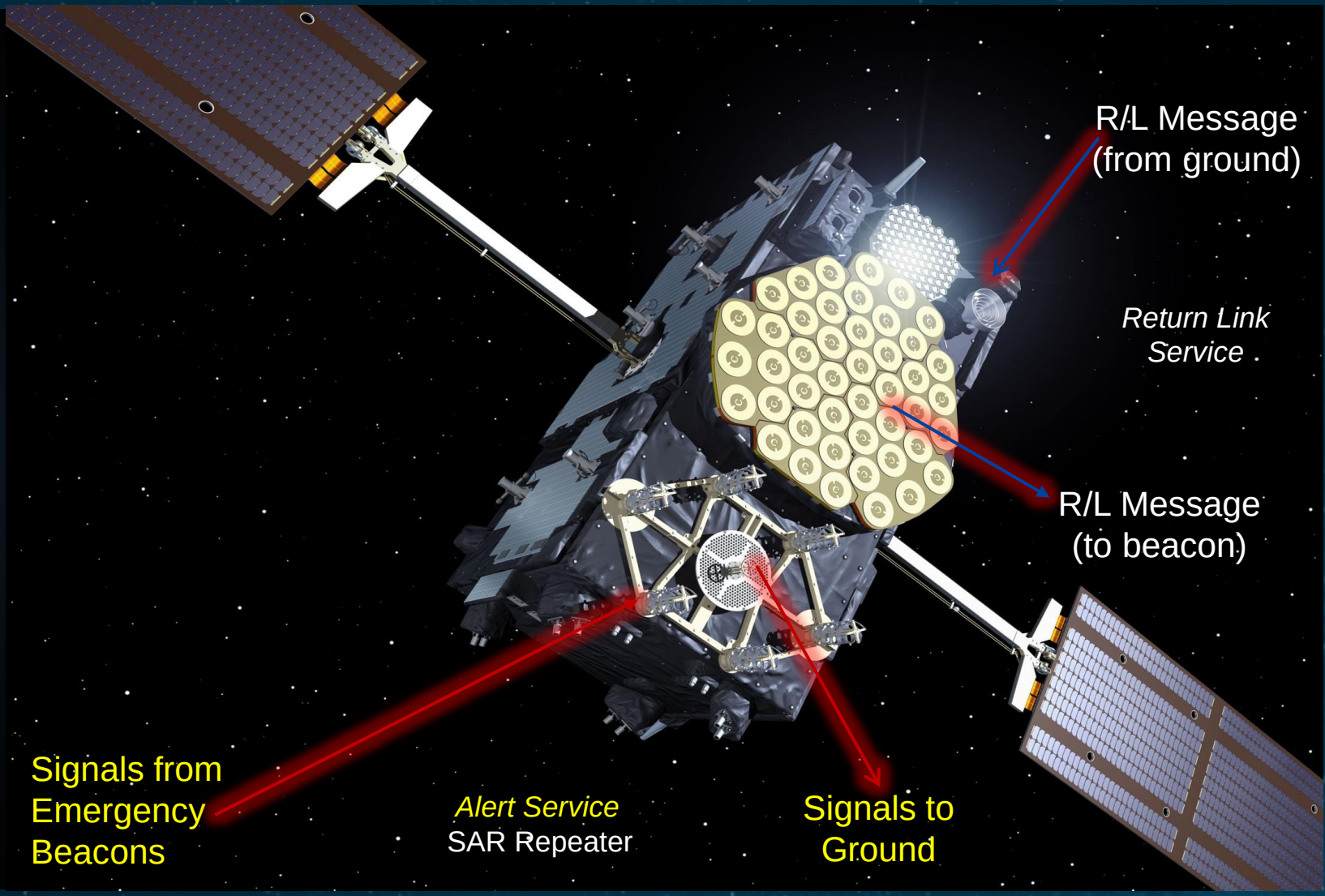
WHAT IS THE GALILEO CONTRIBUTION ?



Galileo Infrastructure

SAR/Galileo Space Segment

24 payloads provided by Galileo



SAR/Galileo Ground Segment

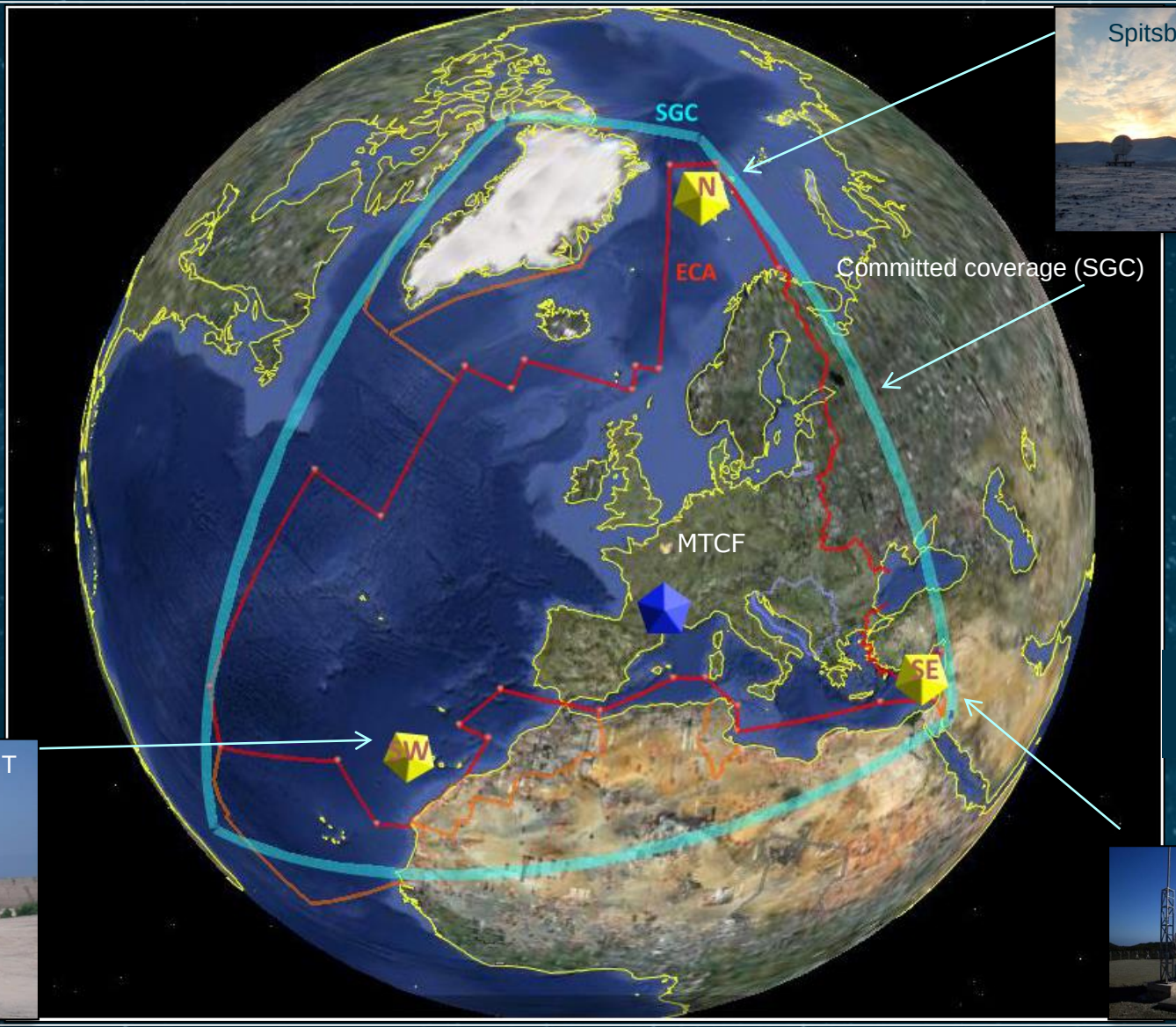
MTCF (Toulouse)
MEOLUT Tracking and Coordination Facility
Monitoring of facilities
Data Archiving
KPI Collection Processor

3 MEOLUTs
Detection and location of alerts

7 Reference Beacons
Provision of signals for performance monitoring
- Toulouse
- Longyearbyen (Svalbard)
- Santa Maria (Azores)
- Maspalomas (Canary Islands)
- Larnaca (Cyprus)
- Greenland (Sondrestom Fjord)
- La Reunion (Indian Ocean)

Calibration Beacons
Enable system calibration in orbit

SAR Server
Provision of precise orbital data to MEOLUTs



Committed coverage (SGC)

MEOLUT NEXT
in La Reunion with array antenna
(all satellites in view tracked)
Under commissioning

The Return Link Service

What is the Return Link Service

- The SAR RL Service is:
  - A means to provide short messages to beacons.
  - Different services available:
    - **Automatic** acknowledgements:
      - **MCC** Acknowledges successful reception of the alert by the MEOSAR system (**type 1 ACK**).
    - **Manual**, human-generated specific messages:
      - RCC Acknowledges, e.g. that help is on the way (**message service**)
      - **Command service (BCS)**, e.g.:
        - **Activate beacons remotely – RBA** (e.g. on missing vessels)
        - **Turn off beacons**
        - Change transmission power or burst rate …
      - **Distress position sharing (DPS)**
    - A different service (not SAR): **Emergency Warning Service (EWS)**

The Overall View of the GALILEO Return Link

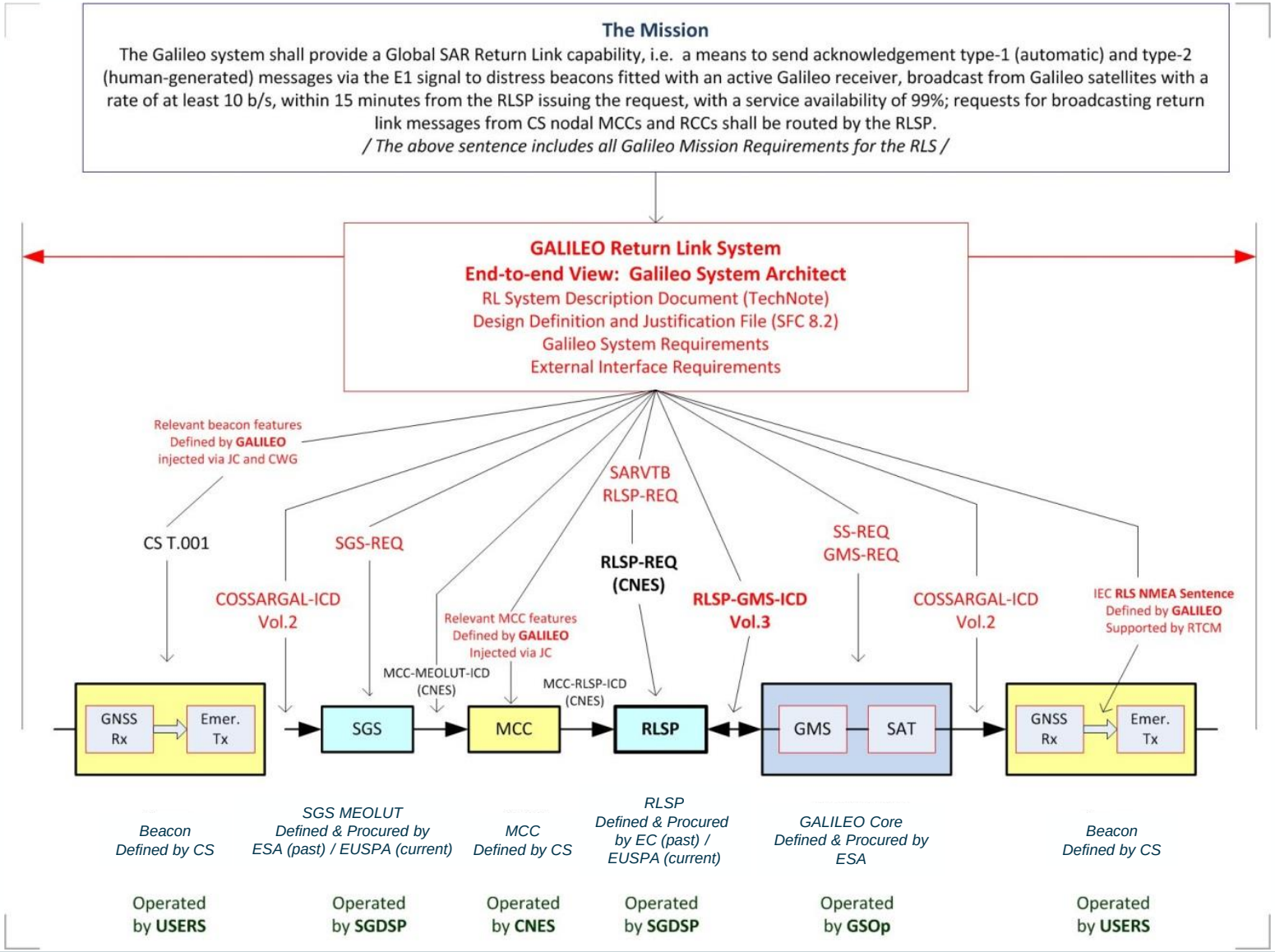
- Procurement of different parts of the GALILEO RL System

  With the engagement of :

  - EC
  - ESA
  - EUSPA
  - SGDSP/CNES
  - *Cospas-Sarsat*

- Overall View

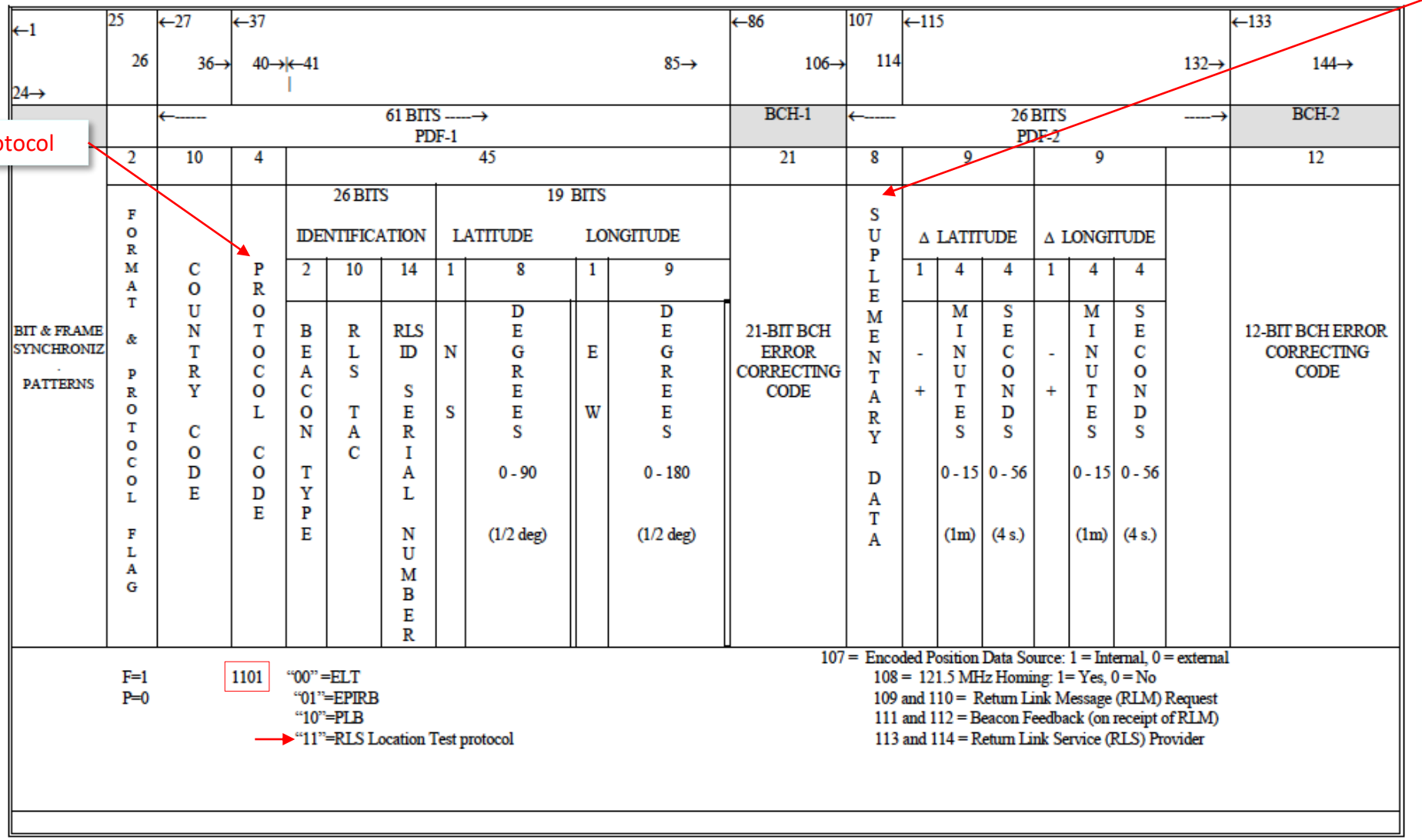
  The system architect in this complex environment ensures that all elements of the system are allocated the functions and performances that they need to have for the system to work as required by the Mission.



RLS Location Protocol (T.001 Beacon)

Bits 109-114: RLS Data

1101: RLS Location Protocol



Return Link Message… where are the bits located

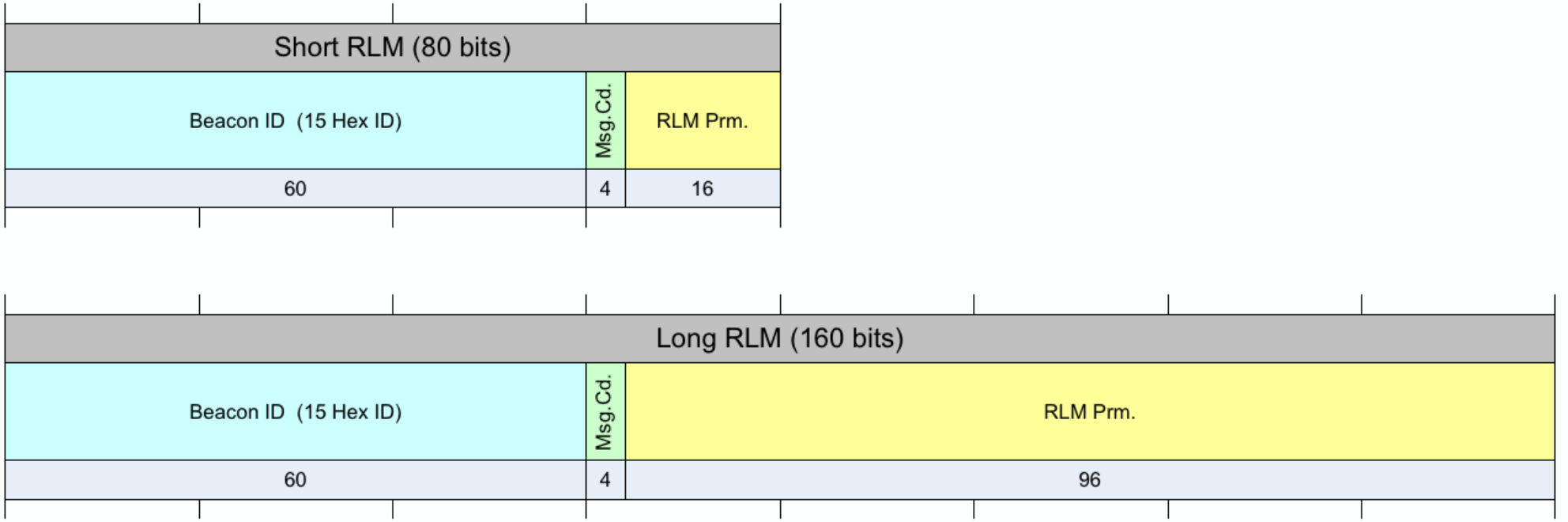
Structure and encapsulation

RLM

Message sent by the Galileo system to the beacon through the Galileo E1 signal (1575.42 MHz)

Defined in Galileo Open Service Signal in Space ICD

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



RLS Message Structure (short RLM)

SAR Data			Total (bits)
Start Bit	Short/Long RLM Identifier	SAR RLM Data	
1	1	20	22

Table 52. SAR Field Bit Structure

E1-B									
Even/odd=1	Page Type	Data j (2/2)	Reserved 1	SAR	Spare	CRCj	Reserved 2	Tail	Total (bits)
1	1	16	40	22	2	24	8	6	120

Part (1/4)			Part (2/4)			Part (3/4)			Part (4/4)			
Start bit = 1	Short RLM	SAR RLM data: Beacon ID (1/3)	Start bit = 0	Short RLM	SAR RLM data: Beacon ID (2/3)	Start bit = 0	Short RLM	SAR RLM data: Beacon ID (3/3)	Start bit = 0	Short RLM	SAR RLM data: Message code	SAR RLM data: Parameters
1	1	20	1	1	20	1	1	20	1	1	4	16
22			22			22			22			

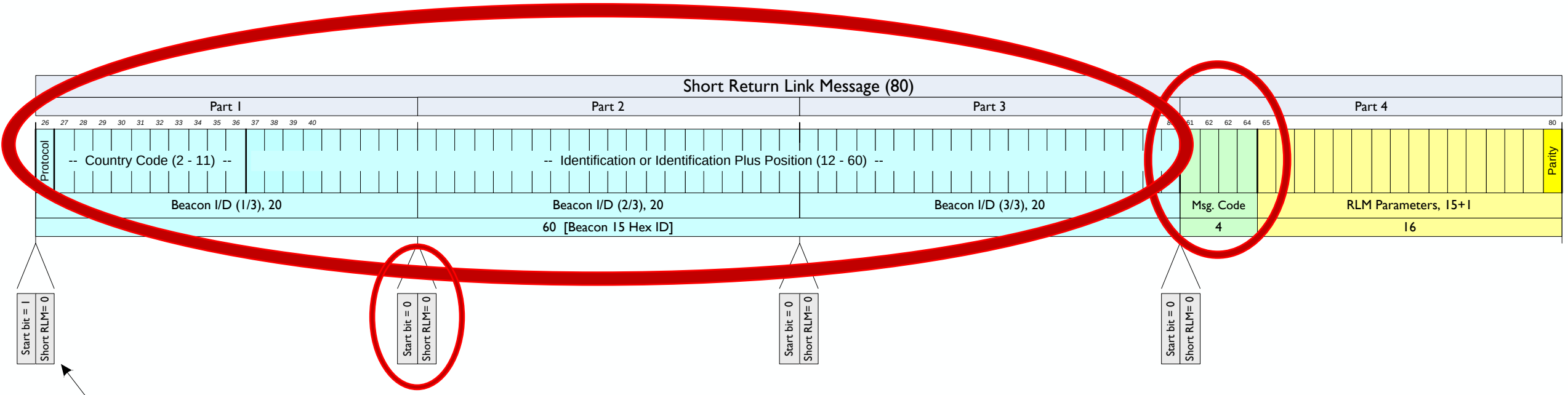
Table 54. SAR Short RLM

EUROPEAN GNSS (GALILEO) OPEN SERVICE

SIGNAL-IN-SPACE
INTERFACE CONTROL
DOCUMENT

OS SIS ICD, Issue 1.3, December 2016

RLS Message Structure (short RLM)



Bits slotted in SIS encapsulation

Italicised bit numbers refer to bits of the beacon message.

Beacon ID (identifies addressed beacon):

This is a repetition of the 60 bit (15 Hex) beacon ID as defined by the C/S T.001 document. This field uniquely distinguishes a beacon and represents the identification of the beacon to which the RLM is addressed.
The Beacon ID field consists of:
Protocol Flag (1 bit), 1= User Protocols; 0 = other.
ITU Country Code (10 bits).
Beacon identification/position (49 bits), specified in C/S T.001 Annex A.

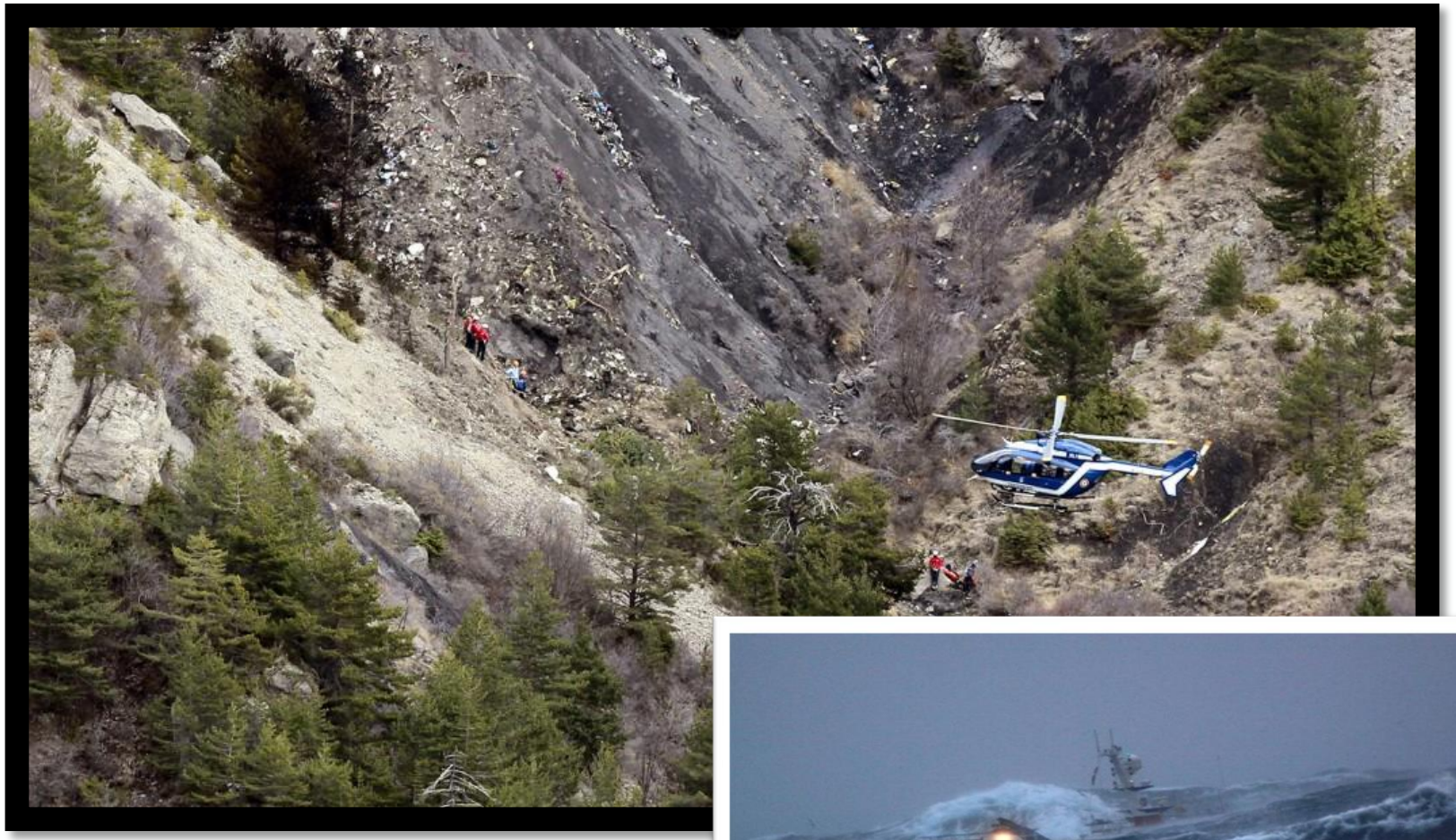
RLM	Message Code (4 bits)	Return Link Service
Short-RLM	0 0 0 1	Acknowledgement Service
Short-RLM	1 1 1 1	Test Service
Short-RLM	Other codes	Spare
Long-RLM	All codes to be defined	Spare

Table 78. SAR RLM Message Code Values

Satellite Selection

Satellite Selection Strategy

- Beacons in distress may be subject to unpredictable and arbitrary positions and particular surroundings, depending on the type of emergency
  - Harsh weather: sandstorms, heavy rain…
  - Blocking: listing ships, crashed aircraft, big waves, mountains...
- RLM delivery can be compromised:
  - Strategy of selecting two satellites with elevation closest to 90° may not be the most adequate because selection of correlated satellite-beacon paths does not improve deliverability.
- Objectives:
  - Improve the probability that the RLM is delivered to the beacon by improving the satellite selection strategy.



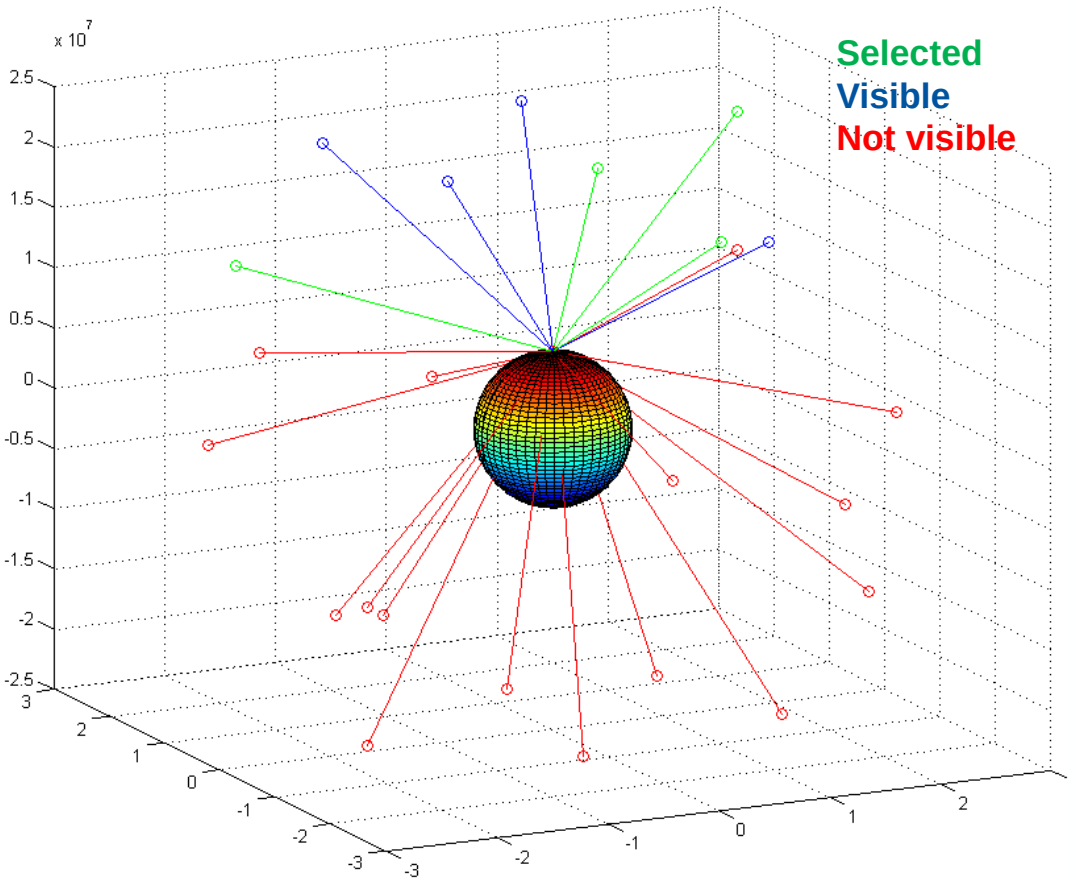
Satellite Selection Strategy

Possible strategy…

- Set up N_{sat} number of satellites to disseminate RLMs (typically 2, but could be more if circumstances allow).
- Set up minimum elevation angle E_{min} for dissemination.
- Choose satellite in contact with elevation with respect to beacon position closer to 90 degrees.
- Choose Nsat-1 satellite to disseminate, from the ones in contact according to:

  Vectors satellite to beacon should be as different as possible to increase the probability of delivering the RLM.

  Computed through covariance matrix of unitary satellite-beacon vector components.



Return Link Message Reception

RLM reception at the distress beacon

The RLMs message will be sent nominally through 2 satellites in visibility of the beacon. The choice of the satellite is made by the RLSP based on the beacon location information and perceived link quality

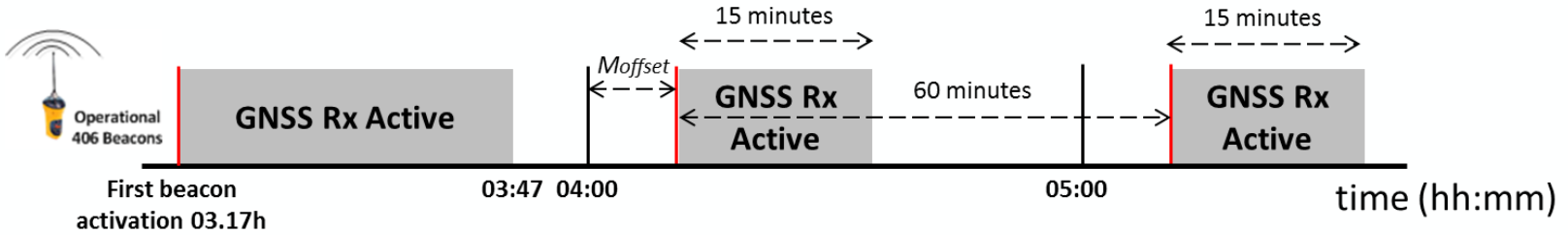
The beacon cannot know a priori which satellites will be used for RLM transmission → needs to track all Galileo satellites in view

The GNSS receiver in the beacon must be maintained ON during certain periods to ensure the reception of the RLM (activation sequence is described in Cospas-Sarsat Documentation)

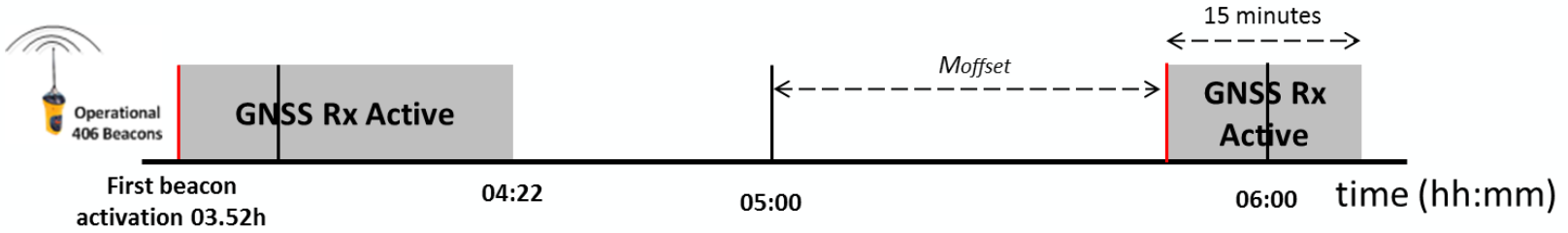
Upon Reception of the Return Link Message, the Beacon will modify its forward link alert message (FLAM) to indicate to the system that the RLM has been received (e.g. to trigger the end of the RLM transmission by Galileo)

Timing Strategies for Galileo Receivers in Beacons

M_{offset} is a number generated from the Beacon ID



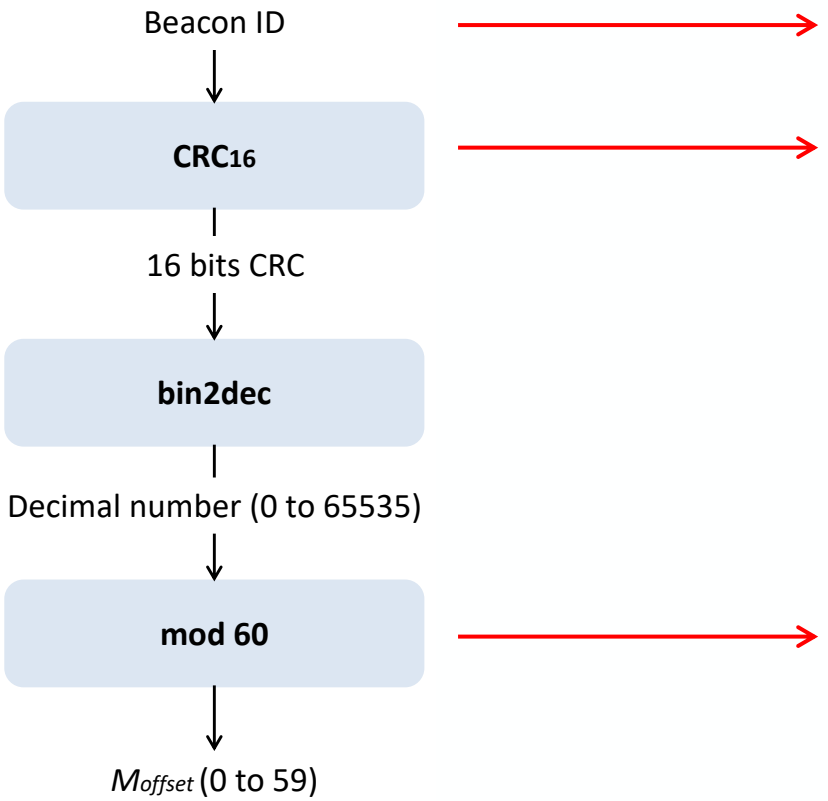
- Activation strategy carried out for 24h.
- M_{offset} value per beacon derived from the 15 HEX ID providing a uniform distribution:



M_{offset} **= BIN2DEC(CRC16(**Beacon_ID)) **mod** 60

Beacon GALILEO Rx Activation Strategy

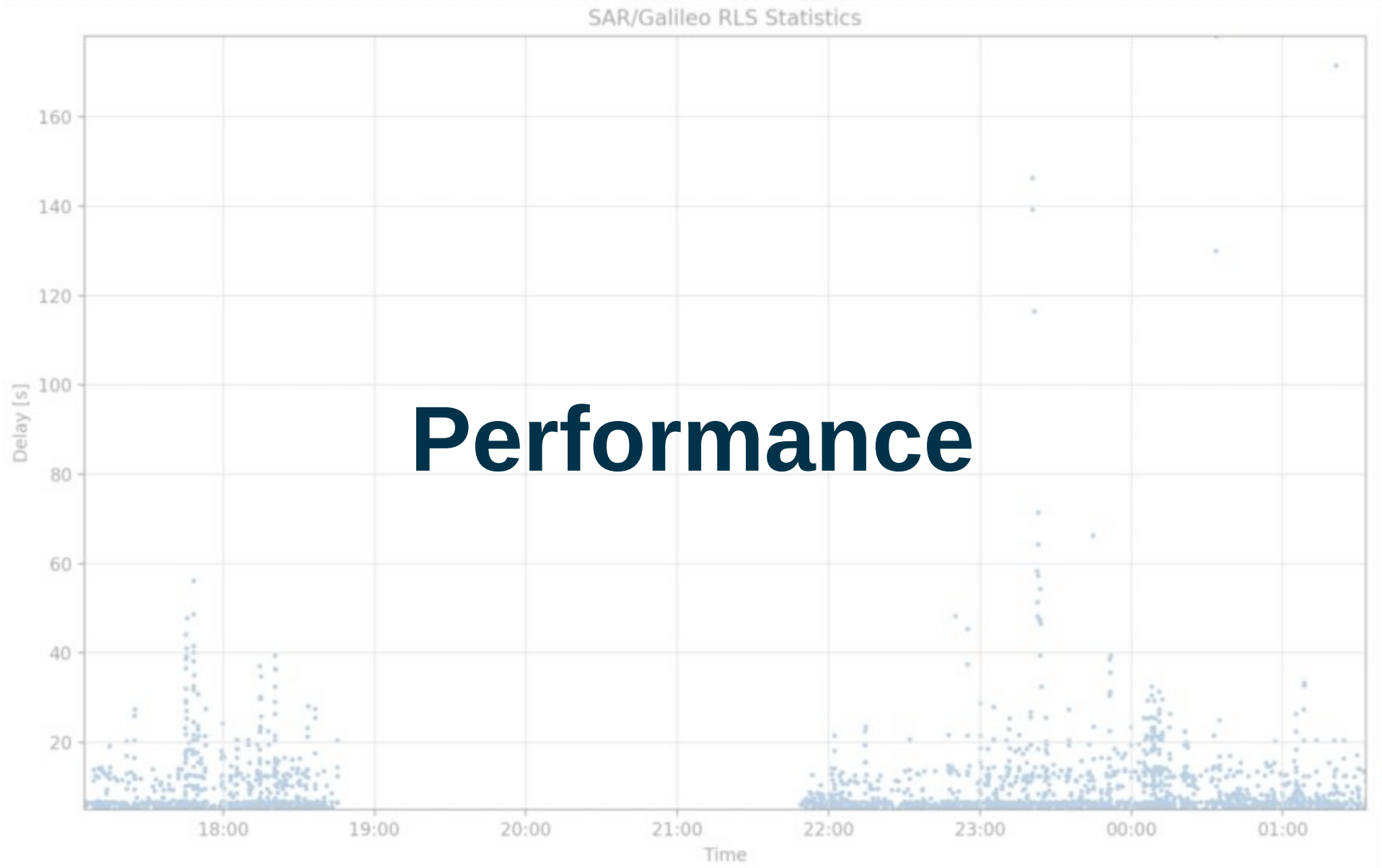
Proposed strategy, but manufacturer can exceed this



Unique 60-bit value available at the BEACON, at the RLSP (and at GMS, MCC)

CRC function ensures randomized outputs even for correlated inputs

Modulo 60 provides M_{offset} (0 : 59)



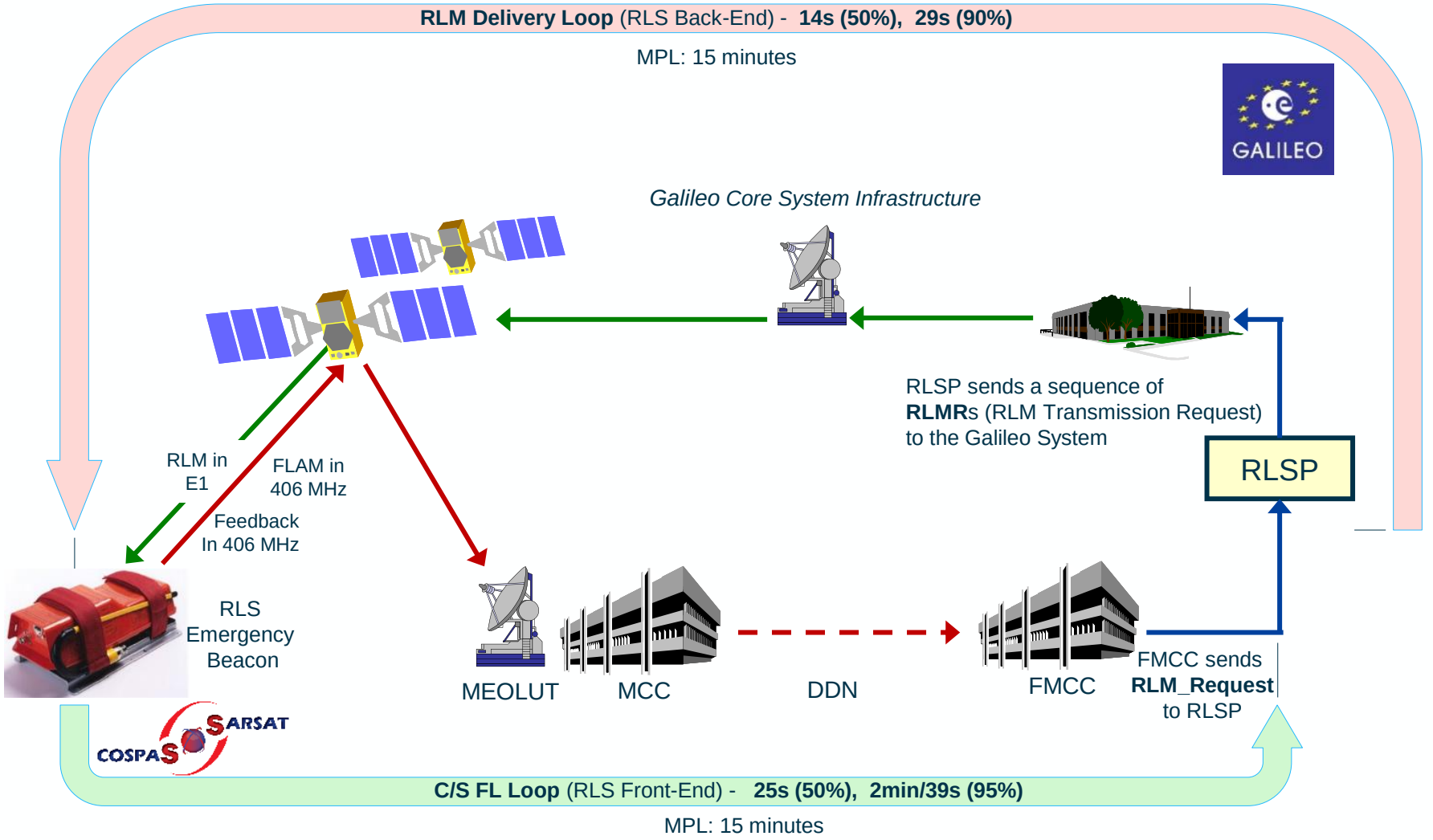
Performance

SAR/Galileo Performance

Performance parameter (monthly, December 2020)	MPL	Observed typical
% of transmitted bursts that are detected by at least one MEOLUT	>99%	>99.8%
Location probability after 1 transmitted burst	>90%	>99.6%
Location probability after 12 transmitted bursts **~10 min**	>98%	>99.9%
Location accuracy within 5km after 1 transmitted burst	>90%	>98.9%
Location accuracy within 5 km after 12 transmitted bursts **~10 min**	>95%	>99.6%
Location accuracy within 2 km after 12 transmitted bursts **~10 min**	>90%	>93.2%
Return Link Message delivery latency < 15 min	>99%	>99.7%
Return Link Message reception probability	>99%	>99.7%
SAR Server (for orbital data provision)	-	>99.3%

Performance: RLM delivery latency

Test results under extreme loading conditions



New Services

New SAR/Galileo Services based on RLS

What is in the pipeline? 4 new services using I/NAV data, with different levels of maturity

- The Return Link Channel / INAV data opportunities can be used beyond the provision of acknowledgements:
  - Low bit rate (10 bits/s); Short messages (80 or 160 bits)
  - Global coverage; Reliable (multiple satellites, available with no ground infrastructure)
- **Beacon Command Service** for Remote Beacon Activation/Deactivation (BCS-RBA) – *Standard published*
  - Use of RLS to activate beacons remotely in case of disappearance, non-responsive crew, high jacking.
  - **The European Organisation for Civil Aviation Equipment (EUROCAE)** WG98-SG1 developed a Minimum Aviation System Performance Standards (MASPS) for remote activation of ELT-DT
- **Two Way Communication** (TWC) – *Demonstration project ongoing*
  - Based on pre-defined coded messages, using RLS channel for the query and FLS for the response.
- **Distress Position Sharing** (DPS) – *Under consideration*
  - Broadcasting distress position using the RLS channel to Galileo receivers (beacons, other devices) in a selected area or within a predefined group.
- **Emergency Warning Service (EWS)** – *Implementation under preparation*
  - Broadcasting emergency warning messages to the public (Galileo receivers)
  - To a specific geographical area; data in INAV E1 and E5 (TBC)
  - Available when no other (terrestrial) means of public addressing is available

Remote Beacon Activation Service (BCS-RBA)

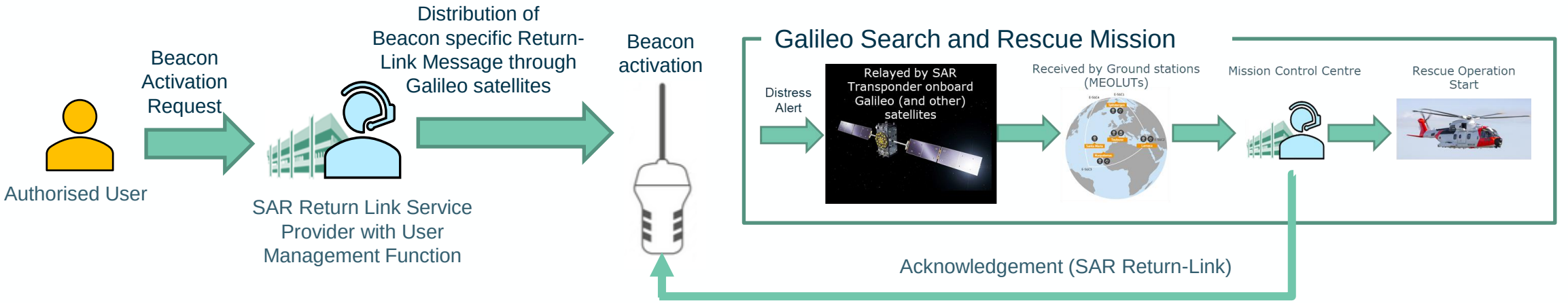
An implementation of the Beacon Commanding Service

- What if a user in a distress situation is not (any longer) able to operate their SAR beacon?

Flight MH370, last contact 08/03/2014

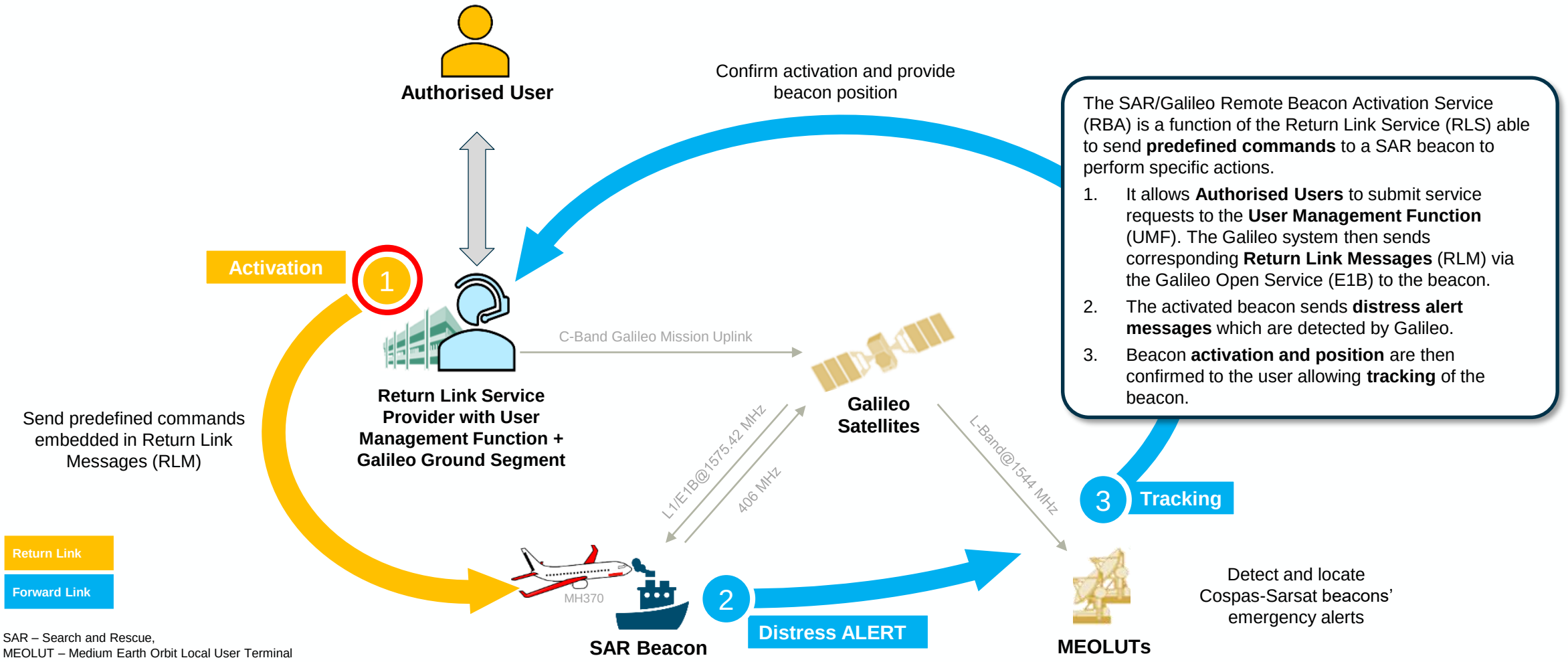
Galileo BCS-RBA would have been of great value for the localisation of flight MH370 that disappeared on 08/03/2014 on its flight from Kuala Lumpur to Beijing

➔ Remote Beacon Activation (RBA) – planned as new capability in Galileo



Remote Beacon Activation Service (BCS-RBA)

An implementation of the Beacon Commanding Service



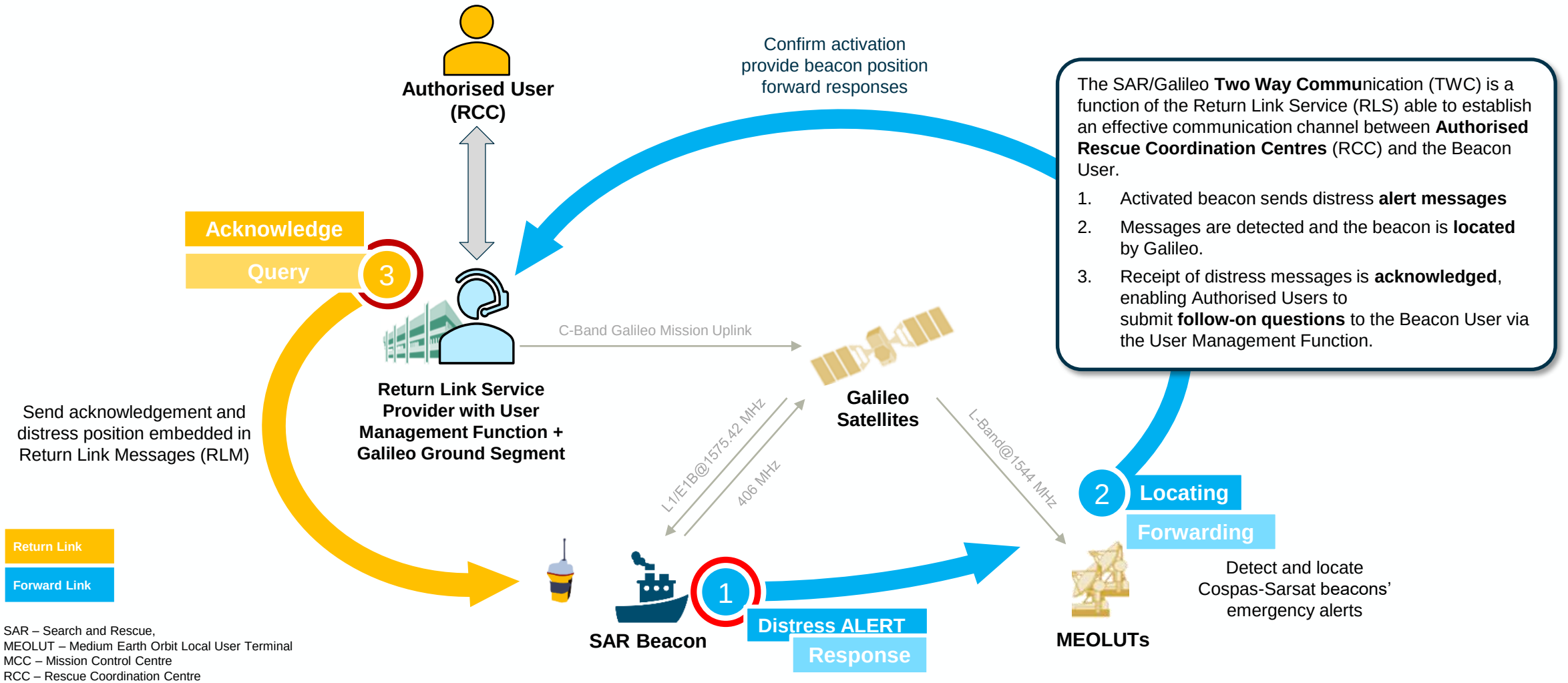
The SAR/Galileo Remote Beacon Activation Service (RBA) is a function of the Return Link Service (RLS) able to send **predefined commands** to a SAR beacon to perform specific actions.

1. It allows **Authorised Users** to submit service requests to the **User Management Function** (UMF). The Galileo system then sends corresponding **Return Link Messages** (RLM) via the Galileo Open Service (E1B) to the beacon.
2. The activated beacon sends **distress alert messages** which are detected by Galileo.
3. Beacon **activation and position** are then confirmed to the user allowing **tracking** of the beacon.

SAR – Search and Rescue,
MEOLUT – Medium Earth Orbit Local User Terminal
MCC – Mission Control Centre
RCC – Rescue Coordination Centre

Two Way Communication (TWC)

Enabling basic but effective communication between the RCC and the persons in distress



The SAR/Galileo **Two Way Commu**nication (TWC) is a function of the Return Link Service (RLS) able to establish an effective communication channel between **Authorised Rescue Coordination Centres** (RCC) and the Beacon User.

1. Activated beacon sends distress **alert messages**
2. Messages are detected and the beacon is **located** by Galileo.
3. Receipt of distress messages is **acknowledged**, enabling Authorised Users to submit **follow-on questions** to the Beacon User via the User Management Function.

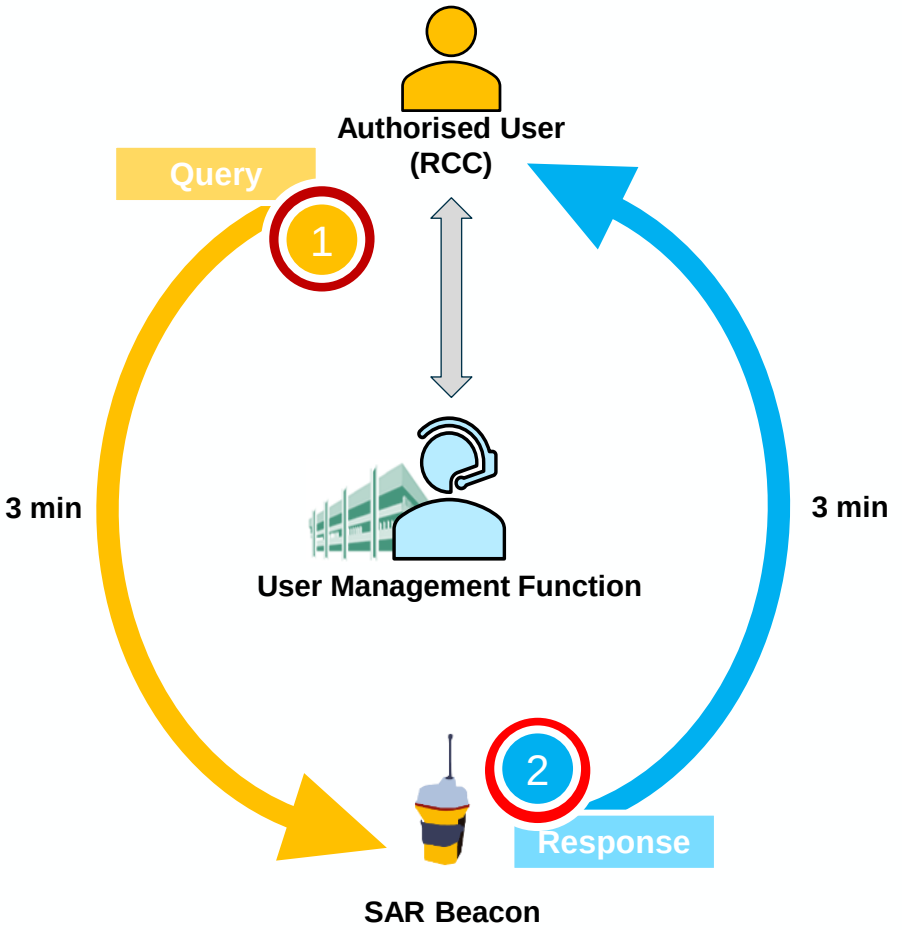
SAR – Search and Rescue,
MEOLUT – Medium Earth Orbit Local User Terminal
MCC – Mission Control Centre
RCC – Rescue Coordination Centre

Two Way Communication (TWC)

Enabling basic but effective communication between the RCC and the persons in distress

- The TWC concept is based on **pre-coded questions** with multiple choice answers, such as:
  - **What type** of distress are you in?
    -> medical, sinking boat, fire, crash, false alert;
  - How many people are **in distress**?
    -> 1, 2, 3, more;
  - How many people are **injured**?
    -> 1, 2, 3, more.
- Short **free text** messages could be an additional option.
- RCCs will have the possibility to **activate several questions** with one single command (RLM) according to the scenario of the distress.

An **H2020 demonstration** project is ongoing, including the development of a prototype. The project includes the involvement of **SAR forces** for the definition of scenarios and the questions/answers database. Interested national SAR forces have been invited to join.



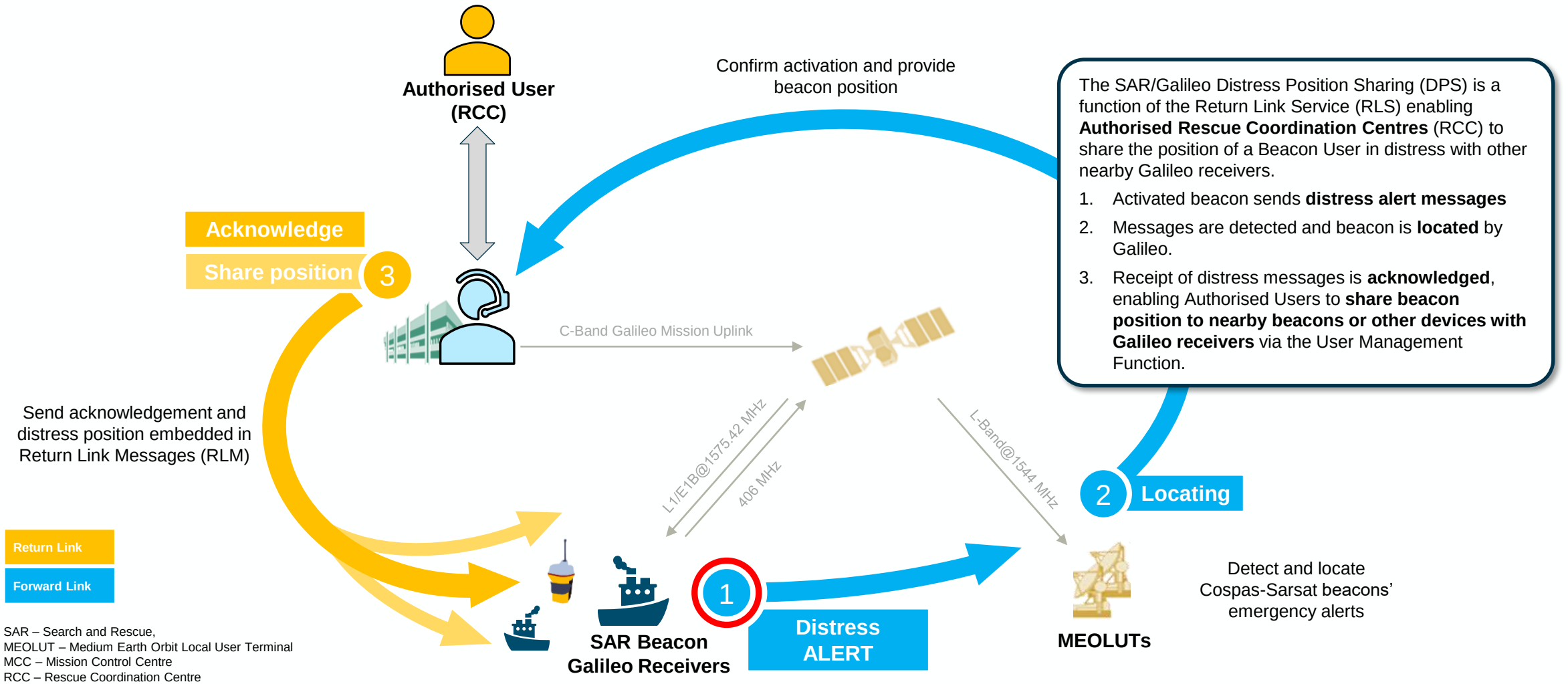
Return Link

Forward Link

SAR – Search and Rescue,
MEOLUT – Medium Earth Orbit Local User Terminal
MCC – Mission Control Centre
RCC – Rescue Coordination Centre

Distress Position Sharing (DPS)

Broadcasting information about an ongoing distress to a particular area or a group of Galileo receivers



The SAR/Galileo Distress Position Sharing (DPS) is a function of the Return Link Service (RLS) enabling **Authorised Rescue Coordination Centres** (RCC) to share the position of a Beacon User in distress with other nearby Galileo receivers.

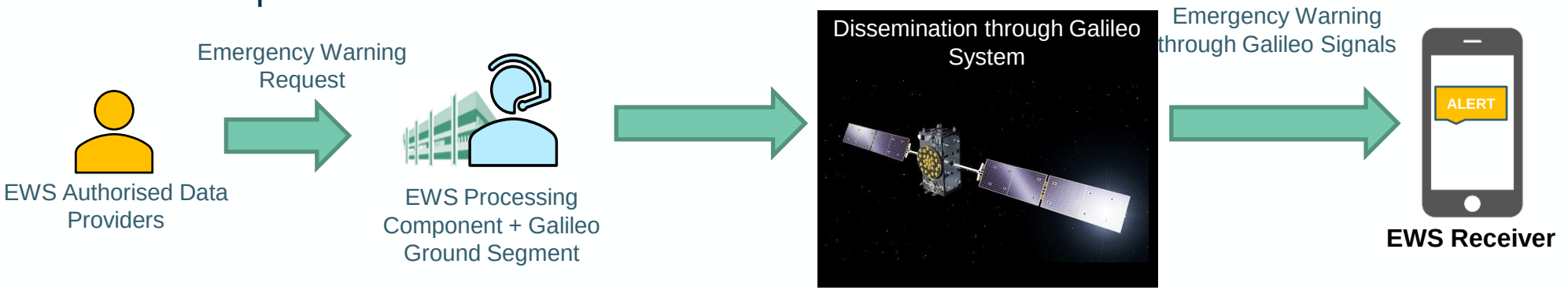
1. Activated beacon sends **distress alert messages**
2. Messages are detected and beacon is **located** by Galileo.
3. Receipt of distress messages is **acknowledged**, enabling Authorised Users to **share beacon position to nearby beacons or other devices with Galileo receivers** via the User Management Function.

SAR – Search and Rescue,
MEOLUT – Medium Earth Orbit Local User Terminal
MCC – Mission Control Centre
RCC – Rescue Coordination Centre

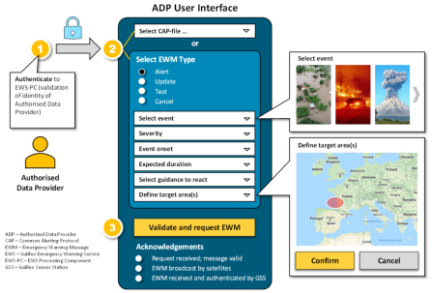
Galileo Emergency Warning Service (EWS)

- Provision of critical information to citizens in emergency situation (e.g. natural disaster) is essential, in particular in case local infrastructure is destroyed

- Galileo Emergency Warning Service (EWS) – planned as new capability in Galileo
- EWS allows to disseminate event specific warning messages to the affected local area; interface to end-user includes smartphones



Galileo Emergency Warning Service (EWS)



Emergency request 1

EWS Authorised Data Providers

4 ACK

Disseminate alert 2

C-Band Galileo Mission Uplink

EWS Processing Component + Galileo Ground Segment

Galileo Satellites

E5b@1207.14 MHz
E1-B@1575.42 MHz

E1-B@1575.42 MHz
E5b@1207.14 MHz

Send emergency warning messages embedded in Navigation data to a specified area

Request/Transmission

Acknowledgement

EWS-PC – Emergency Warning Service Processing Component,
EWS-ADP – EWS Authorised external Data Provider
EWM – Emergency Warning Message

ALERT

EWS Receiver

Receive EWMs 3

ALERT

EWS Receiver

The Galileo Emergency Warning Service (EWS) is a function which is able to alert specific areas worldwide of current or impending emergency events affecting them.

1. **Authorised Data Providers** (e.g. national civil protection authorities) submit service requests to the **EWS processing component** (EWS-PC).
2. The Galileo system then sends corresponding **Emergency Warning Messages** (EWMs) via the Galileo Open Service (E1B/E5) to specific areas and during a determined period of times, both specified in the service requests.
3. End Users with EWS capable equipment receive the Emergency Warning Messages, but only those within the specific area display the alerts.
4. The Galileo system acknowledges the good dissemination of alerts back to the EWS-ADPs.

In action


SEARCH & RESCUE BEACONS
PLB
Personal
Locator
Beacon
ELT
Emergency
Locator
Transmitters
EPIRB
Emergency Position
Indicating Radio
Beacons

SAR/Galileo in action – the Return Link Service

RLS in reality

From the moment the request reaches the Galileo System (i.e. RLSP), in average, the automatic Return Link Message acknowledgment is provided in 37 seconds.

SAR/Galileo in action – Demonstration 1

- Volunteer cast at sea in a life-raft
- 406 MHz PLB activated
- In 3 min / 32 sec :
  - Detected
  - Localized
  - Location confirmed independently
  - Oostende M-RCC informed

SAR/Galileo in action – Demonstration 2

Tangible Performance

The SAR/Galileo Service was put to a test on the 8th of October 2021 in Svalbard at very high latitude above 78º North in a SAR exercise.

A RLS maritime beacon was activated, and the System provided in **2 min key information** to first responders with an accuracy of **730m** from its the true position and the Return Link Message confirmation in 2min 20s

Overall Results	
Beacon GNSS Encoded Position	**78.23 N 15.582E**
Estimated Position	**78.23N 15.614E**
Location Accuracy	**730 meters**
Time to Detect	Instantaneous
Time to Confirm Position	1min 40 seconds
Time to Notify SAR forces	Under 1min
End-to-End Return Link Latency	**2min 20seconds**

SAR/Galileo in action – Real distress

Galileo satellites help rescue Vendée Globe yachtsman [30 Nov. 2020]

Sequence of events

- Skipper Kevin Escoffier, a competitor in the Vendée Globe solo round-the-world yacht race faced disaster off South Africa as raging waves pounded his vessel apart.
- His 406 MHz PLB activated.
- At 13:48:51 UTC the Cospas-Sarsat system's French Mission Control Centre based in Toulouse received the first alert via the SAR transponders on three Galileo satellites, picked up the Galileo MEOLUT in Cyprus.
- The alert was to localised in under two minutes at 13:51.07 UTC, pinning it down within the South African MCC Service Area.
- The alert was immediately forwarded on to the Australian MCC in Canberra, whose data distribution region includes South Africa.
- At the same time, the alert was also forwarded to France's RCC in Griz-Nez – point of contact for Cospas-Sarsat incidents, which immediately notified Vendée Globe Race Directorate in Les Sables d'Olonne.
- The team were able to call on rival racer Jean Le Cam, as the competitor closest to the stricken sailor, who found and rescued Escoffier.

Skipper rescued

- This is prime example of rescue effected by Sharing the Distress Position.

S & R of SAR/Galileo

- SAR/Galileo MEOSAR Alert Service takes the **“search”** out of the **Search And Rescue** by reducing the time for *detection and reliable location of the emergency* down to minutes.

- SAR/Galileo Acknowledgement Return Link Service gives support to the **“rescue”** part of **Search And Rescue**, by providing reassurance to the persons in distress.

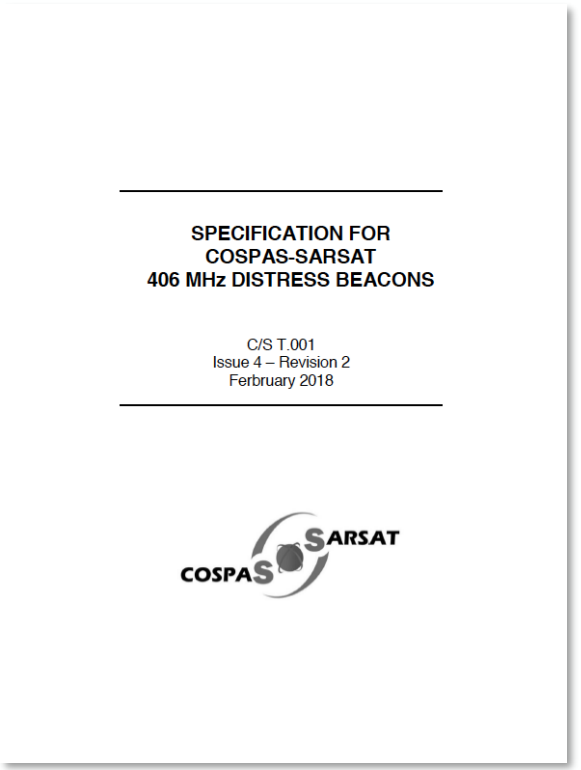
- New services in preparation, based on information embedded in INAV data of Galileo E1 signal and possibly E5.

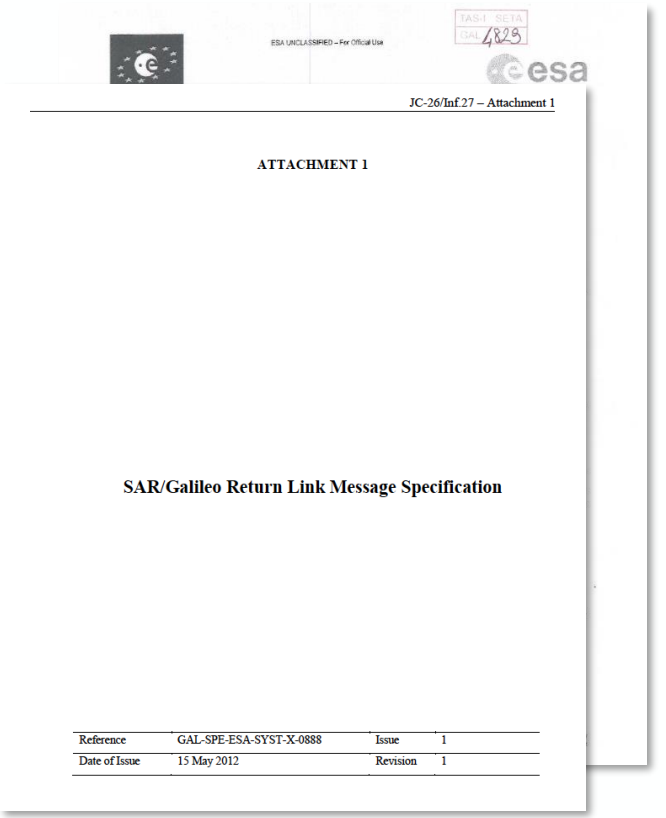
- The activities described in this presentation are the result of collaborative work of: and partners.

- Thank you for your attention! **Questions are welcome**

Eric Bouton
Galileo Search and Rescue engineer
ESA/ESTEC NAV-NFSE
eric.bouton@esa.int

Reference documents





Presented at JC26 as Inf.27 (2012)