COSPAS-SARSAT 406-MHz MEOSAR SYSTEM DEMONSTRATION AND EVALUATION PHASE III REPORT

Issue 1
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COSPAS-SARSAT 406-MHz MEOSAR SYSTEM DEMONSTRATION AND EVALUATION PHASE III REPORT

HISTORY

Issue	Revision	Date	Comments
1	-	March 2021	Approved by the Cospas-Sarsat Council (CSC-64)

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DOCUMENT SUMMARY

This document provides the Phase III results and final report of the Cospas-Sarsat MEOSAR Demonstration and Evaluation (D&E), tests which were conducted from February 2017 to January 2018.

Section 1 provides background on the MEOSAR system and reference material.

Section 2 reviews the planning and conduct of the tests, noting the list of participants, MEOSAR space and ground assets configuration used during the tests and information of interest on the coordination of the tests.

Section 3 details, for each D&E technical test, the key results and interpretations as provided by each test participant that contributed to this Report (EC, France, Russia and USA). The underlying sub-sections were provided under the responsibility of these administrations and, therefore, were not reviewed nor commonly agreed by the Phase III technical test participants.

Section 4 details, for each D&E operational test the key results and interpretations as provided by each test participant that contributed to this Report (France and USA). The underlying sub-sections were provided under the responsibility of these administrations and, therefore, were not reviewed nor commonly agreed by the Phase III operational test participants. Additionally, the following participants contributed with SAR reports to test O-6: Australia, France, and New Zealand.

Section 5 provides the conclusions and recommendations agreed by the Phase III test participants, including general recommendations regarding the implementation of the MEOSAR system.

1 BACKGROUND

1.1 MEOSAR System Description

Figure 1-1 provides a graphical summary of the MEOSAR concept. This picture shows the relay of beacon signals, via multiple satellites, to the MEOLUT. Beacon data is processed by the MEOLUT to derive the beacon locations, and passed onto the MCC, which in turn notifies the RCC.

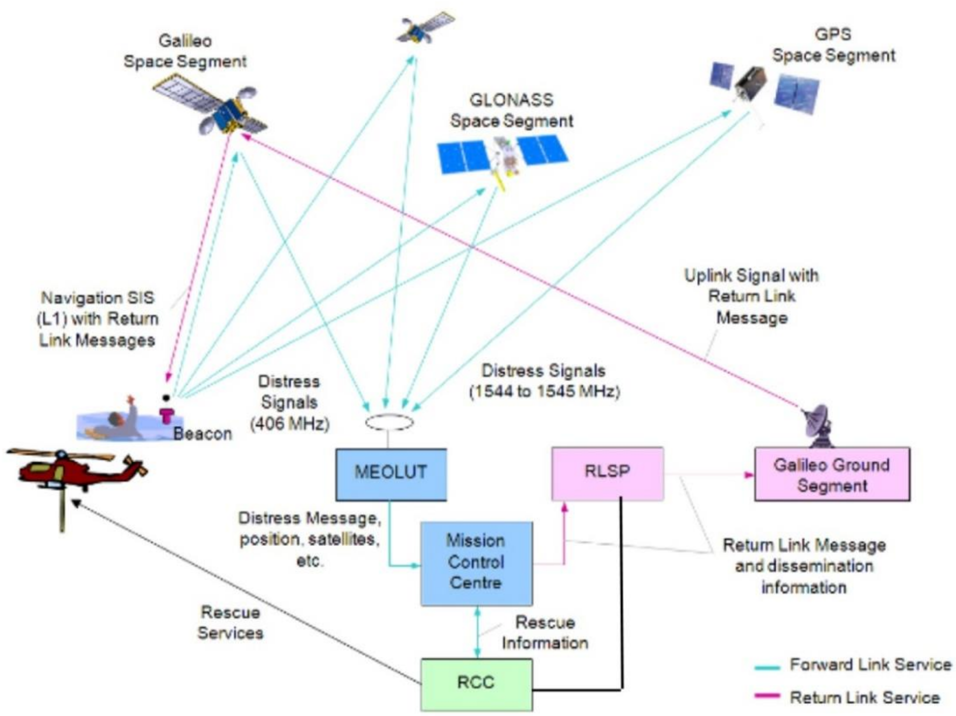


Figure 1-1: The MEOSAR System Concept

1.2 The Cospas-Sarsat MEOSAR Demonstration and Evaluation Plan

The Cospas-Sarsat Council (CSC) has directed that a demonstration and evaluation (D&E) be performed to confirm the expected capabilities and benefits of a satellite system in medium-altitude Earth orbit (MEO) that uses onboard repeater instruments to relay distress alert signals emanating from 406 MHz distress radiobeacons. The CSC further directed that the D&E should establish the technical and operational performance characteristics of the MEOSAR system.

The framework for the D&E of the MEOSAR system is provided in document C/S R.018 "Cospas-Sarsat Demonstration and Evaluation Plan for the 406 MHz MEOSAR System". In particular, this document provides guidelines for:

- conducting the D&E of the MEOSAR system in a standard manner among the participants,

- collecting a set of results from individual participants, using compatible formats, that can be consolidated into a final report for review by Cospas-Sarsat participants and other interested parties,
- analysing and translating the results into a set of recommendations for a decision by the CSC to enter the Initial Operational Capability (IOC) Phase.

Additional resources regarding the MEOSAR system (e.g., space segment information) are available in document C/S R.012 "Cospas-Sarsat 406 MHz MEOSAR Implementation Plan".
CSC-49 agreed to divide the MEOSAR D&E Phase into three phases:

- Phase I, during which the participants perform only technical tests,
- Phase II, during which the participants perform technical and operational tests,
- Phase III, during which the participants replicate the tests of the Phases I and II, when satellites with L-band downlinks are widely available.

The results of the Phase I and II tests are presented and discussed in documents C/S R.021 "Cospas-Sarsat MEOSAR System Demonstration and Evaluation Phase I Report" and C/S R.023 "Cospas-Sarsat MEOSAR System Demonstration and Evaluation Phase II Report".

1.3 The Phase III of the Cospas-Sarsat MEOSAR D&E

1.3.1 Objective of the D&E Phase III

In MEOSAR D&E Phase III, participants performed technical and operational tests (see the detailed definition in document C/S R.018) to characterise the technical and operational performance of the MEOSAR system using L-band SAR repeaters.

1.3.2 Report of the D&E Phase III

The D&E Phase III report was produced with inputs from the Phase III test participants where some of the review and drafting work was achieved by an OWG Splinter Group at JC-32 (see Annex 26A of the JC-32 Report), drafting group at JC-34 and intersessional work by technical test participants, based on:

- the reports on the conduct of the technical and operational tests provided by the test coordinators (see Table 2-1 and Table 2-2),
- contributions from the technical test participants, which provided their interpretation of the test results (see section 3),
- contributions from the operational test participants, which provided their interpretation of the test results (see section 4),
- agreement among the participants on common conclusions and recommendation for the D&E Phase III (see section 5).

- END OF SECTION 1 -

2 CONDUCT OF PHASE III AND MEOSAR SYSTEM CONFIGURATION

2.1 Tests Conducted During the Phase III

Table 2-1 and Table 2-2 provide the list of technical and operational tests planned for the Phase III, respectively, their completeness status, the participants undertaking the role of test coordinator and the reference to the test reports written by the test coordinators. The detailed conduct of each test can be found in the test coordinator's reports. Figure 2-1 provides a Test Planning (as run) of the D&E testing campaign.

Table 2-1 - List of Technical Tests, Test Coordinators and Test Reports

Test	Definition	Run	Status	Test Coordinator
T-1	Processing Threshold and System Margin			USA
T-2	Impact of Interference		No additional Spectrum Monitoring tests were conducted during Phase III. Canada is listed as Test coordinator due to previous work done during Phases I and II.	Canada
T-3	Valid/Complete Message Acquisition			France
T-4	Independent 2D Location Capability			USA
T-5	Independent 2D Location Capability for Operational Beacons			Secretariat
T-6	MEOSAR System Capacity			France
T-7	Networked MEOLUT Advantage		Test not conducted	USA
T-8	Combined MEO/GEO Operation Performance		Optional test not conducted during Phase III	Secretariat

Table 2-2 - List of Operational Tests, Test Coordinators and Test Reports

Test	Definition	Test Coordinator	Test Report Reference
O-1	Potential Time Advantage	France	Section 4.3 of this Report
O-2	Unique Detections by MEOSAR System as Compared to Existing System.	USA	Section 4.4 of this Report
O-3	Volume of MEOSAR Distress Alert Traffic in the Cospas-Sarsat Ground Segment Network	Spain	Section 4.5 of this Report
O-4	406 MHz Alert Data Distribution Procedures	USA	Section 4.6 of this Report
O-5	SAR/Galileo Return Link Service	France (SGDSP)	Section 4.7 of this Report
O-6	Evaluation of Direct and Indirect Benefits of the MEOSAR System	Australia	Section 4.8 of this Report
O-7	MEOSAR Alert Data Distribution –Impact on Independent Location Accuracy	USA	Section 4.9 of this Report

2.2 Participants in the D&E Phase III

Table 2-4 provides the participants in each run of technical test, which provided at least raw data as per Table J.1 of document C/S R.018 or a technical test report. Some participants did not provide technical test results and/or technical test report for test T-5, the participation in test T-5 is identified either in supplying test beacons or in involving MEOLUTs.

Table 2-5 provides the participants in each run of operational tests, which provided raw data using the O-test spreadsheet described in section 5 of document C/S R.018, or have provided reports to be included in the O-6 section.

Table 2-3 - Phase III Test Planning (as Run)

Test	Definition	Dates
T-1	Processing Threshold and System Margin	2017-02-07 – Maryland Run 1
		2017-02-09 – Toulouse Run 1
		2017-02-14 – Florida Run 1
		2017-03-14 – Maryland Run 2
		2017-03-16 – Florida Run 2
		2017-03-27 – Maryland Run 3
T-2	Impact of Interference	Not conducted
T-3	Valid/Complete Message Acquisition	2017-02-21 – Maryland Run 1
		2017-02-28 – Toulouse Run 2
		2017-03-21 – Maryland Run 2
		2017-03-23 – Toulouse Run 2
T-4	Independent 2D Location Capability	2017-06-15 – Toulouse Run 1
		2017-06-20 – Maryland Run 1
		2017-06-22 – Florida Run 1
T-5	Independent 2D Location Capability for Operational Beacons	2017-06-12 to 2017-07-31
T-6	MEOSAR System Capacity	2017-10-01 – Maryland Run 1
		2018-01-08 – Toulouse Run 1
T-7	Networked MEOLUT Advantage	Not conducted
T-8	Combined MEO/GEO Operation Performance	Not conducted

Table 2-4 - Participation in MEOSAR D&E Phase III Technical Tests

Test	Definition		Run	Canada	France	EC/France	Italy	Japan	Norway	Russia	USA		
											Hawaii	Florida	Maryland
T-1	Processing Threshold and System Margin		2		X	X				X			X
T-3	Valid/Complete Message Acquisition		2		X					X			X
T-4	Independent 2D Location Capability		1		X					X			X
T-5	Independent 2D Location Capability for Operational Beacons	Test beacon	1		X	X	X	X	X				
		MEOLUT			X	X				X			X
T-6	MEOSAR System Capacity		1		X								X

Table 2-5 - Participation in MEOSAR D&E Phase III Operational Tests

Test	Definition	Australia	France	New Zealand	USA	Spain	Italy	Netherlands (ESTEC)	Norway
O-1	Potential Time Advantage		X		X				
O-2	Unique Detections by MEOSAR System as Compared to Existing System		X		X				
O-3	Volume of MEOSAR Distress Alert Traffic in the Cospas-Sarsat Ground Segment Network		X		X				
O-4	406 MHz Alert Data Distribution Procedures		X		X				
O-5	SAR/Galileo Return Link Service		X		X	X	X	X	X
O-6	Evaluation of Direct and Indirect Benefits of the MEOSAR System	X	X	X					
O-7	MEOSAR Alert Data Distribution –Impact on Independent Location Accuracy				X				

2.3 Configuration of the D&E Phase III

2.3.1 Experimental Space Segment

Table 2-6 provides the list of MEOSAR L-band satellites available for testing during MEOSAR D&E Phase III.

Table 2-6 - List of Experimental MEOSAR Satellites Used During the MEOSAR D&E Phase III

MEOSAR Constellation	Satellite (C/S ID)	Satellite Availability Status for Phase III
Galileo	401	Available
	402	Available
	403	Available
	404	Available
	405	Available
	407	Available
	408	Available
	409	Available
	418	Available for testing from January 2015 (without ephemeris)
	419	Available
	420	Available for testing from March 2013 (without ephemeris)
	421	Available
	424	Available
	425	Available
	426	Available
	427	Available
	430	Available
	431	Available
Glonass	501	Available with limitations (no ephemeris data available)
	502	Available with limitations (no ephemeris data available)

2.3.2 Experimental Ground Segment

The ground segment equipment in place for the Phase III of the MEOSAR D&E consisted of MEOLUTs located in Australia, Canada[1], Cyprus, France, New Zealand, Norway, Russia, Spain, Turkey, and the USA. Table 2-7 provides the MEOLUTs available for testing, their number of antennas, their software configuration and their availability (note that some participants may have experienced unexpected down periods for some channels, thus limiting their participation in particular tests; see the Test Coordinators reports for more detail).

[1] Canada's MEOLUT was not consistently available due to necessary system upgrades. Canada did not submit results for section 3 or 4 but there was data made available on the D&E site for analysis by the Secretariat and other D&E participants.

Table 2-7 - MEOLUTs Participating in MEOSAR D&E Phase III Tests

Country/ Organisation	Location	Number of Antennas	Configuration	Available for D&E testing since
Australia	Mingenew	6	McMurdo MEOLUT	
Canada	Ottawa	4	HGT MEOLUT 600 Due to necessary system upgrades MSB was not consistently available during the MEOSAR D&E Phase III campaign.	February 2013
Cyprus	Larnaca	4	HGT MEOLUT600 LP v2.0 / SP v2.0 / FP v2.0	May 2015
France	Toulouse	4	HGT MEOLUT600 LP v1.7b / SP v1.5 / FP v1.5 20 L-band channels active antenna	February 2013
New Zealand	Goudies	6	McMurdo MEOLUT	
Norway	Svalbard	4	HGT MEOLUT600 LP v2.0 / SP v2.0 / FP v2.0	May 2015
Russia	Moscow	4	4 antennas (for more information see relevant sections of test reports)	February 2013
Spain	Maspalomas	4	HGT MEOLUT600 LP v2.0 / SP v2.0 / FP v2.0	May 2015
USA	Florida	6	McMurdo MEOLUT v1.0	February 2013
	Hawaii	6	McMurdo MEOLUT v1.0	February 2013
	Maryland	6	McMurdo MEOLUT v1.0	February 2013

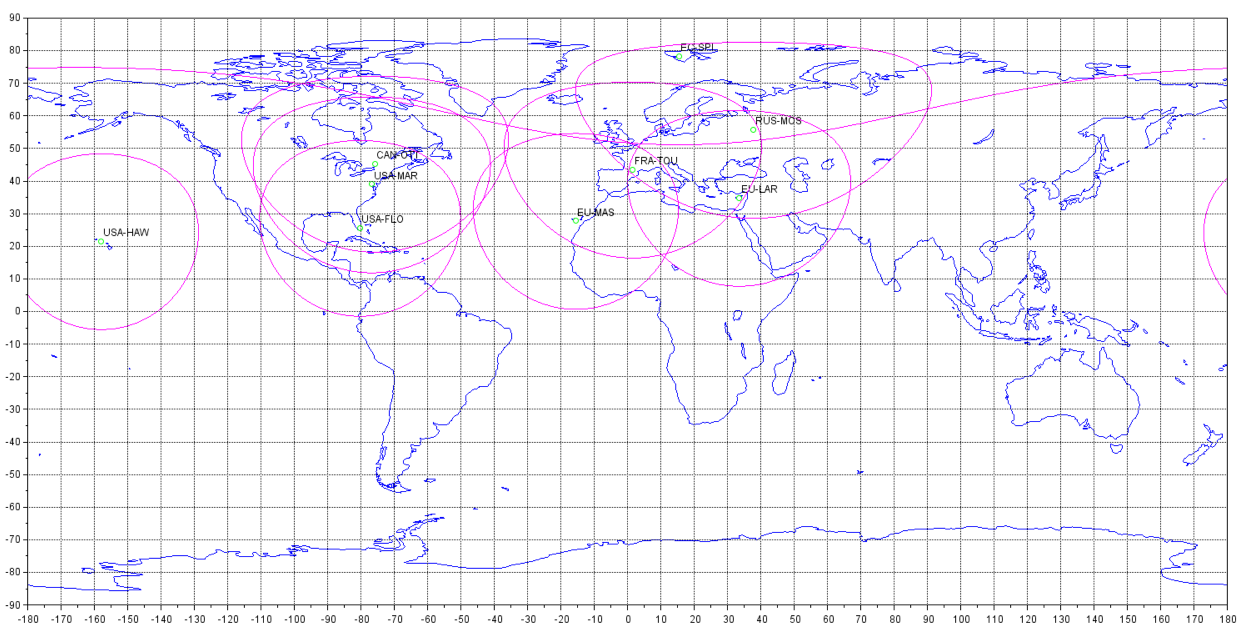


Figure 2-1: MEOLUTs Involved in Phase III Technical Testing with 3,000 km Radius Circles

2.3.2.1 French MEOLUT Configuration

During the D&E Phase III, a new MEOLUT implementation is used with a combination of one L-band active antenna (up to 20 L-band channels) and four dish antennas configured in S band. For the Phase III, data were collected from the L-band active antenna only.

12 L-band Galileo satellites were enabled on the French MEOLUT: 401, 402, 408, 409, 419, 422, 424, 426, 430, [420, 414, and 418][2].

2.3.2.2 European MEOLUTs Configuration

The SAR/Galileo Ground Segment (SGS) is composed of three European MEOLUTs deployed in Maspalomas (Spain), Larnaca (Cyprus), Spitsbergen (Norway) and a MEOLUT Tracking Coordination Facility (MTCF). It nominally operates by exchanging TOA/FOA from 12 coordinated antennas (four antennas for each MEOLUT) by the MTCF. The collected data are almost identical between European MEOLUTs.

2.3.3 Beacon Simulators and Test Beacons

Four beacon simulators were used during the Phase III testing, located in Florida, Hawaii and Maryland, USA and Toulouse, France. After each test, the beacon log files were provided by each administration providing beacon simulators.

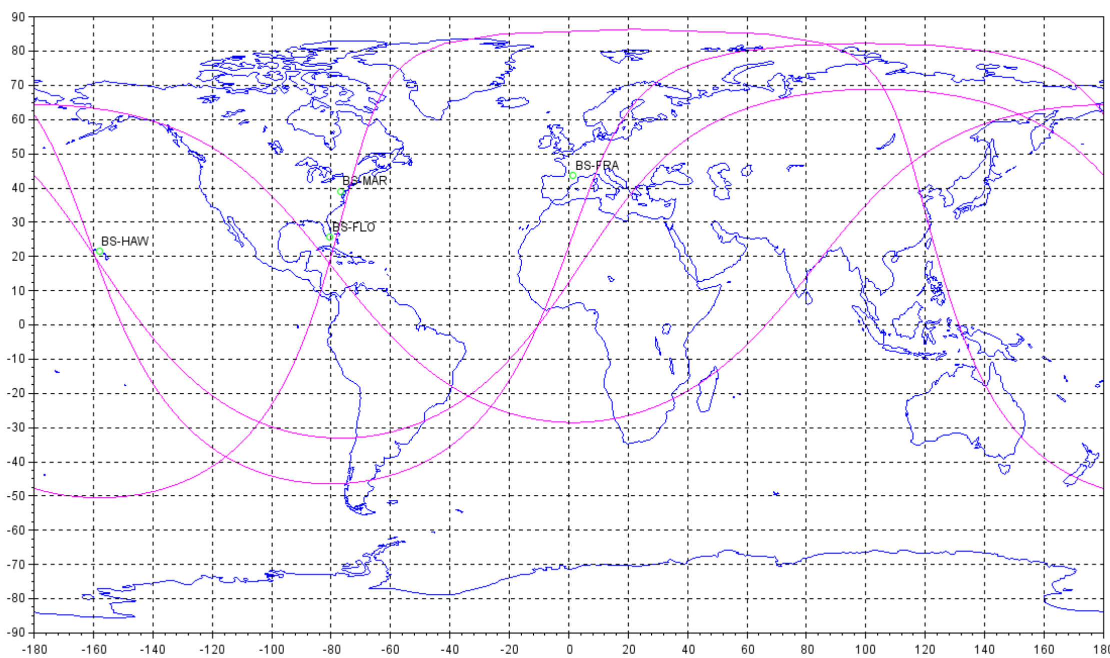


Figure 2-2: Beacon Simulators Used in the MEOSAR D&E Phase III (MEOSAR Visibility Circles at Five Degree Elevation)

[2] With ephemerides from the Galileo Service Center (GCS)

2.4 Test Coordination

A smooth progression of the D&E planning and tests has been observed thanks to the active participation of the Test Coordinators and Test Participants. No formal D&E test had to be postponed or re-scheduled due to a coordination issue. In addition, tests planned by Test Participants were at times similar to those of SAR/Galileo commissioning tests, requiring an active coordination between France and EC/ESA in order to avoid the simultaneous transmission of beacon signals.

2.5 Operational Issues Encountered during the Phase III Testing

No operational issue was encountered during the conduct of the Phase III tests.

2.6 Data Collection

For the technical tests, the participants collected the following data:

- beacon simulator log data to collect the beacon IDs transmitted (if applicable),
- MEOLUT raw data as per csv format defined in Table J.1 of document C/S R.018,
- MEOLUT location data as per csv format defined in Table J.2 of document C/S R.018,
- MEOLUT pass schedule data as per csv format defined in Table J.3 of document C/S R.018.

For the operational tests, the participants collected raw data from the MEOSAR-ready MCCs as requested in section 5 of document C/S R.018. Then participants used the spreadsheet provided in order to produce the operational test tables needed for the analyses presented in this report. All the data provided by the test participants were saved on the MEOSAR D&E FTP server.

- END OF SECTION 2 -

3 RESULTS OF THE TECHNICAL TESTS AND DISCUSSION

The following sections provide, for each test:

- references to the test participant's reports presenting the results of the MEOSAR D&E tests conducted during the Phase I and Phase II testing,
- a summary of the interpretation of the test analyses, as provided by each Administration.

3.1 Test T-1 (Processing Threshold and System Margin)

Test Objectives

According to document C/S R.018, the main objective of test T-1 was to determine the minimum value of the beacon output power for which a single MEOLUT satellite channel and multiple channels were able to produce a valid/complete message for each beacon burst 70% of the time to meet the expected threshold performance. The system margin is the difference between the nominal output power of a beacon and this processing threshold.

For test T-1, the USA took on the role of test coordinator with the support of the Secretariat. Test coordination was performed via the collaboration website Basecamp. For the D&E Phase III, the script and output result tables were the same as ran for the D&E Phase II.

3.1.1 Analysis

The following test reports were provided by the participants:

Table 3-1 - T-1 Test Reports Provided y Participants

Administration	Test report reference
EC/France	SAR-RE-DEMEO-1040-CNES D&E Test Report - MEOSAR D&E Phase 3 Test T-1 SGS Report
France	SAR-RE-DEMEO-1035-CNES D&E Test Report - C/S D&E Phase 3 T-1 Test Report FRMEO
Russia	T-1 "Processing Threshold and System Margin" test report
USA	P3_T1_2018_Sept_7_USA_Maryland_Report

3.1.1.1 EC/France (European MEOLUTs)

3.1.1.1.1 Configuration

During test T-1 of the Phase III, the SAR/GALILEO Ground Segment was configured to track only L-band satellites, in order to get a maximum number of single-channel data. TOA/FOA exchange was activated which is the nominal configuration.

13 L-band satellites were enabled on the SGS MEOLUTs:

- Galileo 401, 402, 408, 409, 419, 422, 424, 426, 430, [420, 414, and 418][3].
- Glonass 502 was also enabled.

The collected data are almost identical among the three European MEOLUTs. For simplification, it was decided to collect data from the Maspalomas MEOLUT only, being representative of one European MEOLUT.

3.1.1.1.2 Analysis

Global Single-Channel System Margin

The results from antenna 4 of Maspalomas were discarded due to an anomaly, inducing a low throughput. The short satellite passes were also discarded.

After these filterings, the system margin values related to a specific satellite are spreading depending on the passes' conditions in terms of geometry. In general, the system margin was higher than 6 dB and could have reached 15 dB. The Glonass satellite 502 provided similar results to the Galileo satellite results.

We can also note that:

- the system margin with L-band satellites was globally better than what was previously observed with the S-band satellites,
- the results for complete messages were nearly as good as for valid messages.

Global Multiple Channel System Margin

As detailed in Table 3-2, the system margin depending on the beacon simulator was very similar for 3 or more combined antennas. A minimum of 14 dB margin was observed for valid messages and 13 dB for complete messages.

Table 3-2 - Multiple Channel System Margin with All Involved Simulators

	France		Maryland		Florida	
Number of Channels	**Valid Messages (dB)**	**Complete Messages (dB)**	**Valid Messages (dB)**	**Complete Messages (dB)**	**Valid Messages (dB)**	**Complete Messages (dB)**
1	9	7	9	6	11	9
2	12	9	12	12	15	15
3	14	14	14	13	15	15
4	14	14	14	14	15	15
5	NA	NA	15	14	15	15
6	NA	NA	15	14	15	15
7	NA	NA	15	14	15	15
8	NA	NA	15	14	NA	NA
9	NA	NA	15	14	NA	NA

[3] using GSC ephemerides

3.1.1.2 France

Global Single-Channel System Margin

Table 3-3 shows the system margin for all satellites depending on the beacon simulator. We can note that:

- the system margin with Galileo satellites was globally better than what was previously observed with the S-band satellites during Phase II,
- the results for complete messages were nearly as good as for valid messages,
- the system margin varied from 1 dB to 12 dB for Toulouse transmission, from 3 dB to 6 dB for Maryland transmission and from 2 dB to 7 dB for Florida transmission,
- for each satellite, the system margin depended on the geometrical conditions of the passes; best results are obtained when the beacon-to-satellite elevation angle remains under 50°,
- the better results observed with satellite 418 could be explained by a more favorable link budget due to the elliptic orbit.

Table 3-3 - Single-Channel System Margin with All Involved Simulators (in Red, Results Below 4 dB)

Satellites		401	402	408	409	414	418	419	420	422	424	426	430
France Run 1	Valid messages	8	7	1	7	3	12	9	9	1	7	11	1
	Complete messages	7	6	1	7	3	11	8	9	0	7	11	1
Maryland Run 2	Valid messages	NA	6	4	5	3	6	NA	3	5	6	5	5
	Complete messages	NA	5	4	5	3	6	NA	2	5	6	4	5
Florida Run 2	Valid messages	5	5	3	2	NA	7	5	5	NA	6	6	5
	Complete messages	4	5	3	2	NA	7	5	5	NA	6	6	5

NA=not available (no data or limited statistics).

Global Multiple-Channel System Margin

For the France transmission, the system margin reached 15 dB from 4 channels for valid messages. For the Maryland and Florida transmissions, the system margin of valid messages reached 11 dB and 10 dB respectively for a 3-channel case (data collected during the tests did not permit computing the system margin with 4 and 5 channels).

Table 3-4 - Multiple Channel System Margin with All Involved Simulators

Number of channels		1	2	3	4	5
France Run 1	Valid messages	7	11	13	15	15
	Complete messages	5	10	12	14	15
Maryland Run 2	Valid messages	5	6	11	n/a	n/a
	Complete messages	4	6	10	n/a	n/a
Florida Run 2	Valid messages	5	9	10	n/a	n/a
	Complete messages	4	7	9	n/a	n/a

All of these results were better than those obtained during the D&E Phases I and II.

3.1.1.3 USA-Maryland

Test T-1 was performed over a pre-determined 24-hour period. During the first Maryland and Florida transmissions, it was observed by France and confirmed by Maryland MEOLUT data that the beacon bursts transmitted at 406.064 MHz collided with the beacon bursts transmitted from the Hawaii reference beacon. These data sets were discarded. Subsequent transmissions were performed with the other two USA reference beacons turned off. The second Maryland beacon simulator worked fine, but the MEOLUT did not operate as expected because of a snowstorm. The third Maryland transmission stopped after 21 hours due to a UPS power issue.

Table 3-5 - T-1 Test Runs

Test	Test Run	Time 1st Tx (yyyy-mm-dd UTC)	Time last Tx (yyyy-mm-dd UTC)	Beacon simulator location	Comments
T-1	1	2017-07-02 14:00:00.000	2017-02-08 14:00:00.000	Maryland	Discarded (beacon burst collision with the Hawaii ref. beacon)
T-1	1	2017-02-09 14:00:00.000	2017-02-10 14:00:00.000	Toulouse	OK
T-1	1	2017-02-14 14:00:00.000	2017-02-15 14:00:00.000	Florida	Discarded (beacon burst collision with the Hawaii ref. beacon)
T-1	2	2017-03-14 14:00:00.000	2017-03-15 14:00:00.000	Maryland	Discarded (snowstorm)
T-1	2	2017-03-16 14:00:00.000	2017-03-17 14:00:00.000	Florida	OK (Hawaii and Maryland ref. beacons off)
T-1	3	2017-03-27 14:00:00.000	2017-03-28 14:00:00.000	Maryland	OK (Hawaii and Florida ref. beacons off; stopped after 21 hours because of a ups power issue)

3.1.1.3.1 Configuration

During test T-1 of the Phase III, the Maryland MEOLUT was configured to track only L-band satellites Galileo 401, 402, 408, 409, 419, 422, 424, 426 and 430.

3.1.1.3.2 Results

Table 3-6 provides an excerpt of the single-channel results for the Maryland MEOLUT. Table 3-7 provides the multi-channel results for the Maryland MEOLUT.

Table 3-6 - T-1 Single-Channel Results Maryland

Antenna: 1	Sat: 426									
Power	NTB	C/No_LinAve	C/No_LogAve	NVIM	NCM	TP(NVM)	TP(NCM)	C/No_Min	C/No_Max	C/No_Std
37	86	54.36	52.97	0	83	0.97	0.97	34.19	59.25	4.47
36	86	53.36	52.31	0	83	0.97	0.97	36.72	58.13	3.73
35	86	52.10	50.42	0	84	0.98	0.98	31.81	56.61	4.99
34	86	51.14	50.19	0	80	0.93	0.93	34.38	56.29	3.50
33	87	50.01	48.71	0	85	0.98	0.98	30.65	56.08	4.19
32	87	48.75	47.44	0	84	0.97	0.97	30.33	53.90	4.13
31	87	47.79	46.62	0	83	0.95	0.95	33.83	53.58	3.61

Antenna: 1	Sat: 426									
Power	NTB	C/No_LinAve	C/No_LogAve	NVIM	NCM	TP(NVM)	TP(NCM)	C/No_Min	C/No_Max	C/No_Std
30	87	46.67	45.36	1	81	0.94	0.93	30.38	54.07	3.84
29	87	45.52	44.59	0	81	0.93	0.93	32.98	52.11	3.03
28	87	44.66	43.65	0	80	0.92	0.92	33.31	49.73	3.17
27	86	43.50	42.36	0	78	0.91	0.91	32.99	49.68	3.29
26	86	42.35	41.37	1	78	0.92	0.91	31.02	46.66	3.10
25	86	41.03	40.25	0	78	0.91	0.91	32.38	46.41	2.78
24	86	39.76	39.11	0	72	0.84	0.84	31.43	44.17	2.51
23	86	38.75	38.21	0	73	0.85	0.85	32.73	43.33	2.20
22	86	37.80	37.00	0	63	0.73	0.73	29.51	42.55	2.81

Table 3-7 - T-1 Multi-Channel Results Maryland

Antenna: 1 4 5 6										
Power	NTB	C/No_LinAve	C/No_LogAve	NVIM	NCM	TP(NVM)	TP(NCM)	C/No_Min	C/No_Max	C/No_Std
37	1511	50.03	49.35	0	1506	1.00	1.00	38.45	56.94	2.54
36	1511	48.98	48.31	0	1506	1.00	1.00	39.23	55.58	2.51
35	1511	47.94	47.27	0	1507	1.00	1.00	37.69	55.65	2.48
34	1511	46.84	46.14	0	1509	1.00	1.00	32.88	53.43	2.58
33	1511	45.83	45.18	0	1508	1.00	1.00	33.59	53.83	2.47
32	1511	44.68	44.03	0	1507	1.00	1.00	36.05	52.14	2.45
31	1511	43.63	42.96	1	1507	1.00	1.00	33.37	50.58	2.47
30	1511	42.55	41.91	0	1502	0.99	0.99	31.84	49.51	2.44
29	1511	41.55	40.88	0	1497	0.99	0.99	30.26	48.01	2.48
28	1511	40.50	39.86	3	1490	0.99	0.99	29.52	48.08	2.38
27	1511	39.47	38.85	0	1477	0.98	0.98	30.51	46.73	2.34
26	1511	38.53	37.93	2	1441	0.95	0.95	27.13	45.24	2.31
25	1511	37.59	37.04	0	1410	0.93	0.93	29.34	43.80	2.23
24	1511	36.71	36.15	10	1337	0.89	0.88	27.17	42.67	2.24
23	1511	35.95	35.44	20	1227	0.83	0.81	28.64	43.33	2.09
22	1511	35.29	34.77	20	1065	0.72	0.70	27.82	42.55	2.11

3.1.1.4 Russia

3.1.1.4.1 Configuration

All four antennas of the Russian MEOLUT were engaged in the test. The signal processor software was specifically configured to enable burst integration technique that takes into account the discrepancies of C/S T.001-compliant beacons signals and beacon simulators signals that emitted according to the test scripts provided in document C/S R.018. The change in the configuration included beacon burst repetition interval (strictly 50 sec, not 50 ± 2.5 sec).

Generally, the purpose of beacon burst integration is to attempt to produce a valid beacon message from multiple beacon bursts pertaining to the same beacon that for some reason a MEOLUT was not able to recover from a single transmitted burst. Table 3-8 lists all beacon simulator emissions that contributed to this report.

Table 3-8 - Beacon Simulator Emissions Schedule

Simulator ID	Simulator Location	Emission Start (UTC)	Emission End (UTC)
1	France, Toulouse	09.02.2015 14:00	10.02.2015 14:00

3.1.1.4.2 Results

Results for Processing Threshold and System Margin obtained for a single satellite channel and a standalone MEOLUT are provided in Table 3-9 and Table 3-10, respectively.

Table 3-9 - Single-Satellite Channel - Toulouse Beacon Simulator-Processing Thresholds and System Margin

Satellite Antenna Channel	Satellite ID	Threshold (dBm)	Margin (dB)
1	419	22	15
1	409	<22	>15
1	418	<22	>15
1	418	<22	>15
1	430	<22	>15
1	422	24	13
2	424	22	15
2	402	<22	>15
2	409	<22	>15
2	409	<22	>15
2	426	<22	>15
2	402	<22	>15
3	414	<22	>15
3	426	<22	>15
3	424	24	13
3	408	25	12
4	401	<22	>15
4	401	<22	>15
4	419	<22	>15
4	414	<22	>15
4	414	<22	>15
4	424	<22	>15
4	430	27	10

Table 3-10 - Standalone MEOLUT - Toulouse Beacon Simulator - Processing Threshold and System Margin

Antenna Set	Threshold (dBm)	Margin (dB)
1	22	15
2	22	15
3	22	15
4	22	15
1,2	<22	>15
1,3	<22	>15
3,4	>22	>15
2,4	<22	>15
1,4	<22	>15
2,3	<22	>15
1,2,3	<22	>15
1,3,4	<22	>15
2,3,4	<22	>15
1,2,4	<22	>15
1,2,3,4	<22	>15

It is clearly seen from Table 3-9 and Table 3-10 that in most cases the System Margin computed for a single-satellite channel was better than 15 dB so the threshold was not reached. The results for sets of two and more antennas in all cases were better than 15 dB and the threshold was not reached.

The results varied from the number of antennas and eventually reached up 15 dB and more of System Margin. In addition, Figure 3-1 shows single-channel throughput as a function of beacon simulator EIRP and beacon-to-satellite elevation angle.

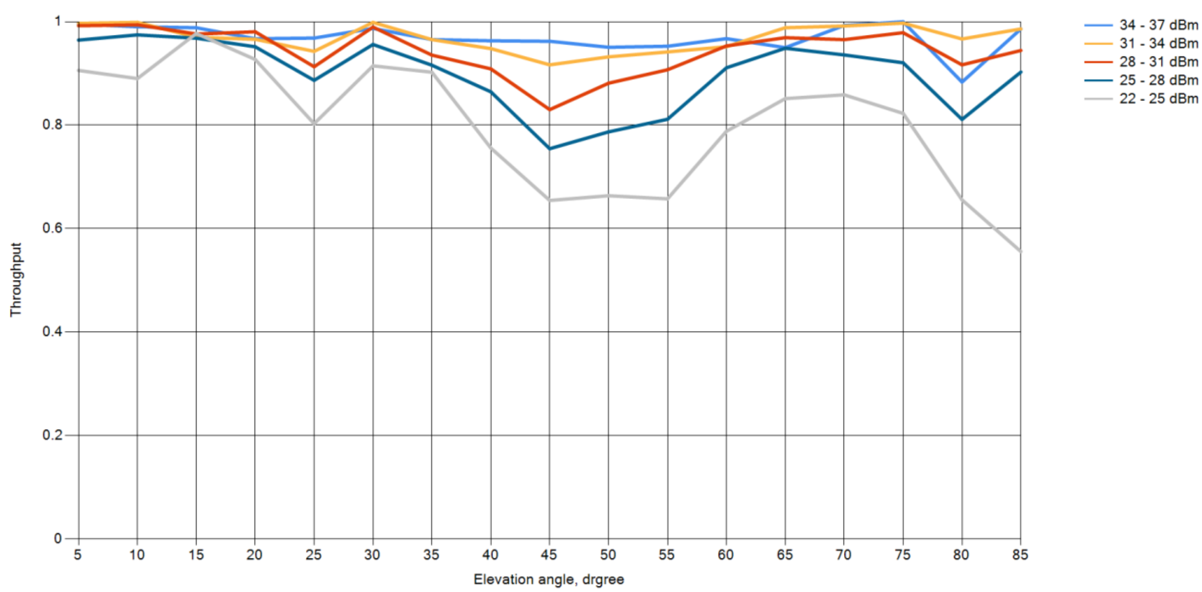


Figure 3-1: Single-Channel Throughput as a Function of Beacon-to-Satellite Elevation Angle

3.1.2 Interpretation

3.1.2.1 EC/France (European MEOLUTs)

The global performances were good but we observed jagged curves due probably to synchronous interferers during the Toulouse transmission (while the French MEOLUT curves were not jagged). The large number of single-satellite channels shows also that the detection performance was depending on the pass configuration in term of geometry.

In addition, the throughput for the valid messages and the complete messages were similar.

The Glonass 502 satellite provided similar performances as the Galileo satellites.

For the multiple-channel combination, the system margin was equal to or higher than 14 dB for three or more channels, which permitted potentially detecting distress beacons in harsh environmental conditions.

Recommendations

From the analysis of the test results, it appeared that an antenna failure could be identified thanks to the single-channel throughput, which was very sensitive. So this low-level parameter could be quite useful for the implementation of the QMS Phase II (identification of failure of individual satellite or antenna).

3.1.2.2 France

The detection performance level observed in Phase III was better than in Phase II. The global performances were good but the geometrical conditions (beacon/satellite/MEOLUT antenna) implied some variation in terms of C/N_0 and single-satellite channel throughput. In addition, the throughput for the valid messages and the complete messages were similar.

For the multiple channel combination, the system margin for valid messages was equal to or higher than 10 dB for three or more channels, which allowed to potentially detect distress beacons in harsh environment conditions. This was not the case for Phase II, with a lower system margin mainly due to fewer L-band channels.

Finally, the complementary analysis demonstrated that the processing anomaly rate was lower than the MEOLUT requirement for commissioning at MEOSAR IOC performance level.

These results demonstrate the good behavior of the L-band active antenna component of the French MEOLUT.

3.1.2.3 USA-Maryland

Results from test T-1 demonstrated the improved performance related to the stronger link performance of the L-band satellites. Detection percentages are near 100 % down to low levels of received signal to noise ratio (C/N_0).

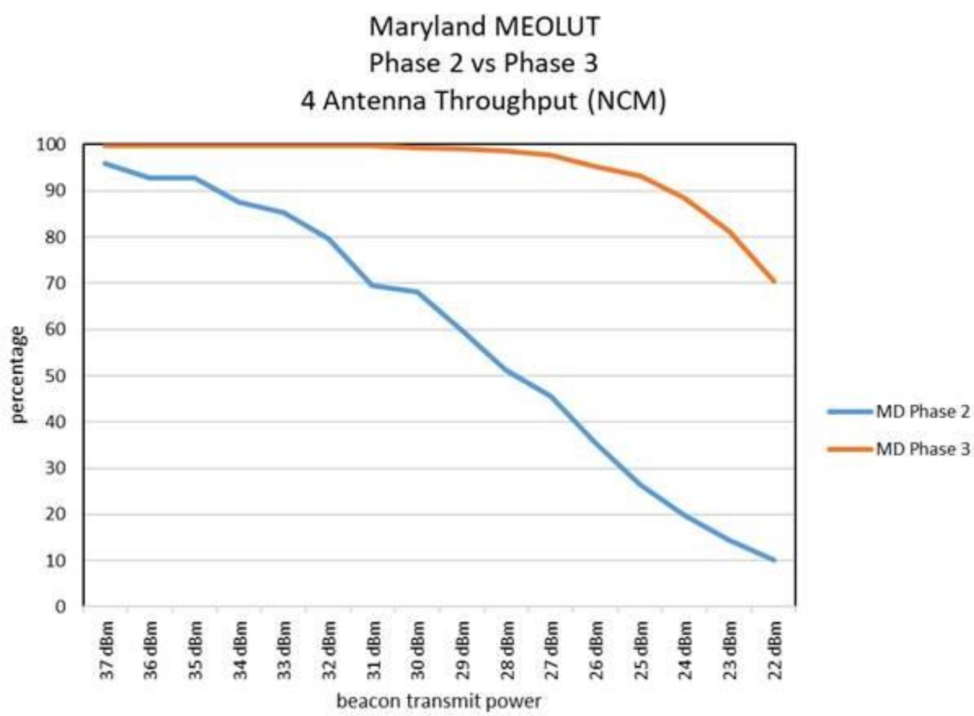


Figure 3-2: T-1: Processing Threshold and System Margin

3.1.2.4 Russia

The Processing Threshold in a standalone MEOLUT configuration was better than 22 dBm. System margin, therefore, was better than 15 dB and the threshold was not reached for this test.

With respect to the single-satellite channel statistics, the System Margin in most cases was better than 15 dB (in a few cases the threshold was slightly less).

These levels have been achieved mostly due to:

a) transition from S-band to L-band satellites with better uplink/downlink power budget,

b) ability of Moscow MEOLUT to integrate C/S T.001 beacon bursts until a valid message was produced.

3.2 Test T-2 (Impact of Interference)

Test T-2 was optional and was not continuously performed during Phase III of the MEOSAR D&E. The presence of interferers in the 406.0- 406.1 MHz band and the degree of such presence strongly depended on the geographical area "visible" to the satellite (i.e., southern Asia regions have seen much more interferers than in other areas) and has not significantly improved since the Phase II testing. It is therefore assumed that the results of Phase II with regards to this test hold true.

3.3 Test T-3 (Valid/Complete Message Acquisition)

Test Objectives

According to document C/S R.018, test T-3 has three main objectives:

(1) Valid/Complete Message Detection Probability
This parameter characterizes the capability of a MEOLUT to detect valid/complete messages in a given period of time after beacon activation (i.e., after one, two, seven and thirteen burst transmissions) and for beacon output powers of 37 dBm and 33 dBm.

(2) Valid/Complete/Confirmed Message Transfer Time
This parameter characterizes the time elapsed between the first burst transmitted for each unique beacon ID and the production of valid/complete/confirmed messages by a MEOLUT for beacon output powers of 37 dBm and 33 dBm.

(3) Valid/Complete Message Detection Probability within X minutes
This parameter characterizes the capability of a MEOLUT to detect valid/complete messages within X minutes after beacon activation and for beacon output powers of 37 dBm and 33 dBm.

The MEOLUT throughput is defined as the ratio of the number of valid (or complete) messages produced by the MEOLUT over the number of bursts emitted during a given period of time.

For test T-3, France took on the role of test coordinator with the support of the Secretariat. Test coordination was performed via the collaboration website Basecamp. For the D&E Phase III, the script and output result tables were the same as ran for the D&E Phase II.

3.3.1 Analysis

The following test reports were provided by the participants.

Table 3-11 - T-3 Test Reports Provided by Participants

Administration	Test report reference
France	SAR-RE-DEMEO-1036-CNES D&E Test Report - MEOSAR D&E Phase III Test T-3 Report
Russia	T-3 “MEOLUT Valid/Complete Message Acquisition” test report
USA	P3_T3_2018_01_Sept_USA_Maryland_Report

3.3.1.1 France

Toulouse Run 2 Transmission

The performance of detection probability within 10 minutes was compliant with respect to the C/S R.012 requirement (≥ 99% within 10 min) for all slots, except for slot 1 and 2 (98%), see Figure 3-3. It can be observed that results from both transmission powers were identical.

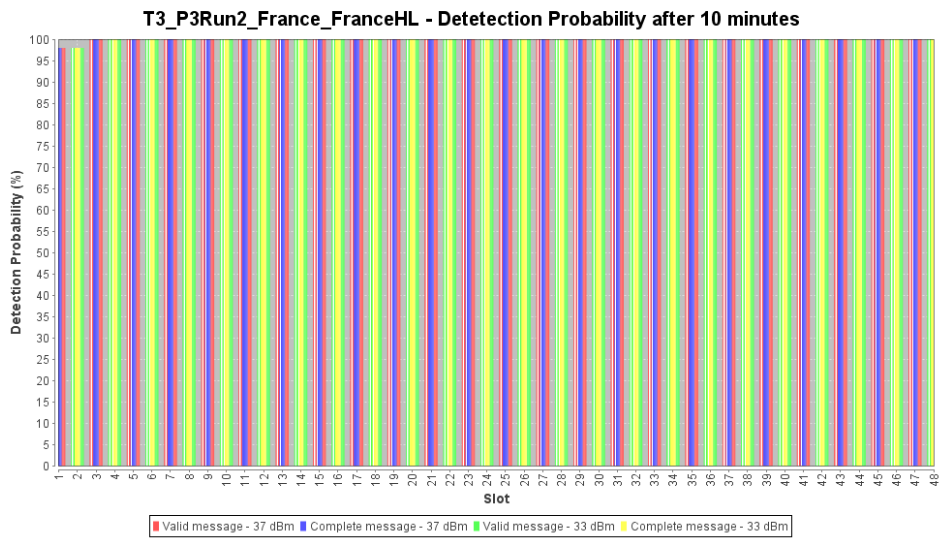


Figure 3-3: Detection Probability Within 10 Minutes – Toulouse Simulator

Maryland Run 2 Transmission

The performance of detection probability within 10 minutes was consistent with respect to the C/S R.012 requirement, except for slot 36 (60%) at 33 dBm, seeFigure 3-4. During this 33 dBm slot, there was only one satellite (408) in mutual visibility, at 75° elevation as seen from Maryland beacon simulator.

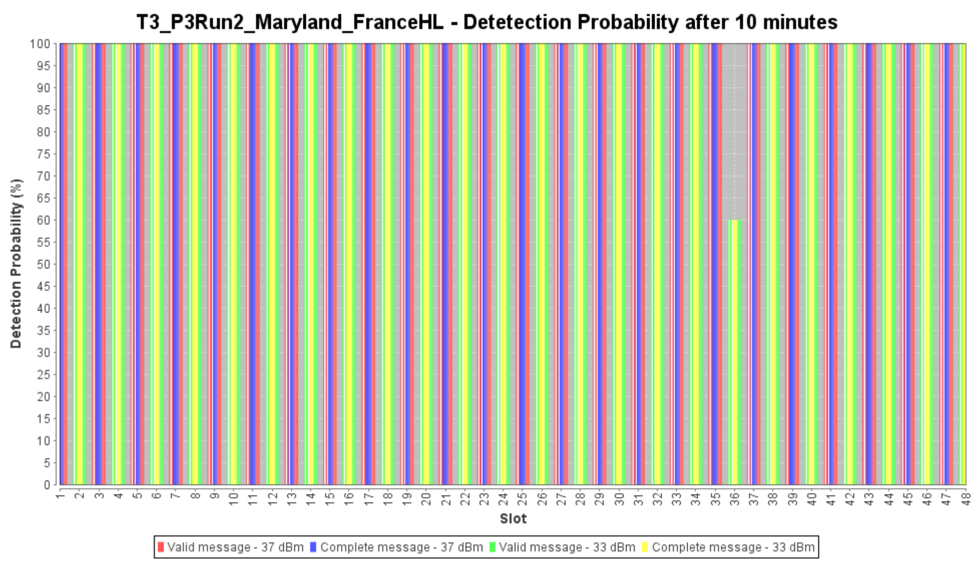


Figure 3-4: Detection Probability Within 10 Minutes – Maryland Simulator

3.3.1.2 USA-Maryland

Test T-3 was performed over a pre-determined 24-hour period.

Table 3-12 - T-3 Test Runs

Run	Time 1st Tx	Time last Tx	Beacon simulator location	Comment
1	2017-02-16 14:00:00.000	2017-02-17 14:00:00.000	Toulouse	Discarded (antenna installation not correct)
1	2017-02-21 14:00:00.000	2017-02-22 14:00:00.000	Maryland	Discarded (beacon burst collision with the Hawaii ref. beacon)
1	2017-02-23 14:00:00.000	2017-02-23 14:00:00.000	Florida	Discarded (beacon burst collision with the Hawaii ref. beacon)
2	2017-02-28 14:00:00.000	2017-03-16 14:00:00.000	Toulouse	OK
2	2017-03-21 14:00:00.000	2017-03-21 14:00:00.000	Maryland	OK (Hawaii and Florida ref. beacons off)
2	2017-03-23 14:00:00.000	2017-03-24 14:00:00.000	Florida	Discarded (issue with the beacon simulator)

3.3.1.2.1 Configuration

During test T-3 of the Phase III, the Maryland MEOLUT was configured to track only L-band satellites Galileo 401, 402, 408, 409, 419, 422, 424, 426 and 430. No optimization to the satellite pass schedule was performed.

3.3.1.2.2 Results

The following tables are excerpts of the results for the Maryland beacon simulator transmission for single-burst and multiple (13) bursts, at beacon power levels of 33 dBm and 37 dBm.

Table 3-13 - Single Burst (33 dBm Beacon Power)

Maryland MEOLUT - Maryland Simulator @ 33 dBm 1 burst						
Beacon Emission Power	Slot No	NTBI	NVIM after 1 burst	NCM after 1 burst	%NVIM after 1 burst	%NCM after 1 burst
33	2	50	50	50	100	100
33	4	50	50	50	100	100
33	6	50	50	50	100	100
33	8	50	50	50	100	100
33	10	50	50	50	100	100
33	12	50	50	50	100	100
33	14	50	50	50	100	100
33	16	50	50	50	100	100
33	18	50	50	50	100	100
33	20	50	50	50	100	100
33	22	50	50	50	100	100
33	24	50	50	50	100	100
33	26	50	50	50	100	100

Maryland MEOLUT - Maryland Simulator @ 33 dBm 1 burst						
Beacon Emission Power	**Slot No**	**NTBI**	**NVIM after 1 burst**	**NCM after 1 burst**	**%NVIM after 1 burst**	**%NCM after 1 burst**
33	28	50	50	50	100	100
33	30	50	50	50	100	100
33	32	50	50	50	100	100
33	34	50	50	50	100	100
33	36	50	50	50	100	100
33	38	50	50	50	100	100
33	40	50	50	50	100	100
33	42	50	50	50	100	100
33	44	50	50	50	100	100
33	46	50	50	50	100	100
33	48	50	50	50	100	100

Table 3-14 - Single Burst (37 dBm Beacon Power)

Beacon Emission Power	Slot No	NTBI	NVIM after 1 burst	NCM after 1 burst	%NVIM after 1 burst	%NCM after 1 burst
37	1	50	50	50	100	100
37	3	50	50	50	100	100
37	5	50	50	50	100	100
37	7	50	50	50	100	100
37	9	50	50	50	100	100
37	11	50	50	50	100	100
37	13	50	50	50	100	100
37	15	50	50	50	100	100
37	17	50	50	50	100	100
37	19	50	50	50	100	100
37	21	50	48	48	96	96
37	23	50	50	50	100	100
37	25	50	50	50	100	100
37	27	50	50	50	100	100
37	29	50	50	50	100	100
37	31	50	50	50	100	100
37	33	50	50	50	100	100
37	35	50	50	50	100	100
37	37	50	50	50	100	100
37	39	50	50	50	100	100

Beacon Emission Power	Slot No	NTBI	NVIM after 1 burst	NCM after 1 burst	%NVIM after 1 burst	%NCM after 1 burst
37	41	50	50	50	100	100
37	43	50	50	50	100	100
37	45	50	50	50	100	100
37	47	50	50	50	100	100

Table 3-15 - Multiple Bursts (33 dBm Beacon Power)

Beacon Emission Power	Slot No	NTBI	NVIM after 13 bursts	NCM after 13 bursts	%NVIM after 13 bursts	%NCM after 13 bursts
33	2	50	50	50	100	100
33	4	50	50	50	100	100
33	6	50	50	50	100	100
33	8	50	50	50	100	100
33	10	50	50	50	100	100
33	12	50	50	50	100	100
33	14	50	50	50	100	100
33	16	50	50	50	100	100
33	18	50	50	50	100	100
33	20	50	50	50	100	100
33	22	50	50	50	100	100
33	24	50	50	50	100	100
33	26	50	50	50	100	100
33	28	50	50	50	100	100
33	30	50	50	50	100	100
33	32	50	50	50	100	100
33	34	50	50	50	100	100
33	36	50	50	50	100	100
33	38	50	50	50	100	100
33	40	50	50	50	100	100
33	42	50	50	50	100	100
33	44	50	50	50	100	100
33	46	50	50	50	100	100
33	48	50	50	50	100	100

Table 3-16 - Multiple Bursts (37 dBm Beacon Power)

Beacon Emission Power	Slot No	NTBI	NVIM after 13 bursts	NCM after 13 bursts	%NVIM after 13 bursts	%NCM after 13 bursts
37	1	50	50	50	100	100
37	3	50	50	50	100	100
37	5	50	50	50	100	100
37	7	50	50	50	100	100
37	9	50	50	50	100	100
37	11	50	50	50	100	100
37	13	50	50	50	100	100
37	15	50	50	50	100	100
37	17	50	50	50	100	100
37	19	50	50	50	100	100
37	21	50	50	50	100	100
37	23	50	50	50	100	100
37	25	50	50	50	100	100
37	27	50	50	50	100	100
37	29	50	50	50	100	100
37	31	50	50	50	100	100
37	33	50	50	50	100	100
37	35	50	50	50	100	100
37	37	50	50	50	100	100
37	39	50	50	50	100	100
37	41	50	50	50	100	100
37	43	50	50	50	100	100
37	45	50	50	50	100	100
37	47	50	50	50	100	100

3.3.1.3 Russia

3.3.1.3.1 Configuration

All four antennas of the Russian MEOLUT were engaged in the test. The signal processor software was specifically configured to enable burst integration technique that takes into account the discrepancies of C/S T.001-compliant beacons signals and beacon simulators signals that emitted according to the test scripts provided in document C/S R.018. The change in the configuration included beacon burst repetition interval (strictly 50 sec, not 50 ± 2.5 sec).

Generally, the purpose of beacon burst integration is to attempt to produce a valid beacon message from multiple beacon bursts pertaining to the same beacon that for some reason a MEOLUT was not able to recover from a single-burst.

Table 3-17 lists all beacon simulator emissions that contributed to this report.

Table 3-17 - Beacon Simulator Emissions that Contributed

Simulator ID	Simulator Location	Emission Start (UTC)	Emission End (UTC)
1	France, Toulouse	2017-02-28 14:00	2017-03-01 14:00

3.3.1.3.2 Results

Presented below are the summary tables that included consolidated results for detection probability after 1, 2, 7 and 13 emitted bursts (Table 3-18, Table 3-19, Table 3-20 and Table 3-21) and transfer time (Table 3-22).

Table 3-18 - Detection Probability after 1 Emitted Burst

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 2 Bursts.	NCM After 2 Bursts.	Valid Message Det. Prob. (%) After 2 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 2 Bursts NCM/NTBI
37	1	3	50	50	50	100	100
33	2	2	50	50	48	100	96
37	3	1	50	48	46	96	92
33	4	1	50	48	48	96	96
37	5	2	50	50	50	100	100
33	6	2	50	50	50	100	100
37	7	3	50	50	50	100	100
33	8	3	50	50	50	100	100
37	9	3	50	50	50	100	100
33	10	3	50	50	50	100	100
37	11	3	50	50	50	100	100
33	12	4	50	50	50	100	100
37	13	4	50	50	50	100	100
33	14	3	50	50	50	100	100
37	15	3	50	50	50	100	100
33	16	3	50	50	50	100	100
37	17	4	50	50	50	100	100
33	18	4	50	50	50	100	100
37	19	3	50	50	50	100	100
33	20	3	50	50	50	100	100
37	21	2	50	50	50	100	100
33	22	2	50	50	50	100	100
37	23	2	50	50	50	100	100
33	24	2	50	50	50	100	100
37	25	2	50	50	50	100	100
33	26	3	50	50	50	100	100
37	27	3	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 2 Bursts.	NCM After 2 Bursts.	Valid Message Det. Prob. (%) After 2 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 2 Bursts NCM/NTBI
33	28	3	50	50	50	100	100
37	29	3	50	50	50	100	100
33	30	3	50	50	50	100	100
37	31	3	50	50	50	100	100
33	32	3	50	50	50	100	100
37	33	4	50	50	50	100	100
33	34	4	50	50	50	100	100
37	35	4	50	50	50	100	100
33	36	4	50	50	50	100	100
37	37	4	50	50	50	100	100
33	38	3	50	50	50	100	100
37	39	3	50	50	50	100	100
33	40	3	50	50	50	100	100
37	41	2	50	50	50	100	100
33	42	2	50	50	50	100	100
37	43	2	50	50	50	100	100
33	44	2	50	50	50	100	100
37	45	2	50	50	50	100	100
33	46	2	50	50	50	100	100
37	47	3	50	50	50	100	100
33	48	3	50	50	50	100	100

Table 3-19 - Detection Probability after 2 Emitted Bursts

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 2 Bursts.	NCM After 2 Bursts.	Valid Message Det. Prob. (%) After 2 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 2 Bursts NCM/NTBI
37	1	3	50	50	50	100	100
33	2	2	50	50	50	100	100
37	3	1	50	50	50	100	100
33	4	1	50	49	49	98	98
37	5	2	50	50	50	100	100
33	6	2	50	50	50	100	100
37	7	3	50	50	50	100	100
33	8	3	50	50	50	100	100
37	9	3	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 2 Bursts.	NCM After 2 Bursts.	Valid Message Det. Prob. (%) After 2 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 2 Bursts NCM/NTBI
33	10	3	50	50	50	100	100
37	11	3	50	50	50	100	100
33	12	4	50	50	50	100	100
37	13	4	50	50	50	100	100
33	14	3	50	50	50	100	100
37	15	3	50	50	50	100	100
33	16	3	50	50	50	100	100
37	17	4	50	50	50	100	100
33	18	4	50	50	50	100	100
37	19	3	50	50	50	100	100
33	20	3	50	50	50	100	100
37	21	2	50	50	50	100	100
33	22	2	50	50	50	100	100
37	23	2	50	50	50	100	100
33	24	2	50	50	50	100	100
37	25	2	50	50	50	100	100
33	26	3	50	50	50	100	100
37	27	3	50	50	50	100	100
33	28	3	50	50	50	100	100
37	29	3	50	50	50	100	100
33	30	3	50	50	50	100	100
37	31	3	50	50	50	100	100
33	32	3	50	50	50	100	100
37	33	4	50	50	50	100	100
33	34	4	50	50	50	100	100
37	35	4	50	50	50	100	100
33	36	4	50	50	50	100	100
37	37	4	50	50	50	100	100
33	38	3	50	50	50	100	100
37	39	3	50	50	50	100	100
33	40	3	50	50	50	100	100
37	41	2	50	50	50	100	100
33	42	2	50	50	50	100	100
37	43	2	50	50	50	100	100
33	44	2	50	50	50	100	100
37	45	2	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 2 Bursts.	NCM After 2 Bursts.	Valid Message Det. Prob. (%) After 2 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 2 Bursts NCM/NTBI
33	46	2	50	50	50	100	100
37	47	3	50	50	50	100	100
33	48	3	50	50	50	100	100

Table 3-20 - Detection Probability after 7 Emitted Bursts

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 7 Bursts.	NCM After 7 Bursts.	Valid Message Det. Prob. (%) After 7 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 7 Bursts NCM/NTBI
37	1	3	50	50	50	100	100
33	2	2	50	50	50	100	100
37	3	1	50	50	50	100	100
33	4	1	50	50	50	100	100
37	5	2	50	50	50	100	100
33	6	2	50	50	50	100	100
37	7	3	50	50	50	100	100
33	8	3	50	50	50	100	100
37	9	3	50	50	50	100	100
33	10	3	50	50	50	100	100
37	11	3	50	50	50	100	100
33	12	4	50	50	50	100	100
37	13	4	50	50	50	100	100
33	14	3	50	50	50	100	100
37	15	3	50	50	50	100	100
33	16	3	50	50	50	100	100
37	17	4	50	50	50	100	100
33	18	4	50	50	50	100	100
37	19	3	50	50	50	100	100
33	20	3	50	50	50	100	100
37	21	2	50	50	50	100	100
33	22	2	50	50	50	100	100
37	23	2	50	50	50	100	100
33	24	2	50	50	50	100	100
37	25	2	50	50	50	100	100
33	26	3	50	50	50	100	100
37	27	3	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 7 Bursts.	NCM After 7 Bursts.	Valid Message Det. Prob. (%) After 7 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 7 Bursts NCM/NTBI
33	28	3	50	50	50	100	100
37	29	3	50	50	50	100	100
33	30	3	50	50	50	100	100
37	31	3	50	50	50	100	100
33	32	3	50	50	50	100	100
37	33	4	50	50	50	100	100
33	34	4	50	50	50	100	100
37	35	4	50	50	50	100	100
33	36	4	50	50	50	100	100
37	37	4	50	50	50	100	100
33	38	3	50	50	50	100	100
37	39	3	50	50	50	100	100
33	40	3	50	50	50	100	100
37	41	2	50	50	50	100	100
33	42	2	50	50	50	100	100
37	43	2	50	50	50	100	100
33	44	2	50	50	50	100	100
37	45	2	50	50	50	100	100
33	46	2	50	50	50	100	100
37	47	3	50	50	50	100	100
33	48	3	50	50	50	100	100

Table 3-21 - Detection Probability after 13 Emitted Bursts

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 13 Bursts.	NCM After 13 Bursts.	Valid Message Det. Prob. (%) After 13 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 13 Bursts NCM/NTBI
37	1	3	50	50	50	100	100
33	2	2	50	50	50	100	100
37	3	1	50	50	50	100	100
33	4	1	50	50	50	100	100
37	5	2	50	50	50	100	100
33	6	2	50	50	50	100	100
37	7	3	50	50	50	100	100
33	8	3	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 13 Bursts.	NCM After 13 Bursts.	Valid Message Det. Prob. (%) After 13 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 13 Bursts NCM/NTBI
37	9	3	50	50	50	100	100
33	10	3	50	50	50	100	100
37	11	3	50	50	50	100	100
33	12	4	50	50	50	100	100
37	13	4	50	50	50	100	100
33	14	3	50	50	50	100	100
37	15	3	50	50	50	100	100
33	16	3	50	50	50	100	100
37	17	4	50	50	50	100	100
33	18	4	50	50	50	100	100
37	19	3	50	50	50	100	100
33	20	3	50	50	50	100	100
37	21	2	50	50	50	100	100
33	22	2	50	50	50	100	100
37	23	2	50	50	50	100	100
33	24	2	50	50	50	100	100
37	25	2	50	50	50	100	100
33	26	3	50	50	50	100	100
37	27	3	50	50	50	100	100
33	28	3	50	50	50	100	100
37	29	3	50	50	50	100	100
33	30	3	50	50	50	100	100
37	31	3	50	50	50	100	100
33	32	3	50	50	50	100	100
37	33	4	50	50	50	100	100
33	34	4	50	50	50	100	100
37	35	4	50	50	50	100	100
33	36	4	50	50	50	100	100
37	37	4	50	50	50	100	100
33	38	3	50	50	50	100	100
37	39	3	50	50	50	100	100
33	40	3	50	50	50	100	100
37	41	2	50	50	50	100	100
33	42	2	50	50	50	100	100
37	43	2	50	50	50	100	100
33	44	2	50	50	50	100	100

Beacon emission power	Slot №	Number of satellites in mutual visibility	NTBI Number transmitted beacon IDs	NVIM After 13 Bursts.	NCM After 13 Bursts.	Valid Message Det. Prob. (%) After 13 Bursts. NVIM/NTBI	Complete Message Det. Prob (%) After 13 Bursts NCM/NTBI
37	45	2	50	50	50	100	100
33	46	2	50	50	50	100	100
37	47	3	50	50	50	100	100
33	48	3	50	50	50	100	100

Table 3-22 - Transfer Time

Slot №	Beacon emission power	Number of satellites in mutual visibility	Mean value of Valid Mess. Transfer time	Mean value of Confirmed Valid Mess. Transfer time	Mean value of Complete Mess. Transfer time	Mean value of Confirmed Complete Mess. Transfer time
1	3	37	0.395	12.403	0.395	13.403
2	2	33	0.391	16.399	2.392	21.399
3	1	37	2.385	53.385	4.385	55.385
4	1	33	3.383	53.383	4.383	56.383
5	2	37	0.385	0.414	0.385	0.414
6	2	33	0.386	0.41	0.386	0.41
7	3	37	0.384	0.4	0.384	0.4
8	3	33	0.366	0.392	0.366	0.392
9	3	37	0.354	0.396	0.354	0.396
10	3	33	0.349	3.393	0.35	4.392
11	3	37	0.345	0.391	0.345	0.391
12	4	33	0.348	0.384	0.348	0.384
13	4	37	0.357	0.376	0.357	0.376
14	3	33	0.368	0.386	0.368	0.386
15	3	37	0.377	0.393	0.377	0.393
16	3	33	0.362	0.392	0.362	0.392
17	4	37	0.365	0.393	0.365	0.393
18	4	33	0.37	0.396	0.371	0.396
19	3	37	0.386	0.397	0.386	0.397
20	3	33	0.384	0.397	0.384	0.397
21	2	37	0.385	2.398	0.385	2.398
22	2	33	0.384	0.4	0.384	0.4
23	2	37	0.386	0.405	0.386	0.405
24	2	33	0.376	26.387	0.376	26.387
25	2	37	0.363	6.39	0.364	7.389
26	3	33	0.358	0.396	0.358	0.396
27	3	37	0.362	0.399	0.362	0.399

Slot №	Beacon emission power	Number of satellites in mutual visibility	Mean value of Valid Mess. Transfer time	Mean value of Confirmed Valid Mess. Transfer time	Mean value of Complete Mess. Transfer time	Mean value of Confirmed Complete Mess. Transfer time
28	3	33	0.372	0.394	0.372	0.394
29	3	37	0.382	0.389	0.382	0.389
30	3	33	0.385	0.394	0.385	0.394
31	3	37	0.385	0.4	0.385	0.4
32	3	33	0.377	0.384	0.377	0.384
33	4	37	0.372	0.385	0.372	0.385
34	4	33	0.369	0.386	0.369	0.386
35	4	37	0.37	0.388	0.37	0.388
36	4	33	0.374	0.392	0.374	0.392
37	4	37	0.388	0.396	0.388	0.396
38	3	33	0.391	0.397	0.391	0.397
39	3	37	0.389	0.402	0.389	0.402
40	3	33	0.387	4.404	0.387	4.404
41	2	37	0.391	4.405	0.391	4.405
42	2	33	0.392	0.4	0.392	0.4
43	2	37	0.395	2.396	0.395	2.396
44	2	33	0.391	2.401	0.391	2.401
45	2	37	0.389	25.397	0.389	25.397
46	2	33	0.382	5.387	0.382	5.387
47	3	37	0.37	0.389	0.37	0.389
48	3	33	0.361	0.391	0.361	0.391

In accordance with requirement the detection probability or the probability of detecting the transmission of a 406 MHz beacon and recovering at the MEOLUT a valid beacon message shall be within 10 minutes from the first beacon message transmission with probability 0.99. It is seen from Table 3-41 and Table 3-42 that the probability of detection of at least one valid/complete messages at the MEOLUT was 100% in all cases after 2 transmitted bursts (or within 2 minutes after beacon activation) for both 37 dBm and 33 dBm values of beacon emission power.

3.3.2 Interpretation

3.3.2.1 France

The detection performances observed during Phase III were better than observed in Phase II, for both Maryland and Toulouse transmissions. It appeared that during a 24-hour period, due to the variation of L-band satellites configuration, most of the slots met expected results but it remained a few numbers of slots for which the performances were slightly degraded.

So the S-band satellites were still required to obtain a sufficient coverage over time.

The future L-band satellite deployment should improve the message detection performances thanks to a better link budget and an increased number of satellites in beacon-MEOLUT mutual visibility. Once a full L-band constellation is available, it should be possible to detect in real-time beacons as far as 6,000 km.

3.3.2.2 USA-Maryland

Results from test T-3 demonstrate the improved performance related to the stronger link performance of the L-band satellites for single-burst at 33 dBm. Detection percentages are near 100 % as a result of low levels of received signal to noise ratio (C/N_0).

3.3.2.3 Russia

In accordance with the requirements the detection probability or the probability of detecting the transmission of a 406 MHz beacon and recovering at the MEOLUT a valid beacon message shall be within 10 minutes from the first beacon message transmission with the probability of 0.99.

It is seen from the results that the probability of detection of at least one valid/complete message at the MEOLUT was 100% in all cases after 2 transmitted bursts (or within 2 minutes after beacon activation) for both 37 dBm and 33 dBm values of beacon emission power. Thus, it can be concluded that the requirement was met with a solid margin of time.

3.4 Test T-4 (Independent 2D Location Capability)

Test Objectives

According to document C/S R.018, test T-4, "Independent 2D Location Capability" is defined as the three parameters used to characterize the MEOSAR system 2D independent location capability. They are evaluated for stand-alone MEOLUTs.

Independent Location Probability - Characterize the probability for a stand-alone MEOLUT to provide an independent 2D location with a location error less than X km (X = 1, 5 or 10 km), for a given number of transmitted bursts (1 to 7 bursts) and for a beacon transmitting at 37 dBm and 33 dBm.

Independent Location Accuracy - Characterize the cumulative distribution of location errors for independent locations produced by a stand-alone MEOLUT after a given number of transmitted bursts (1 to 7 bursts) and for a beacon transmitting at 37 dBm and 33 dBm.

Time to First Independent Location - Characterize the time elapsed between the first burst transmitted and the first 2D independent location provided by a stand-alone MEOLUT with an error less than X km (X = 1, 5 or 10 km) and for a beacon transmitting at 37 dBm and 33 dBm.

3.4.1 Analysis

The following test reports were provided by the participants:

Table 3-23 - T-4 Test Reports Provided by Participants

Administration	Test report reference
France	JC-32-Inf-23
Russia	T-4Independent location Capability test report
USA	P3_T4_2018_09_04_USA_Maryland_Report (JC-32)

3.4.1.1 France

During this test T-4, 13 L-band satellites were enabled on the French MEOLUT: 401, 402, 405, 407, 408, 409, 419, 422, 424, 430, [414, 418 and 420][4]

Location Probability

Toulouse Run 2 Transmission

Figure 3-5 shows the location probability within 10 minutes depending on the slot number. The location probability within 10 minutes is equal to 100% for all slots except slots 40 and 42-46 for which the space segment coverage is degraded (less than 4 satellites in co-visibility).

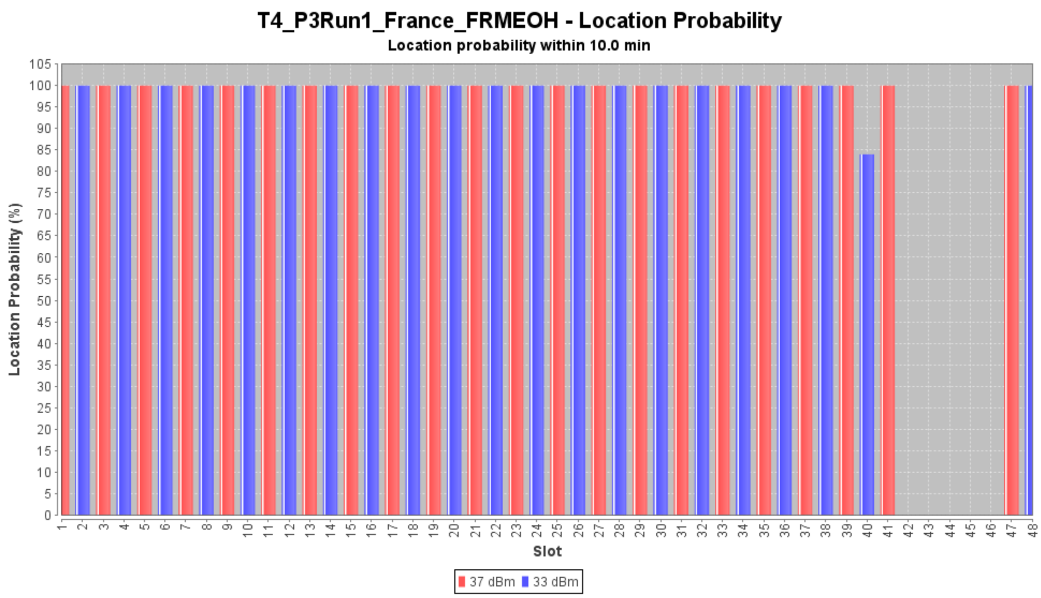


Figure 3-5: Location Probability Within 10 Minutes – Toulouse Transmission

Maryland Run 2 Transmission

Figure 3-6 shows the location probability within 10 minutes depending on the slot number. The location probability within 10 minutes is equal to 100% for slots 23, 25, 27, 33, 39, 41 and 45 at 37 dBm. For other 37 dBm slots, the location probability is not consistent with the C/S T.019 requirement (98% within 10 min), mainly due to the limited co-visibility of the tracked satellites. The behaviour of the 33 dBm slots is similar.

[4] Using GSC ephemerides

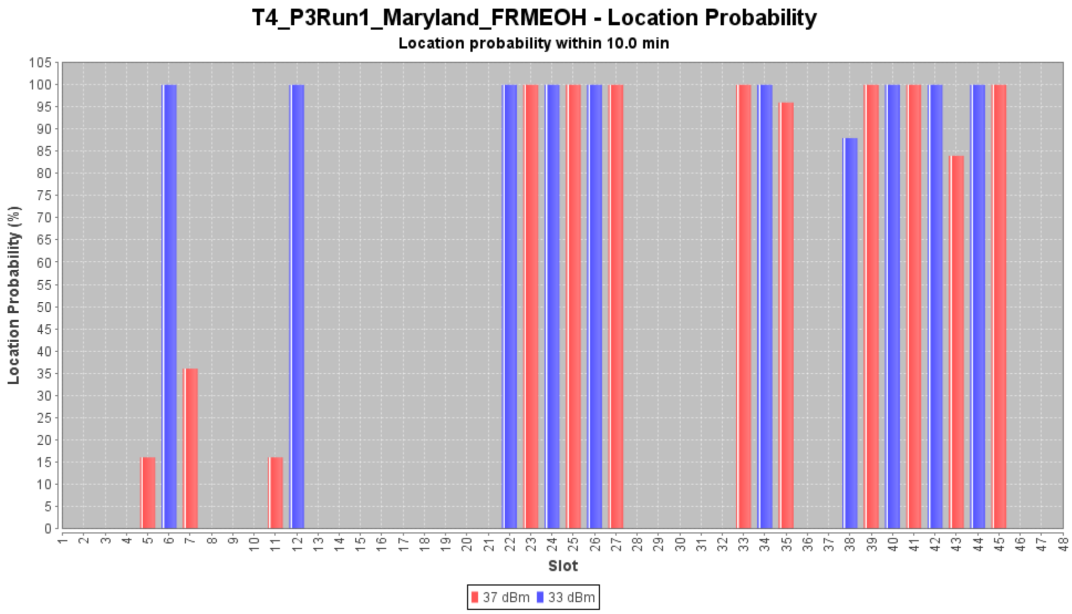


Figure 3-6: Location Probability Within 10 Minutes – Maryland Transmission

Location Accuracy

Toulouse Run 2 Transmission

Figure 3-7 shows the cumulative distribution of the location errors based on the number of satellites used to compute the location, at transmission power equal to 37 dBm. Considering all locations, the performance was 95% within 4.9 km.

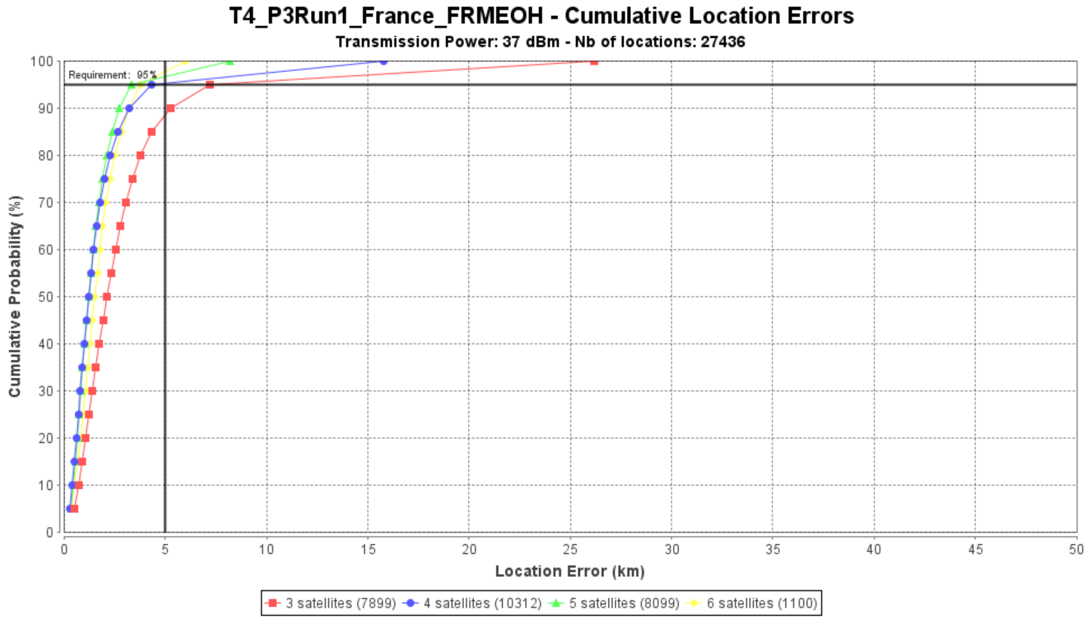


Figure 3-7: Cumulative Distribution of Location Errors Depending on the Number of Satellites Used to Compute Location – 37 dBm – Toulouse Transmission

Maryland Run 2 Transmission

Figure 3-8 shows the cumulative distribution of the location errors based on the number of satellites used to compute the location, at transmission power equal to 37 dBm. Considering all locations, the performance was 95% within 8.0 km.

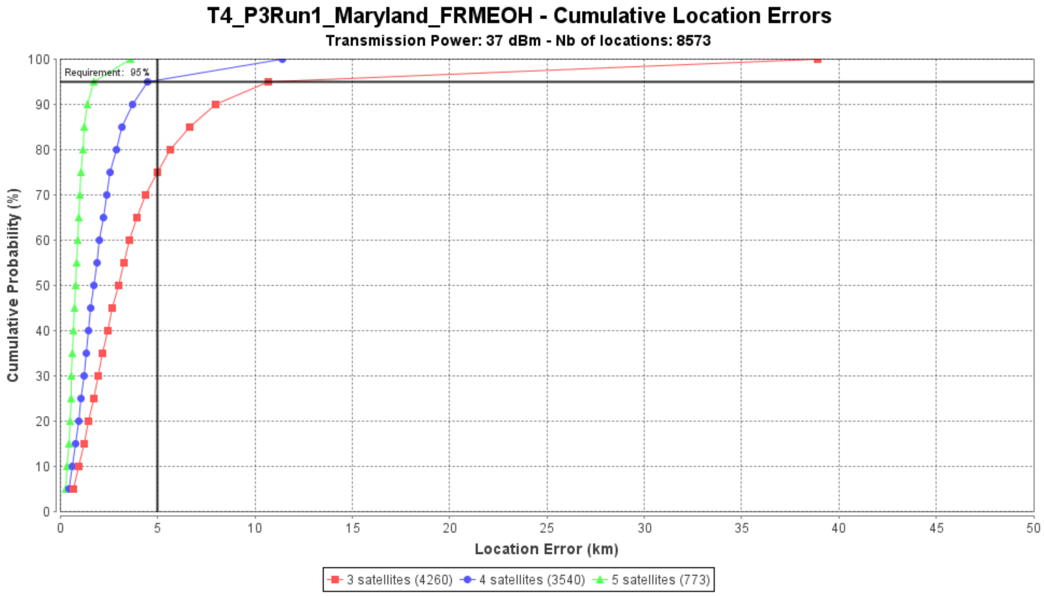


Figure 3-8: Cumulative Distribution of Location Errors Depending on the Number of Satellites Used to Compute Location – 37 dBm – Maryland Transmission

The number of satellites to compute the location has a big impact in term of accuracy and the four or more satellite locations are accurate although the Maryland beacon simulator is at 6,300 km from the French MEOLUT.

3.4.1.2 USA

For test T-4, the USA took on the role of test coordinator with the support of the Secretariat. Test coordination was performed via the collaboration website Basecamp.

During the Phase II T-4 pre-test meeting, the following changes were proposed and incorporated into the T-4 script:

- Add a 13-burst block,
- Remove the 6 and 4 blocks,
- Add a wait before changing power levels,
- Keep both power levels within one hour,
- Keep the test at 24 hours.

Table 3-24 - T-4 Test Runs

Start date	Test	Run	Time 1st Tx	Time last Tx	Beacon simulator location	Comment
2017-06-15	T-4	1	2017-06-01 14:00:00	2017-06-16 14:00:00	France	MD, Hi, Fla reference beacons OFF
2017-06-20	T-4	1	2017-06-20 14:00:00	2017-06-21 13:55:00	Maryland	Hi, and Fla reference beacons OFF
2017-06-22	T-4	1	2017-06-22 14:00:00	2017-06-23 13:55:00	Florida	MD and Hi reference beacons OFF

France conducted preliminary analysis of the new T-4 beacon scripts to make sure that there were no problems with the SARP-3 processing and to limit the risk of producing false alert messages.

3.4.1.2.1 Configuration

During test T-4, the Maryland MEOLUT was configured in stand-alone, non-networked mode. There was an error prior to the start of the test and the pass schedule was NOT modified to only select L-band satellites. Maryland used a combination of S-band and L-band satellites. Maryland channels 1, 3, 4, 5 and 6 were available for the test.

3.4.1.2.2 Results

Summary of Maryland MEOLUT results from Maryland simulator

Table 3-25 - T-4 Maryland Summary of Results

Parameter	Tx Power	13 Bursts	7 Bursts	5 Bursts	3 Bursts	2 Bursts	1 Burst
Independent Location (any) Probability (%)	33	1	0.98	0.99	0.91	0.85	0.69
	37	1	1	0.99	0.99	0.98	0.88
Independent Location Probability for errors less than 5 km (%)	33	0.75	0.70	0.71	0.58	0.44	0.32
	37	0.80	0.76	0.69	0.62	0.57	0.43
Independent Location Errors 95th percentile (km)	33	9.44	9.32	9.51	10.51	10.84	12.97
	37	7.47	8.18	8.52	10.27	10.04	12.38

3.4.1.3 Russia

3.4.1.3.1 Configuration

All four antennas of the Russian MEOLUT were engaged in the test. The signal processor software was specifically configured to enable burst integration technique that takes into account the discrepancies of C/S T.001-compliant beacons signals and beacon simulators signals that emitted according to the test scripts provided in document C/S R.018.

The change in the configuration included beacon burst repetition interval (strictly 50 sec, not 50 ± 2.5 sec). Generally, the purpose of beacon burst integration is to attempt to produce a valid beacon message from multiple beacon bursts pertaining to the same beacon that for some reason a MEOLUT was not able to recover from a single-burst.

Table 3-26 lists all beacon simulator emissions that contributed to this report.

Table 3-26 - Beacon Simulator Emissions Schedule

Simulator ID	Simulator Location	Emission Start (UTC)	Emission End (UTC)
#1	France, Toulouse	2015-06-15 14:00	2015-06-16 14:00

For the purpose of generating independent location probability tables, only locations that included maximum transmitted bursts per beacon event (i.e., expecting 1, 2, 3, 5, 7 and13 bursts per beacon sequence) were used to compute such statistics. Time periods corresponding to the beacon burst sequences when the MEOLUT was not able to “see” all beacons within that sequence at least by three single-satellite channels, were discarded from analysis.

As EHE value is expressed in km, it deemed appropriate to compare real location errors with EHE values, not with JDOP. In all tables, instead of JDOP values there were EHE values computed assuming receiving 1 packet from each satellite in mutual visibility of radio beacon and MEOLUT. EHE for multi-burst solutions can be derived from single-burst EHE by dividing it by √N, where N is number of emitted bursts used in a solution. Thus, EHE for multi-burst solution computed with 13 emitted bursts is 3.6 times better than single-burst EHE.

Locations were generated using TOA and FOA as a function of the C/N_0 of the burst received. The values of FOA as a function of the C/N_0 were computed as per the chart depicted at Figure 3-9. As the TOA measurement accuracy does not have tangible impact on the location accuracy in case of FGBs, TOA measurement accuracy values were assumed to be constant and approximated at 25 ms. Since location accuracy (up to 100 m) in many cases was comparable with beacon elevation (214 m), the value of this elevation was used in location processing.

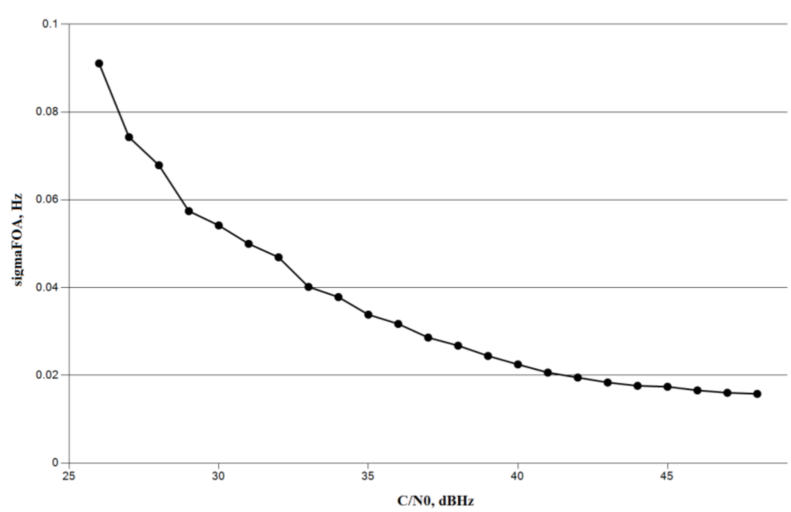


Figure 3-9: Experimental Graph of Sigma FOA as a Function of C/N_0 for L-Band Satellites

3.4.1.3.2 Results

Table 3-27 presents the summary table for independent location probabilities, independent location accuracy and time-to-first location averaged over 48 slots.

Table 3-27 - Averaged over 48 Slots Results of Test T-4

Burst sequence length	**1 b**	**2 b**	**3 b**	**5b**	**7 b**	**13 b**
Probabilities for errors less than 1 km	0.844	0.911	0.904	0.919	0.904	0.921
Probabilities for errors less than 5 km	0.936	0.978	0.973	0.978	0.988	0.999
Probabilities for errors less than 10 km	0.943	0.985	0.978	0.986	1.000	1.000
Location accuracy, 50th percentile (km)	0.586	0.517	0.359	0.361	0.421	0.307
Location accuracy, 75th percentile (km)	1.015	0.760	0.617	0.560	0.578	0.430
Location accuracy, 95th percentile (km)	2.004	1.329	1.295	0.941	0.840	0.638
Time to first location with errors less than 1 km (sec)	29.69					
Time to first location with errors less than 5 km (sec)	13.92					
Time to first location with errors less than 10 km (sec)	11.96					

As could be noted from Table 3-27, the test results indicated that MEOSAR performance requirements were met with good margins. However, additional analysis revealed a number of factors that, in some cases, could seriously degrade beacon location accuracy and defeat the adequacy of the EHE as location quality indicator. These factors are considered in detail in the Russia's report and included:

a) partial space segment,

b) beacon simulator site elevation,

c) measurement errors model on location accuracy,

d) systematic errors (bias).

3.4.1.3.3 Complimentary Analysis

Effects of Partial Space Segment

A limited space segment resulted in EHE_{APR} (an a priori estimate of EHE) being significantly higher in several slots than on average. These slots are further referred to as "anomalous". To demonstrate this, averaged EHE_{APR} calculated over 10-minute intervals are shown in Figure 3-10. EHE_{APR} in these slots significantly exceeded the average levels resulting in additional errors.

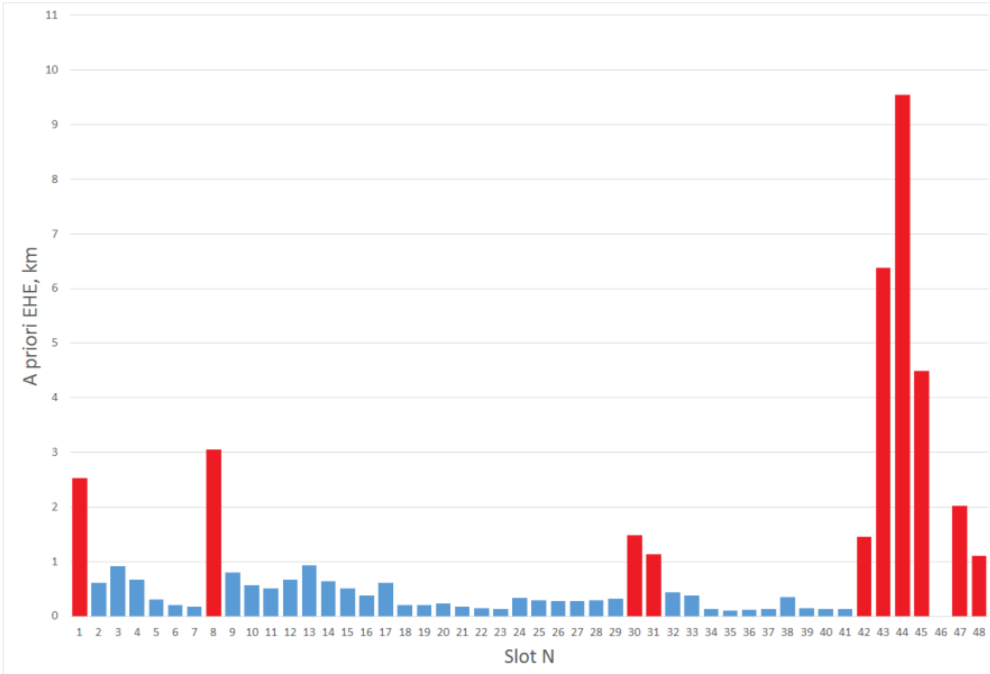


Figure 3-10: Averaged over a Slot EHE_{APR} from Test T-4

In order to evaluate potential results that could be achieved with increased number of satellites in the constellation, "anomalous" slots Nos. 1, 8, 30, 31, 42, 43, 44, 45, 47 and 48 with large EHE_{apr} have been discarded, and the test objective results from remaining ones are integrated in Table 3-28.

Table 3-28 - Averaged Results for Slots with "Normal" EHE_{APR}

Burst sequence length	**1 b**	**2 b**	**3 b**	**5 b**	**7 b**	**13 b**
Probabilities for errors less than 1 km	0.946	0.987	0.964	0.984	0.997	0.999
Probabilities for errors less than 5 km	0.979	0.997	0.982	0.987	1.000	1.000
Probabilities for errors less than 10 km	0.981	0.997	0.982	0.987	1.000	1.000
Location accuracy, 50^{th} percentile (km)	0.247	0.189	0.194	0.146	0.136	0.124
Location accuracy, 75^{th} percentile (km)	0.377	0.297	0.282	0.220	0.209	0.175
Location accuracy, 95^{th} percentile (km)	0.713	0.469	0.449	0.332	0.327	0.251
Time to first location with errors less than 1 km (sec)	3.1					
Time to first location with errors less than 5 km (sec)	1.4					
Time to first location with errors less than 10 km (sec)	1.3					

It can be seen from Table 3-28 that elimination of the results from the "abnormal" slots yield to nearly three times the performance enhancements that can be anticipated and validated with the greatest number of L-band SAR payloads in the space segment.

Effects of Beacon Simulator Site Elevation

In order to evaluate the impact of beacon site elevation on the beacon coordinates' accuracy, location was computed in two ways: one computation assumed a zero elevation, while the other accounted for real elevation (214 m) of the Toulouse beacon simulator site. Comparison results are represented in Figure 3-11.

The significance of the vertical dimension in calculating location solution is clearly seen at Figure 3-11. For some beacon-to-satellite geometries, discarding the beacon position elevation of a few hundred meters could degrade twofold the location accuracies and lead to errors exceeding the EHE values, requirement allowance and the elevation values.

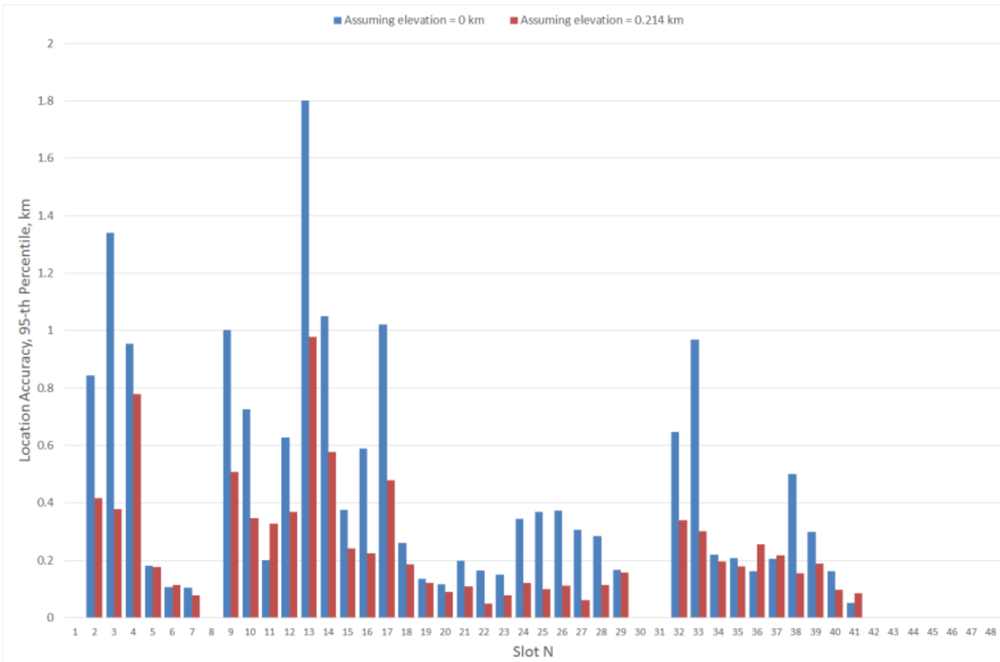


Figure 3-11: Impact of the Beacon Simulator Site Elevation on the Location Accuracy over 10-min Interval (13 Bursts)

Effects of Measurement Errors Model on Location Accuracy

To evaluate the effects of the measurement errors model, locations were computed twice – with fixed $Sigma_{FOA}$ = 0.02 Hz, and using FOA error as a function of C/N_0 per graph in Figure 3-9. Comparison of these two cases for the 95th percentile is shown in Figure 3-12.

It can be concluded from this comparison that in most cases the difference is tolerable. Thus, the assumption suggesting application of fixed sigma TOA and sigma FOA is deemed to be acceptable for developing tracking algorithms, calculation of EHE_{APR} and evaluating whether the accuracy requirements for a given beacon-to-satellite geometry are met.

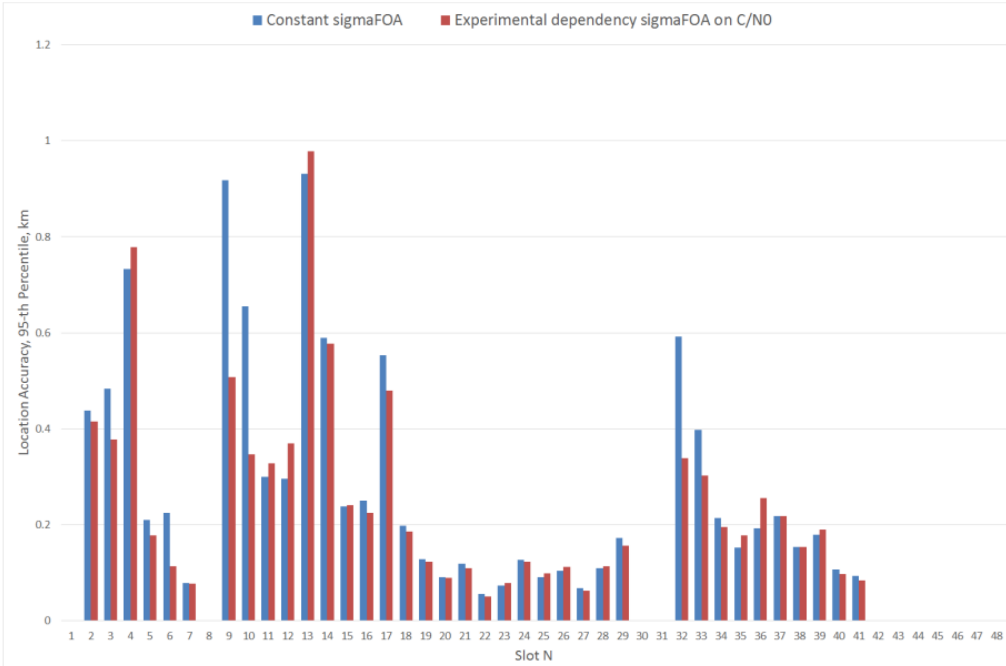


Figure 3-12: Impact of FOA Error Model on Location Accuracy over 10-min Intervals (13 Bursts)

Effects of Systematic Errors (Bias)

It was noted in the analysis that, in some slots, location errors were randomly distributed and centered over the true beacon coordinates. An example of such a slot, slot No 27, is shown in Figure 3-13 with errors observed during a 10-min interval (13 bursts).

However, systematic (bias) errors were also observed in some of the cases. In Figure 3-14 and Figure 3-15, errors for multi-burst (10-min) and single-burst locations in slot No 18 are respectively represented. Combining several bursts in multi-burst location can help to reduce noise error, but not bias errors, so they affect multi-burst location accuracy much more than single-burst location accuracy and have to be accounted for in calculating of the EHE value. Based on test T-4 results, bias errors can be ignored in the single-burst locations for most of the cases.

Bias errors in location errors stem from measurement errors in satellite channels. To demonstrate this, the measurement errors for each satellite channel in slot No. 18 were determined and were as follows:

Channel 1: mean error = 0.007 Hz, RMS = 0.012 Hz
Channel 2: mean error = 0.006 Hz, RMS = 0.035 Hz
Channel 3: mean error = 0.017 Hz, RMS = 0.020 Hz
Channel 4: mean error = -0.011 Hz, RMS = 0.016 Hz

These errors are shown in Figure 3-16 together with their associated C/N_0 graphs.

The causes of systematic measurement errors have not been determined at this point, although they are most likely due to ionosphere effects. The systematic error can be of the same order of magnitude as noise errors or even exceed them.

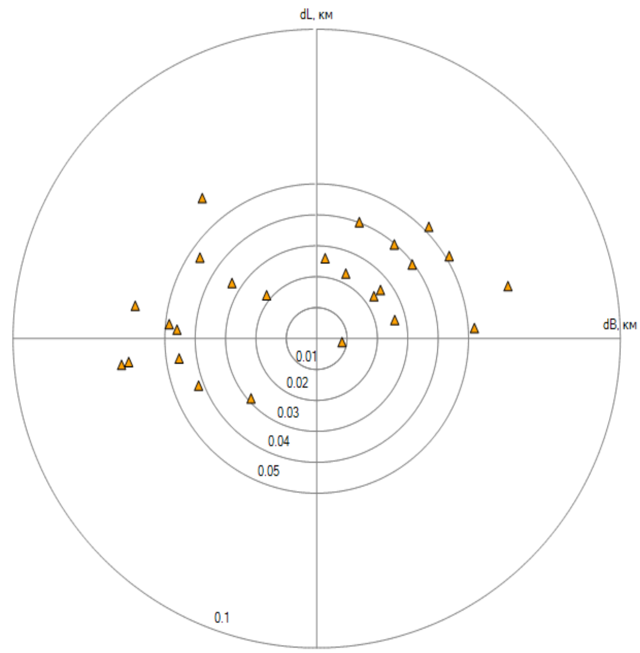


Figure 3-13: Location Errors over 10-min Intervals in Slot No 27

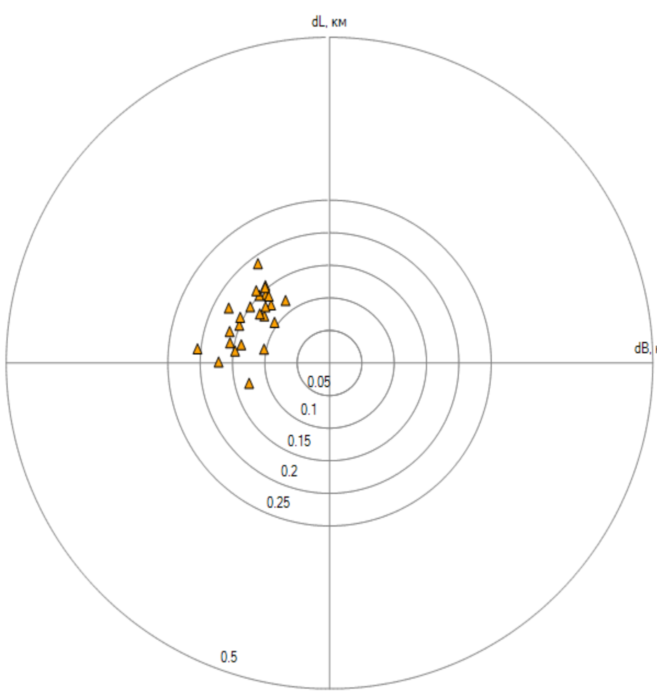


Figure 3-14: Location Errors over 10-Min Intervals in Slot No. 18.

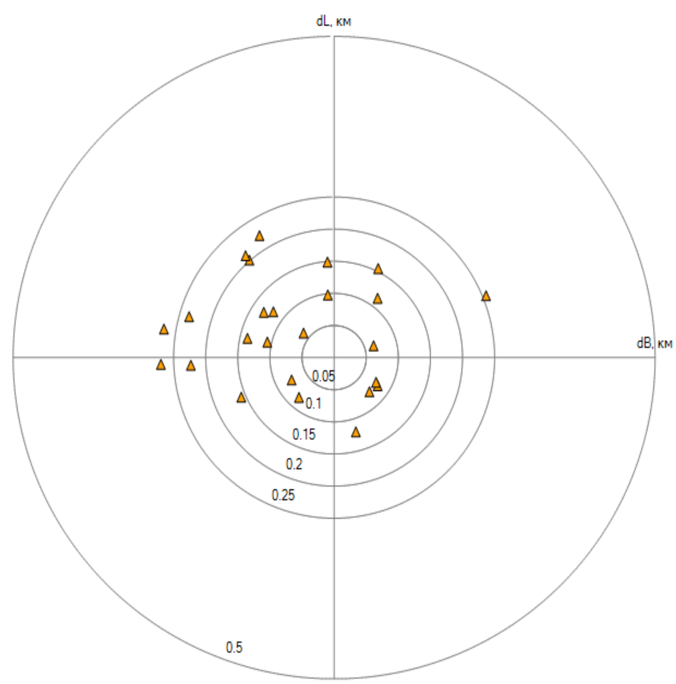


Figure 3-15: Location Errors for Single-Burst Solution in Slot No. 18.

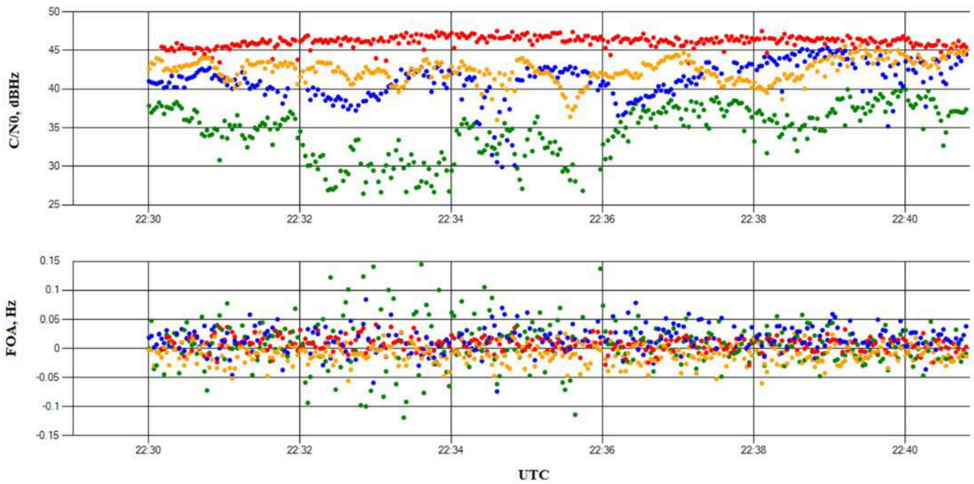


Figure 3-16: FOA Errors and Associated C/N_0 in Slot No. 18

Characterization of Location Accuracy Using the Error Ellipse

At the Moscow MEOLUT, an Expected Horizontal Error is defined as a major semi-axis of an error ellipse. In some cases, the ellipse might be very extended along its major axis as shown, for example, in Figure 3-17 for slot No 8. In this particular case, the area of the error ellipse was approximately 40 times less than the area of the circle of EHE radius. For this case, error ellipse could have significantly reduced the search and rescue area.

With an increased number of available L-band satellites, appropriate tracking scheduling would allow alleviating the narrow error ellipse cases in the declared MEOLUT coverage area. However, error ellipses beyond this area would sometimes look alike, yet would still be more informative than EHE for search and rescue.

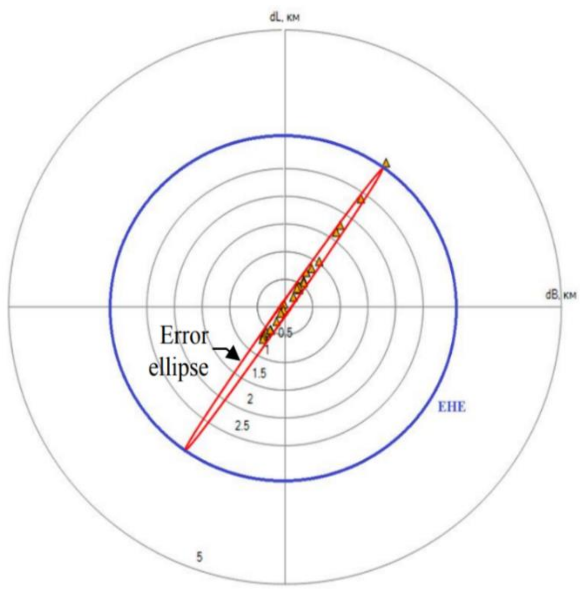


Figure 3-17: Locations over 10-Min Intervals (13 bursts) with the Extended Error Ellipse in Slot No. 8

3.4.2 Interpretation

3.4.2.1 France

Globally, the location performance in terms of location probability and location accuracy is better than that observed during previous Phase I and Phase II.

The location probability achieved the C/S T.019 requirement (98% within 10 min) when four or more satellites are in co-visibility for Toulouse beacon simulator transmission. For the Maryland and Florida simulator transmissions, the location probability meets the C/S T.019 requirement for several time slots.

As observed during Phase II, the number of satellites to compute the location is the main parameter in term of location accuracy. The location accuracy requirement (95% within 5 km) is met for the locations computed from four or more satellites during the Toulouse and Maryland simulator transmissions. During the Florida simulator transmission, the location accuracy is clearly degraded, with most of locations computed with three satellites.

The future deployment of L-band satellites will improve the location performance by increasing the number of satellites in co-visibility, as the French MEOLUT can track up to 20 L-band satellites.

3.4.2.2 USA-Maryland

Unfortunately, the tracking schedule was not modified to utilize only L-band satellites for this test. However, more L-band satellites were included in the testing than in previous MESOAR D&E testing. This is evident in improved probability of location statistics.

3.4.2.3 Russia

In the course of the test T-4 Run1 basic MEOSAR location parameters were evaluated:

- Independent Location Probability (with errors less than 1, 5 and 10 km);
- Independent Location Accuracy (50^{th}, 75^{th} and 95^{th} percentiles); and
- Time to First Independent Location (for locations with errors less than 1, 5 and 10 km).

It was noted from the results of analysis that Independent location capability performance of Moscow MEOLUT met the MEOSAR minimum performance requirements with respect to location performance stated in Annex E of document C/S R.012 "Cospas-Sarsat 406 MHz MEOSAR Implementation plan" and that:

- test results reconfirmed the significant impacts of the space segment availability and tracking algorithm feasibility on the location accuracy, even for static FGBs, introducing variations of location accuracy of up to a hundred times;
- disregarding the beacon position elevation in the localization procedure could result in systematic errors in some cases exceeding the elevation value and noise errors;
- bias errors in measurements add bias errors to location errors - this could be neglected in most single-burst solutions, but not in the multi-burst solutions where bias errors might be

comparable with noise errors and, therefore, have to be accounted for in calculating of EHE values;

- the characterization of the location errors using an error ellipse appears to be significantly more informative than using the EHE, at least by reducing the searching area in some cases;
- according to preliminary estimates, the increased number of L-band satellites would help to achieve location accuracy within 100-300 meters for multi-burst solutions (over 10 minutes) and within 0.3-1.0 km for single-burst solutions for fixed first-generation beacons; and
- achieving similar order of accuracy for moving beacons would require a greater number of measurements and the use of joint velocity and position location algorithm.

3.5 Test T-5 (Independent 2D Location Capability for Operational Beacons)

Test Objectives

According to document C/S R.018, test T-5, “Independent 2D Location Capability for Operational Beacons”, is defined as:

Characterize the 2D independent location performance of the (stand-alone) MEOSAR system after each transmitted single burst, two consecutive transmitted bursts, three consecutive bursts, and so on up to seven consecutive bursts for each operational first generation beacon used in the test, by determining the following parameters:

- MEOLUT System Throughput and Optional Single-Channel Throughput,
- n-Burst Independent Location Probability,
- n-Burst Independent Location Probability with Errors Less Than X km, and
- n-Burst Independent Location Accuracy.

Phase III of the MEOSAR D&E test T-5 was carried out using operational beacons. Test coordination and the beacon activation schedule was kept up to date on the Basecamp web site.

Table 3-29 provides the list of beacons activated by test participants for test T-5.

Table 3-29 - Operational Test Beacons Activated by T-5 Test Participants

Administration	Location	Moving/Not moving	Date and Frequency (MHz)											
			13-Jun	20-Jun	5-Jul	10-Jul	11-Jul	12-Jul	13-Jul	16-Jul	20-Jul	25-Jul	31-Jul	5-Sep
Canada	Woodlawn, North West Ottawa	Static			406.038									
Canada	Woodlawn, North West Ottawa	Static			406.037									
Canada	Belleville, Ontario	Moving			X									
Canada	Belleville, Ontario	Static			X									
Canada		Moving												
Canada/USA	Lake George, NY state, USA	Moving									406.037	406.037		
France	Audinghen, France	Static				406.028								406.028
France	Papeete1, French Polynesia	Static							406.xxx					
France	Papeete2, French Polynesia	Static							406.xxx					
France	Tel Aviv, Israel	Moving										406.031	406.031	
France	Tel Aviv, Israel	Moving										406.031	406.031	
France	Tel Aviv, Israel	Moving										406.031	406.031	
France	Brest-France	Static				406.040								406.040
		Moving								406.040				
France	Toulouse1-France	Static				406.037								
France	Toulouse2-France	Static				406.037								406.037
Italy	Bari - Italy	Static				406.037								406.037
Japan	Tokyo	Static			406.028									
Japan	Tsushima	Moving						406.028						
Norway	Bodoe	Moving	406.037	406.037										
Norway	Bodoe	Static				406.037								406.037
USA	Boston	Static					406.037		406.037					
USA	New Orleans	Static					406.037		406.037					
USA	Cleveland	Static					406.037		406.037					
USA	Alameda	Static					406.037		406.037					
USA	Seattle	Static					406.037		406.037					
USA	Juneau	Static					406.037		406.037					

3.5.1 Analysis

The following test reports were provided by the participants:

Table 3-30 - T-5 Test Reports Provided by Participants

Administration	Test report reference
Russia	T-5 «Independent 2D Location Capability for Operational Beacons» test report
France	JC-31/Inf.31 MEOSAR D&E Test T-5: Phase III Results from the French MEOLUT
USA	P3_T5_2018_09_03_USA_Maryland_Report
EC/France	JC-31/Inf.43 MEOSAR D&E Test T-5: Phase III Results from the Spitsbergen European MEOLUT

3.5.1.1 EC/France (European MEOLUTs)

A first transmission named scenario #1 was performed from 9 to 12 July 2017, and a second transmission scenario #2 was performed from 5 to 6 September 2017.

System Throughput

Table 3-31 shows the MEOLUT System Throughput of the EU-NO/MEOLUT for both scenarios.

Table 3-31 - EU-NO/MEOLUT System Throughput

		Scenario #1					Scenario #2				
Name	Beacon ID	MEOLUT System Throughput (%)	C/N$_0$ (dB.Hz)	C/N$_0$ GPS (dB.Hz)	C/N$_0$ GALILEO (dB.Hz)	C/N$_0$ GLONASS (dB.Hz)	MEOLUT System Throughput (%)	C/N$_0$ (dB.Hz)	C/N$_0$ GPS (dB.Hz)	C/N$_0$ GALILEO (dB.Hz)	C/N$_0$ GLONASS (dB.Hz)
Audinghen-France	1C7C084B20FFBFF	99.95	38.2	35.5	40.6	39.0	99.94	37.9	36.2	39.2	38.3
Toulouse2-France	1C7C0CF1E6FFBFF	99.60	41.9	39.7	44.7	41.4	99.67	41.3	38.9	44.0	41.8
Toulouse1-France	1C7C8C8880FFBFF	99.26	37.8	36.0	39.7	36.0					
Brest-France	1C7DF3800CFFBFF	99.94	37.7	35.7	39.2	37.1	99.80	36.5	34.8	37.7	38.0
Bari-Italy	1EFC6A87D0FFBFF	99.88	40.5	38.0	43.4	39.7	90.99	37.6	36.0	39.0	37.1
Bodoe-Norway	2065E84560FFBFF	99.94	39.8	37.5	42.0	38.9	99.71	39.3	37.3	41.1	38.9

All the values are higher than 99% except for the Bari-Italy beacon during scenario #2 for which the C/N$_0$ is 3 dB lower than the one during scenario #1. We assume that the beacon battery was low after 96 hour-activation (2 days in Phase II, 2 days in Phase III). It can be noticed that C/N$_0$ values are lower than those obtained with the beacon simulator at 37 dBm.

The single-channel throughput (see Figure 3-18) is better for L-band satellite channels.

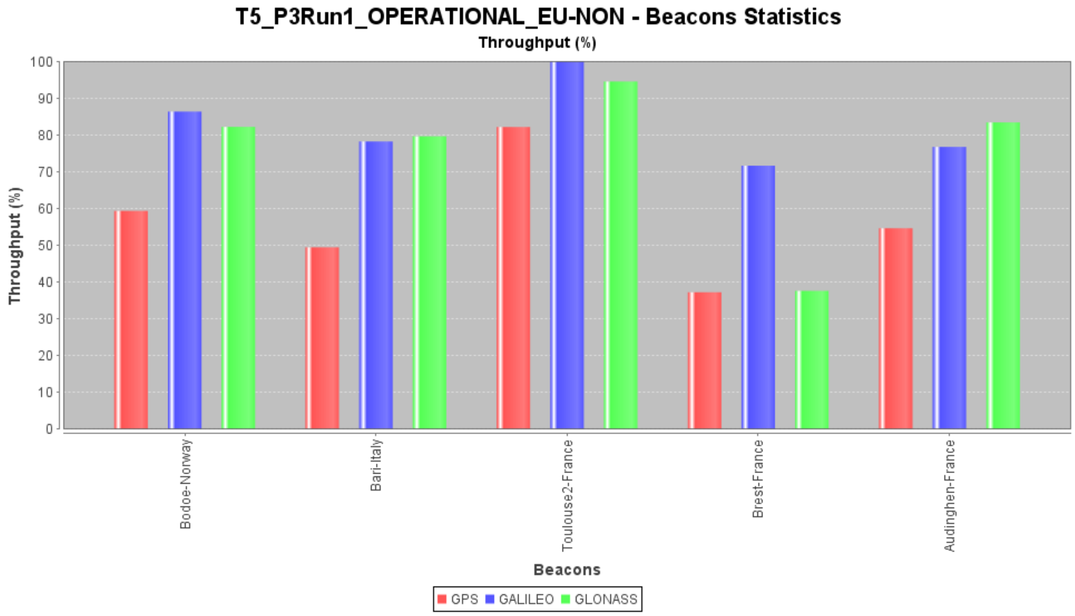


Figure 3-18: Single-Channel Throughput for each Beacon - Scenario #2

Single-Burst Location Probability

Table 3-32 shows the single-burst location probability for static beacons and for both scenarios. MEOSAR IOC requirement (90%) is nearly met for all beacons.

Table 3-32 - Static Beacons Single-Burst Location Probability

		Scenario #1	Scenario #2
Name	**ID**	**Single-Burst Location Probability (%)**	
Audinghen-France	1C7C084B20FFBFF	95.91	97.77
Toulouse2-France	1C7C0CF1E6FFBFF	99.48	99.61
Toulouse1-France	1C7C8C8880FFBFF	94.92	-
Brest-France	1C7DF3800CFFBFF	94.99	88.54
Bari-Italy	1EFC6A87D0FFBFF	98.96	88.06
Bodoe-Norway	2065E84560FFBFF	99.19	98.84

Location Accuracy

Figure 3-19 shows the cumulative distribution of location error for each number of satellites used in the location process. A significant improvement between 3 and 6 satellites can be observed. 6 satellites are required to meet the MEOSAR IOC requirement (5 km at 95%). Considering all locations, the location accuracy requirement is met with 4 km.

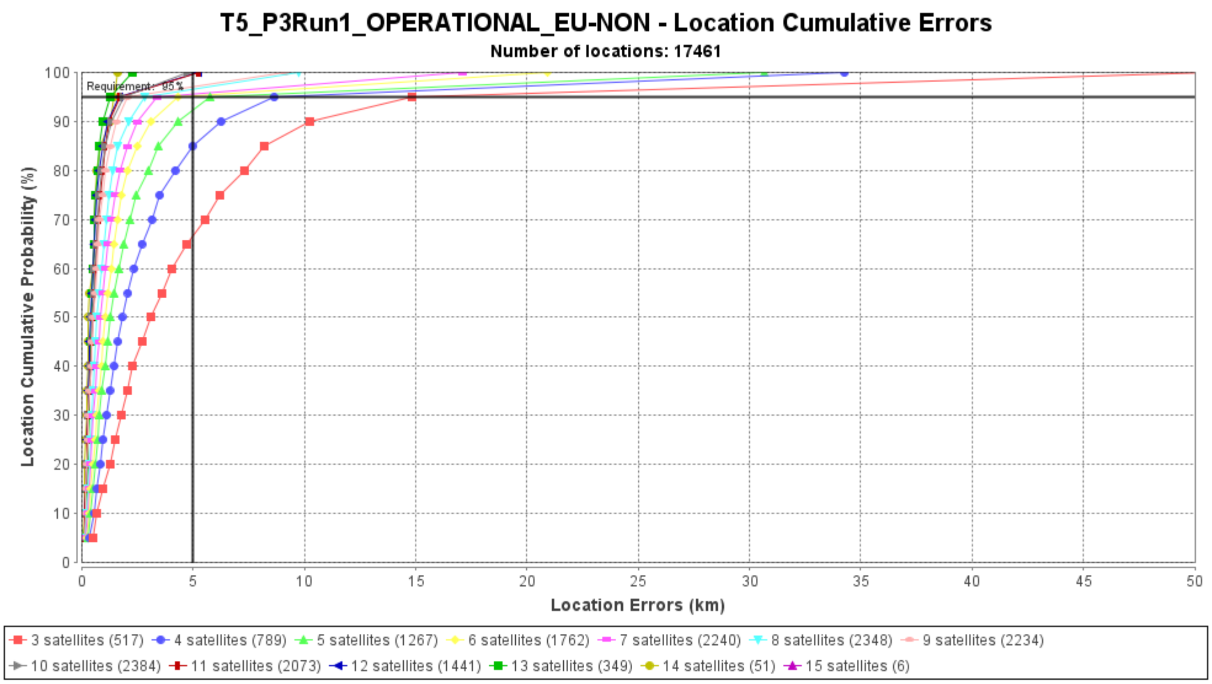


Figure 3-19: Cumulative Distribution of Location Error

Moving beacons

The system throughput for Brest-France and TelAviv2-Israel beacons is respectively 87.7% and 95.6%. The single-burst Location Probability for the Brest-France and TelAviv2-Israel beacons is respectively 72.3% and 56.1%. EOC requirement (75%) is not met.

Location accuracy

Figure 3-20 shows the cumulative distribution of single-burst location error for Brest-France.

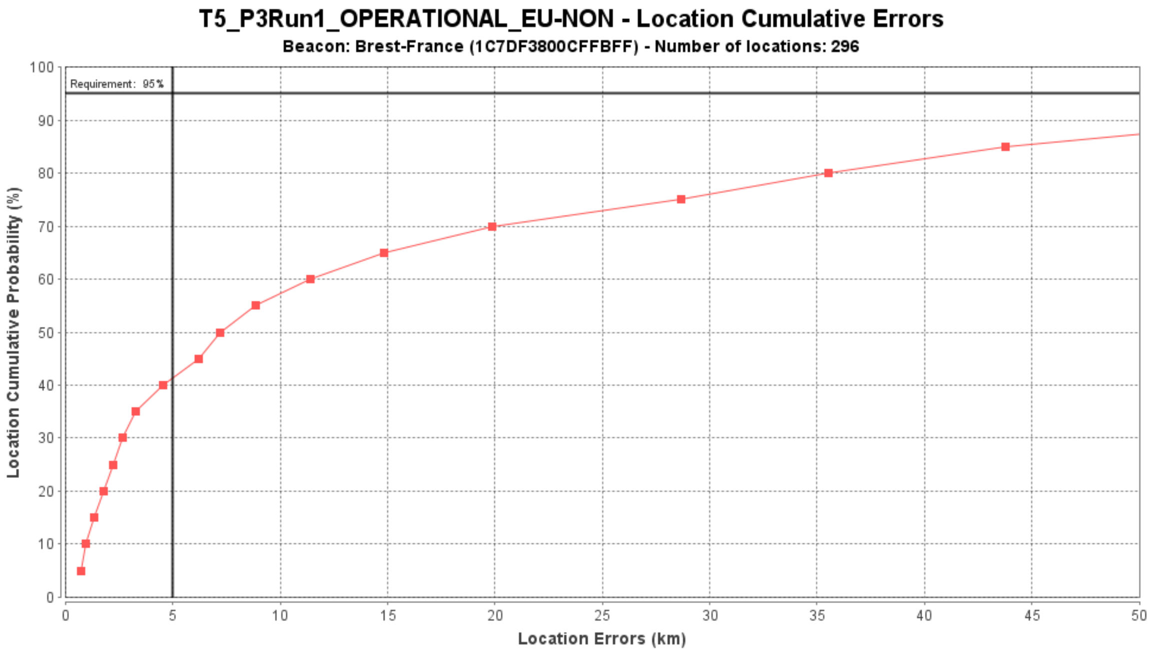


Figure 3-20: Single-Burst Location Error of Brest-France Beacon

The location accuracy at 70% for Brest-France and TelAviv2-Israel is respectively 20 km and 32 km. The MEOSAR EOC requirement (5 km at 70%) is not met.

3.5.1.2 France

For test T-5 Phase III, data were collected for two MEOLUT configurations:

- from the L-band active antenna only (later referred as "D&E configuration"),
- from S-band dish antennas and the L-band active antenna (later referred as "operational configuration").

During the run of test T-5, 36 MEOSAR satellites were available for tracking by the French MEOLUT:

- 20 S-band GPS/DASS satellites: 301, 302, 303, 306, 308, 309, 310, 312, 315, 316, 317, 318, 319, 323, 324, 326, 327, 329, 330, 332,
- 14+2 L-band GALILEO satellites: 401, 402, [403, 404], 405, 407, 408, 409, 419, 422, 424, 426, 430), [414, 418, and 420].

A first transmission named scenario #1 was performed from 19 to 12 July 2017, and a second transmission scenario #2 was performed 5 to 6 September 2017.

System Throughput

Table 3-33 shows the System Throughput of the French MEOLUT in the D&E configuration (only L-band satellites) for both scenarios.

Table 3-33 - MEOLUT System Throughput (L-Band Only)

		Scenario #1		Scenario #2	
Name	**Beacon 15 Hex ID**	**MEOLUT System Throughput (%)**	**C/N_0 (dB.Hz)**	**MEOLUT System Throughput (%)**	**C/N_0 (dB.Hz)**
Audinghen-France	1C7C084B20FFBFF	96.39	38.9	91.25	37.8
Toulouse2-France	1C7C0CF1E6FFBFF	97.65	41.6	99.45	41.1
Toulouse1-France	1C7C8C8880FFBFF	86.88	37.9		
Brest-France	1C7DF3800CFFBFF	60.51	37.9	59.38	36.8
Bari-Italy	1EFC6A87D0FFBFF	97.17	40.4	83.70	37.6
Bodoe-Norway	2065E84560FFBFF	95.95	39.9	94.62	39.3

All the values are higher than 87% except for:

- Brest-France beacon for which the values are 61% and 59% for scenario #1 and scenario #2 respectively, whereas the C/N_0 values are very close to Toulouse1-France and Audinghen-France values,
- Bari-Italy beacon during scenario #2 for which the C/N_0 value is 3 dB lower than the one during scenario #1. We assume that the beacon battery was low after 96 hour-activation (two days in Phase II, two days in Phase III).

It can be noticed that C/N_0 values are lower than those observed with the beacon simulator at 37 dBm

Single-Burst Location Probability

Table 3-34 shows the single-burst location probability for both configurations and both scenarios. The MEOSAR EOC requirement is 75%.

Table 3-34 - Static Beacons Single-Burst Location Probability

		Operational		D&E	
		Scenario #1	**Scenario #2**	**Scenario #1**	**Scenario #2**
Name	**ID**	**Single-Burst Location Probability (%)**	**Single-Burst Location Probability (%)**	**Single-Burst Location Probability (%)**	**Single-Burst Location Probability (%)**
Audinghen-France	1C7C084B20FFBFF	75.41	60.98	48.25	30.55
Toulouse2-France	1C7C0CF1E6FFBFF	94.10	91.81	65.94	82.84
Toulouse1-France	1C7C8C8880FFBFF	68.80		45.41	
Brest-France	1C7DF3800CFFBFF	13.74	10.58	7.05	4.46
Bari-Italy	1EFC6A87D0FFBFF	88.41	54.71	59.11	31.73
Bodoe-Norway	2065E84560FFBFF	44.85	68.73	48.55	48.73

- D&E Configuration

Only Toulouse2-France (ELT) for scenario #2 value is compliant with MEOSAR EOC requirement. Performances are scattered from one beacon to the other but correlated with the single-channel throughput.

- Operational Configuration

For scenario #1, 3 beacons provide compliant results with EOC requirement. For scenario #2, lower results are observed, except for Bodoe-Norway beacon. All these results are worse than those obtained with a beacon simulator (D&E T-4 and MEOLUT commissioning report).

Location Accuracy

Figure 3-21 shows the cumulative distribution of location error depending on the number of satellites used to compute the location. A significant improvement between 3 and 5 satellites can be observed. 5 satellites are required to meet the requirement (95% within 5 km). Considering all locations, the performance is 95% within 9 km.

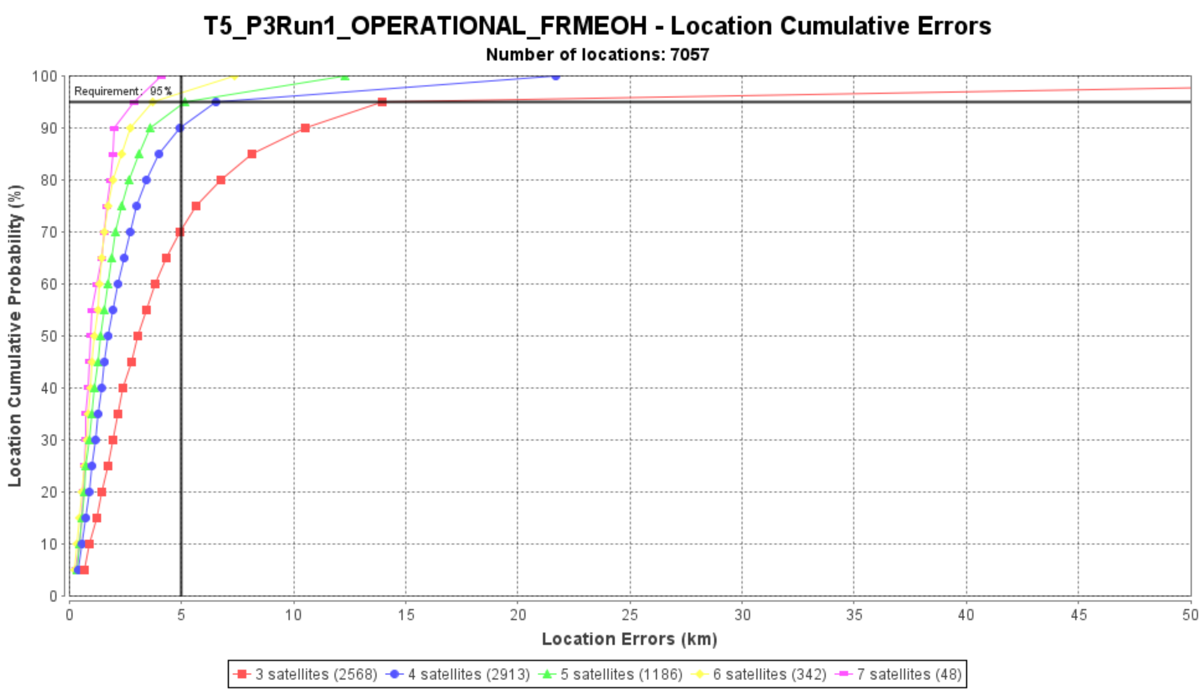


Figure 3-21: Cumulative Distribution of Location Error

Moving Beacons

Table 3-35 shows the MEOLUT throughput and the Single-Burst Location Probability.

Table 3-35 - System Throughput and Single-Burst Location Probability

Beacon	System Throughput (%)	Single-Burst Location Probability (%)
Brest-France	82	18
Tel-Aviv2-Israel	81	7

Location accuracy

For slow-moving beacons, it is more appropriate to analyze the single-burst locations. Figure 3-22 shows the cumulative distribution of single-burst location error for Tel-Aviv2 beacon. The number of single-burst locations is low due to short test duration and low probability of single-burst location (18%), so the distribution curve is not smooth.

The performance is 90% within 18 km. The location error is larger for the Brest-France beacon due to a greater mean speed (3.4 m/s versus 1.7 m/s).

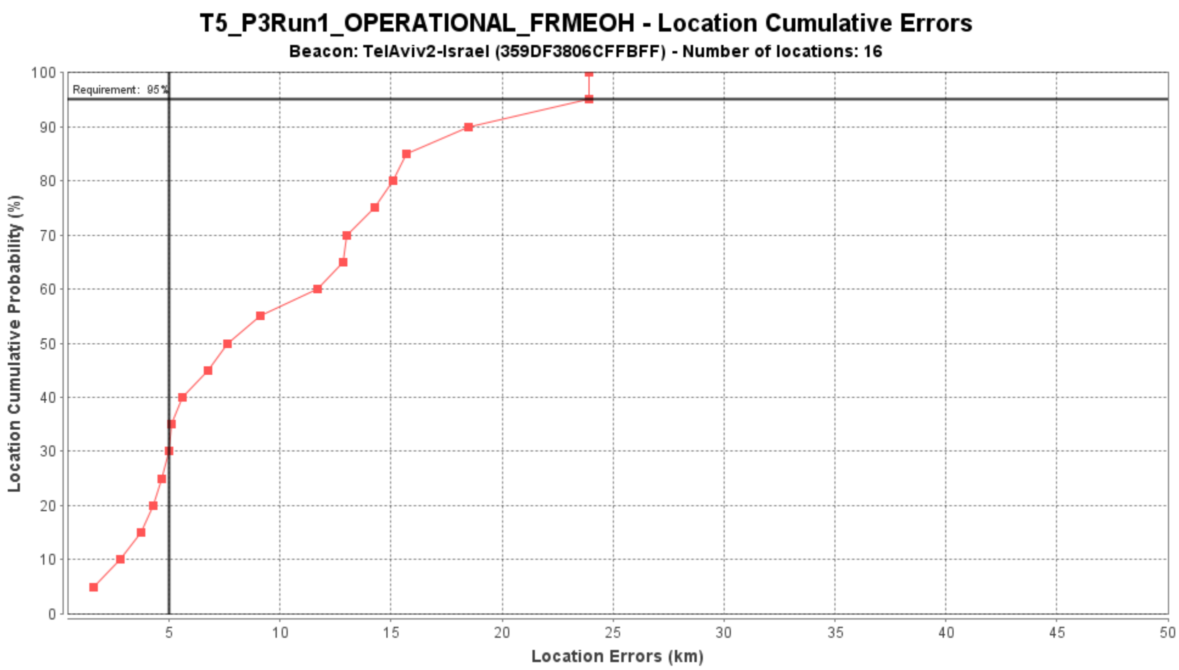


Figure 3-22: Tel-Aviv2-Israel Cumulative Distribution of Single-Burst Location Error

3.5.1.3 USA-Maryland

3.5.1.3.1 Configuration

During test T-5, the Maryland MEOLUT was configured in stand- alone, non-networked mode. There was an error prior to the start of the test and the pass schedule was NOT modified to only select L-band satellites. Maryland used a combination of S-band and L-band satellites. Only Maryland channels

1,3,4, and 6 were available at the time of the moving test. Maryland channels 1,3,4,5, and 6 were available for the static test.

The test ran between June and September 2017 spread over twelve days by six Administrations around the world. Only the beacons activated in the USA are reported in the Maryland report. These beacons were spread from the east to the west coast of the USA and are listed below.

Table 3-36 - T-5 Test Beacons Activated by the USA

Beacon 15 Hex ID	Beacon Type	USA Location	Approx. distance from Maryland MEOLUT (km)	Moving/Static	Activation Dates
279C753BAEFFBFF	EPIRB	Lake George, NY	560	Moving	July 20 & 25
2DDC878CC4FFBFF	PLB	Cleveland	500	Static	July 11 & 13
2DDC878CC2FFBFF	PLB	Boston	620	Static	July 11 & 13
2DDC878CCAFFBFF	PLB	New Orleans	1,575	Static	July 11 & 13
2DDC878CC8FFBFF	PLB	Seattle	3,740	Static	July 11 & 13
2DDC878CC6FFBFF	PLB	Alameda	3,920	Static	July 11 & 13
2DDC878CC0FFBFF	PLB	Juneau	4,560	Static	July 11 & 13

3.5.1.3.2 Methodology

Single-burst locations were processed offline after the tests were over in order to produce merged locations. The analysis included two separate grouping methods for combining solutions into a merged solution. The same procedure was then used to compute the combined location and quality estimates for each grouping method.

Method 1

The first grouping method was based on bursts received by the MEOLUT, not transmitted bursts. This method is similar to the real-time operation of the MEOLUT.

For a given beacon, single-burst locations were combined in order by time until the grouping window was closed. Two parameters controlled when the grouping window was closed: number of bursts and maximum window time range. The analysis was done so that at most 7 bursts or 5 minutes of data could be combined into a merged location.

Method 2

The second grouping method was based on transmitted bursts. Given the activation time for each beacon, the transmitted bursts were divided into windows of 7 bursts.

The goal for this method was to see how well the MEOLUT could locate the beacon after 1,2,3,…,7 transmissions. Note that the number of single-burst locations was not necessarily equal the number of transmitted bursts.

3.5.1.3.3 Results

Results from all static beacons were combined to produce the table below. The solution counts are shown below.

Table 3-37 - Static Beacons Method 1

	1 Burst	2 Bursts	3 Bursts	4 Bursts	5 Bursts	6 Bursts	7 Bursts
Error 1 km	3	4	6	11	18	19	15
Error 5 km	37	91	133	213	301	312	269
Error 10 km	67	138	205	303	409	421	349
Total	88	171	231	336	427	440	355

Results from all static beacons were combined to produce the table below. The solution counts are shown below.

Table 3-38 - Static Beacons Method 2

	1 Burst	2 Bursts	3 Bursts	4 Bursts	5 Bursts	6 Bursts	7 Bursts
Error 1 km	42	49	61	72	70	81	85
Error 5 km	689	975	1135	1233	1317	1404	1444
Error 10 km	1131	1550	1744	1867	1965	2007	2039
Total	1378	1796	1985	2089	2159	2204	2245

Results from all of the moving beacon tests were combined to produce the table below. The solution counts are shown below.

Table 3-39 - Moving Beacons Method 1

	1 Burst	2 Bursts	3 Bursts	4 Bursts	5 Bursts	6 Bursts	7 Bursts
Error 1 km	2	0	0	1	0	0	0
Error 5 km	13	8	16	19	5	10	1
Error 10 km	30	17	21	22	11	11	2
Total	44	23	28	25	13	12	2

Results from all of the moving beacon tests were combined to produce the table below. The solution counts are shown below.

Table 3-40 - Moving Beacons Method 2

	1 Burst	2 Bursts	3 Bursts	4 Bursts	5 Bursts	6 Bursts	7 Bursts
Error 1 km	2	6	4	4	3	4	3
Error 5 km	25	47	58	66	71	77	80
Error 10 km	54	85	102	112	116	126	129
Total	67	105	125	139	147	159	166

3.5.1.4 Russia

3.5.1.4.1 Configuration

All four antennas of the Russian MEOLUT (hereafter referred as "MEOLUT") were engaged in the test. No special settings were applied for the test processing.

Statistics provided in this test based on operational beacons emitting bursts from 2017-7-10 09:00 to 2017-7-11 09:00 (UTC).

The processing methodology and data collection procedures for this test are described in section 3.4.1.3 of this Report.

Beacons located further than 3,000 km from Moscow were not included in the analysis as being located outside expected DCA of Moscow MEOLUT.

The tables provided hereafter may not fully comply with the C/S R.018 reporting guidelines and provide an agreed by experts high-level view of the results obtained. This approach should not whatsoever detract or distort the meaning and values of parameters required by document C/S R.018.

3.5.1.4.2 Results

MEOLUT System Throughput

Table 3-41 provides the summary table that includes consolidated results for detection probability (throughput) evaluated for an entire MEOLUT.

The number of transmitted bursts was computed based on the post-knowledge of a beacon location, by dividing the period of 1+ satellite co-visibility by 50 seconds. This simplified computation might lead to unrealistic results when comparing the numbers of transmitted and received bursts. That was caused by the fact that according to document C/S T.001, the beacon repetition period values are randomly distributed over the interval of 47.5 to 52.5 seconds.

Table 3-41 - MEOLUT System Throughput

#	15 Hex ID	Country	Distance (km)	Bursts Emitted	Bursts Received	Throughput
1	2065E84560FFBFF	Norway	1758	1715	1753	1
2	1EFC6A87D0FFBFF	Italy	2216	1715	1751	1
3	1C7C084B20FFBFF	France	2425	1715	1740	1
4	1C7C8C8880FFBFF	France	2888	1715	1683	0.981
5	1C7C0CF1E6FFBFF	France	2888	1715	1725	1
6	1C7DF3800CFFBFF	France	2961	1715	1676	0.977

N-Burst Independent Location Probability

See Table 3-42 for the N-Burst Independent Location Probability for 3+ satellites with errors less than 1 kilometer calculated per 1, 2, 3, 4, 5, 6, 7 and 13 burst time-equivalent slots.

See Table 3-43 for the N-Burst Independent Location Probability for 3+ satellites with Errors less than 5 kilometers calculated per 1,2,3,4,5,6,7 and 13 burst time-equivalent slots.

See Table 3-44 for the N-Burst Independent Location Probability for 3+ satellites calculated per 1,2,3,4,5,6,7 and 13 burst time-equivalent slots.

Table 3-42 - N-Burst Independent Location Probability for 3+ Satellites with Errors Less than 5 km Calculated per 1,2,3,4,5,6,7 and 13 Burst Time-Equivalent Slots

#	15 Hex ID	Country	Distance (km)	Single-Burst Locations Produced	1b	2b	3b	4b	5b	6b	7b	13b
1	2065E84560FFBFF	Norway	1758	1397	0.66	0.64	0.79	0.83	0.88	0.9	0.89	0.96
2	1EFC6A87D0FFBFF	Italy	2216	1234	0.72	0.71	0.82	0.88	0.9	0.91	0.92	0.94
3	1C7C084B20FFBFF	France	2425	1193	0.78	0.79	0.89	0.93	0.93	0.95	0.96	0.99
4	1C7C8C8880FFBFF	France	2888	1065	0.72	0.71	0.81	0.84	0.86	0.89	0.88	0.94
5	1C7C0CF1E6FFBFF	France	2888	1197	0.84	0.83	0.92	0.95	0.97	0.99	1	0.99
6	1C7DF3800CFFBFF	France	2961	931	0.5	0.5	0.64	0.72	0.71	0.76	0.76	0.89

Table 3-43 - N-Burst Independent Location Probability for 3+ satellites with Errors less than 5 km Calculated per 1,2,3,4,5,6,7 and 13 Burst Time-Equivalent Slots.

#	15 Hex ID	Country	Distance (km)	Single-Burst Locations Produced	1b	2b	3b	4b	5b	6b	7b	13b
1	2065E84560FFBFF	Norway	1758	1397	0.9	0.87	0.97	0.98	0.99	1	1	1
2	1EFC6A87D0FFBFF	Italy	2216	1234	0.9	0.89	0.96	0.98	0.98	0.98	1	1
3	1C7C084B20FFBFF	France	2425	1193	0.91	0.89	0.96	0.98	0.98	0.99	0.99	0.99
4	1C7C8C8880FFBFF	France	2888	1065	0.84	0.82	0.89	0.91	0.92	0.93	0.93	0.94
5	1C7C0CF1E6FFBFF	France	2888	1197	0.94	0.93	0.98	1	0.99	1	1	1
6	1C7DF3800CFFBFF	France	2961	931	0.74	0.74	0.83	0.88	0.89	0.91	0.91	0.95

Table 3-44 - N-Burst Independent Location Probability for 3+ Satellites Calculated per 1,2,3,4,5,6,7 and 13 burst Time-Equivalent Slots.

#	15 Hex ID	Country	Distance (km)	Single-Burst Locations Produced	1b	2b	3b	4b	5b	6b	7b	13b
1	2065E84560FFBFF	Norway	1758	1397	0.93	0.9	0.98	0.99	1	1	1	1
2	1EFC6A87D0FFBFF	Italy	2216	1234	0.92	0.9	0.97	0.98	0.99	0.99	1	1
3	1C7C084B20FFBFF	France	2425	1193	0.92	0.9	0.96	0.98	0.98	0.99	0.99	0.99
4	1C7C8C8880FFBFF	France	2888	1065	0.84	0.83	0.89	0.91	0.92	0.93	0.93	0.94
5	1C7C0CF1E6FFBFF	France	2888	1197	0.95	0.93	0.98	1	1	1	1	1
6	1C7DF3800CFFBFF	France	2961	931	0.77	0.77	0.86	0.89	0.9	0.92	0.92	0.95

It could be concluded that Moscow MEOLUT meets independent location probability with error less than 5 km requirement with good margin. On the other hand, independent location probability (with any error) requirement was not meet for all beacons involved in the test. Possible causes of that could be partial space segment and insufficient number of antennas at the MEOLUT. Because of these reasons in many cases there were only beacon simulator three satellites being tracked by antennas of MEOLUT and had a beacon in visibility. As it takes at least three satellites to generate a location, missing measurements (for example because of local obstructions or interference) from one of the satellites in such cases would not let generate a solution. It is expected that with six antennas and expanded space segment independent location probability requirement will be met.

N-Burst Independent Location Accuracy

See Table 3-45 for the N-Burst Independent Location Errors (95th percentile) for three and more satellites averaged for 1, 2, 3, 4, 5, 6, 7 and 13 burst time-equivalent slots. It is clearly seen that independent location accuracy requirement was met for all static beacons with good margin.

Table 3-45 - N-Burst Independent Location Accuracy (95% Percentile) for 3+ Satellites Calculated per 1,2,3,4,5,6,7 and 13 Burst Time-Equivalent Slots.

#	Hex ID	Country	Distance (km)	Single-Burst Locations Produced	1b	2b	3b	4b	5b	6b	7b	13b
1	2065E84560FFBFF	Norway	1758	1397	3.83	3.9	2.55	2.11	2	1.52	1.68	0.84
2	1EFC6A87D0FFBFF	Italy	2216	1234	2.95	2.7	1.88	1.59	1.46	1.37	1.28	1.18
3	1C7C084B20FFBFF	France	2425	1193	2.36	1.76	1.27	1.03	0.98	0.93	0.82	0.59
4	1C7C8C8880FFBFF	France	2888	1065	2.05	1.83	1.48	1.27	1.07	0.95	1.05	0.8
5	1C7C0CF1E6FFBFF	France	2888	1197	1.93	1.76	1.19	1.03	0.75	0.65	0.65	0.46
6	1C7DF3800CFFBFF	France	2961	931	4.21	3.92	3.51	2.66	2.35	2.26	2.3	1.04

Figure 3-23 to Figure 3-28 show independent location errors (red squares) and a priori EHE values (blue line) for single-burst solutions and Figure 3-29 to Figure 3-34 show the same for solutions generated over 10-minute intervals. When the MEOLUT changed the satellite combination being tracked by its antennas blue line (a priori EHE) had a gap.

The limited L-band space segment would not allow to make tracking schedule so as to keep a priori EHE value (and independent location accuracy respectively) in a more or less constant level. In future with expanded space segment (especially in L-band) it will be possible to make tracking schedule in the way to provide a priori EHE value constant enough within DCA.

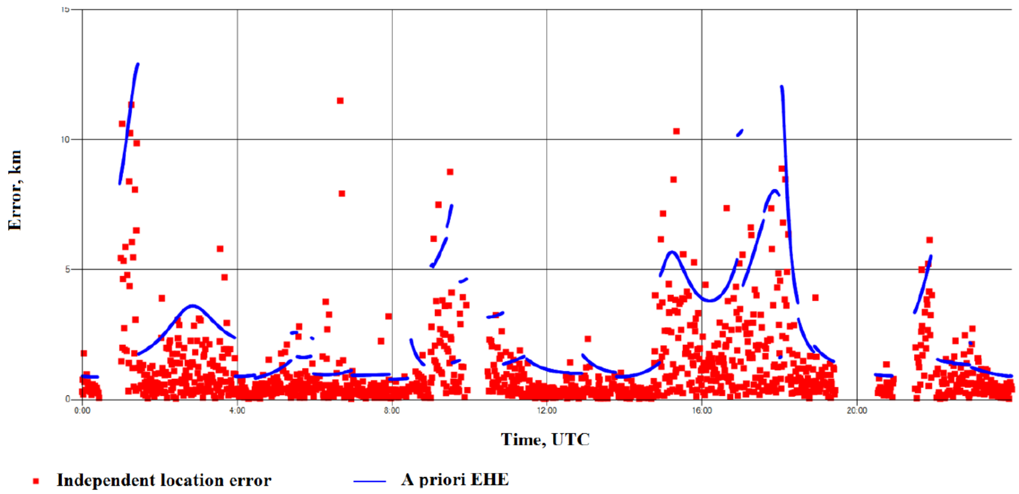


Figure 3-23: Beacon ID 2065E84560FFBFF (Norway). Single-Burst Solutions

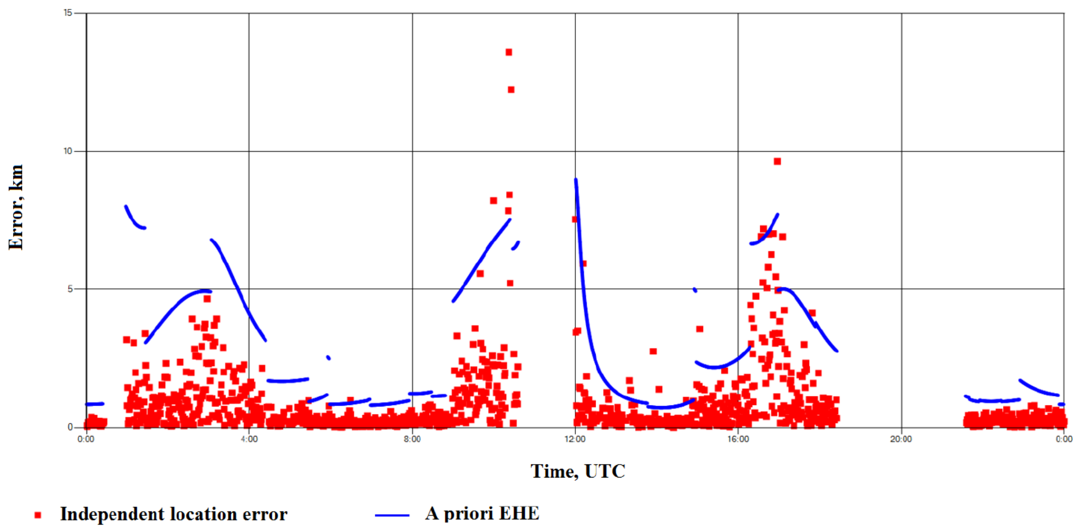


Figure 3-24: Beacon ID 1EFC6A87D0FFBFF (Italy) - Single-Burst Solutions

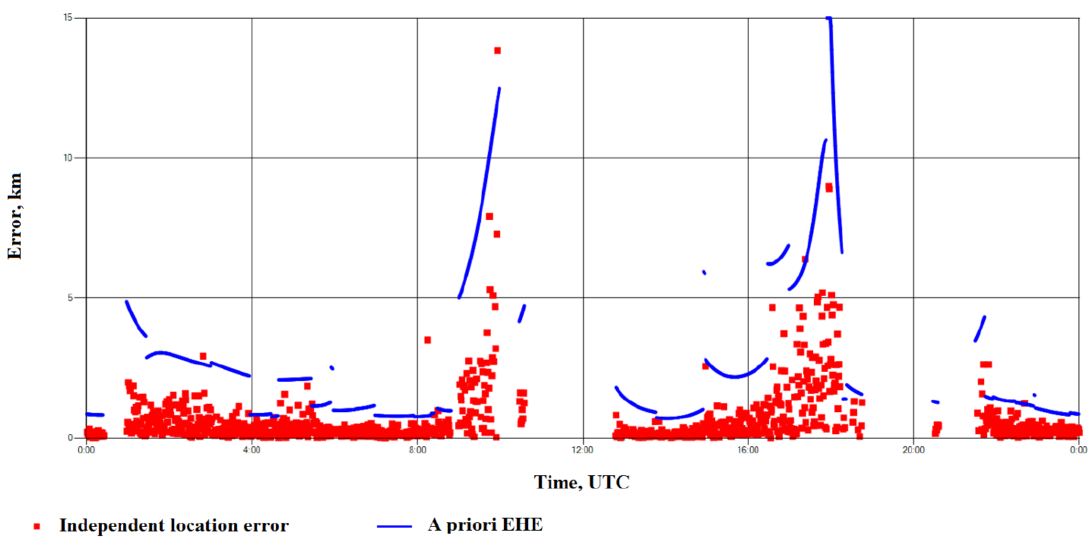


Figure 3-25: Beacon ID 1C7C084B20FFBFF (France) - Single-Burst Solutions

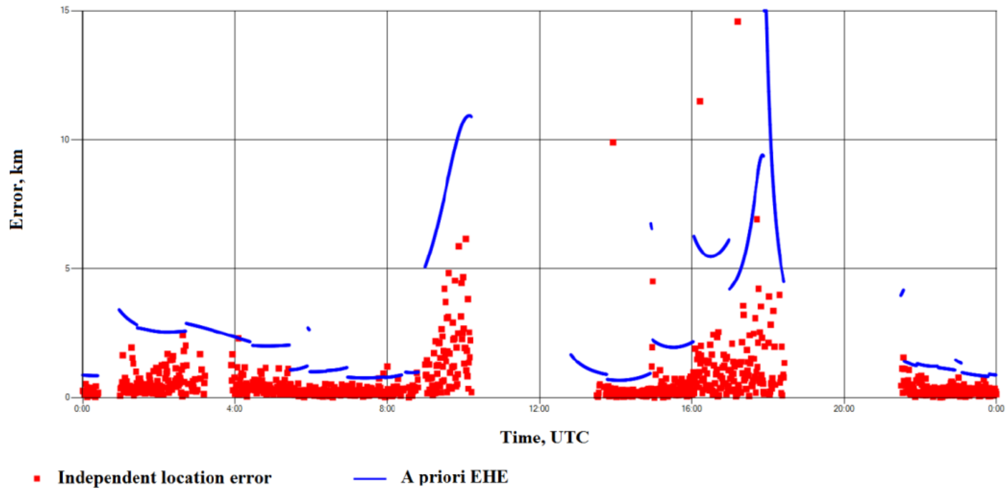


Figure 3-26: Beacon ID 1C7DF3800CFFBFF (France) - Single-Burst Solutions

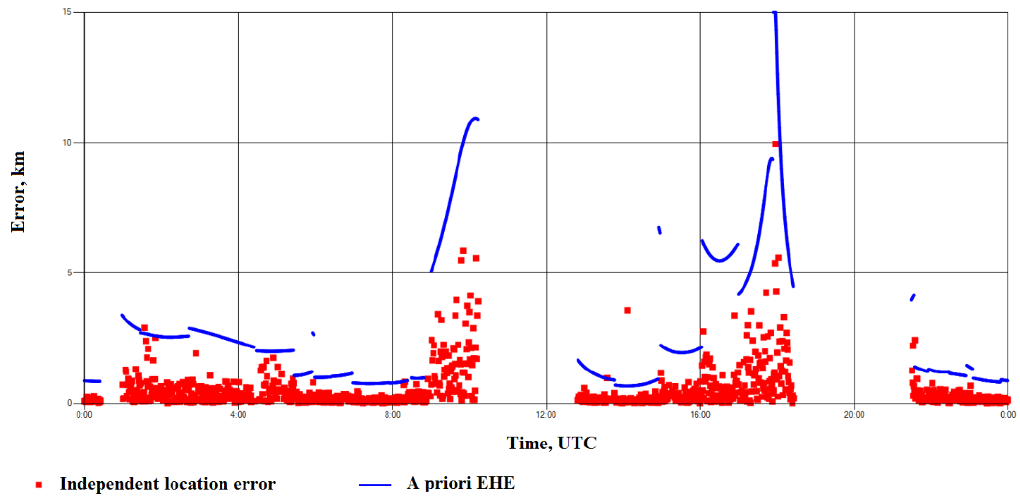


Figure 3-27: Beacon ID 1C7C0CF1E6FFBFF (France) - Single-Burst Solutions

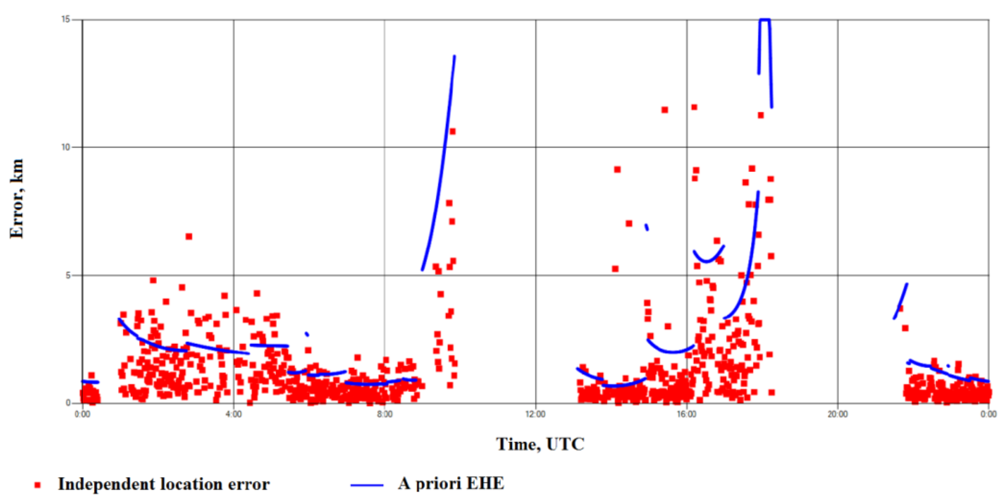


Figure 3-28: Beacon ID 1C7C084B20FFBFF (France) - Single-Burst Solutions

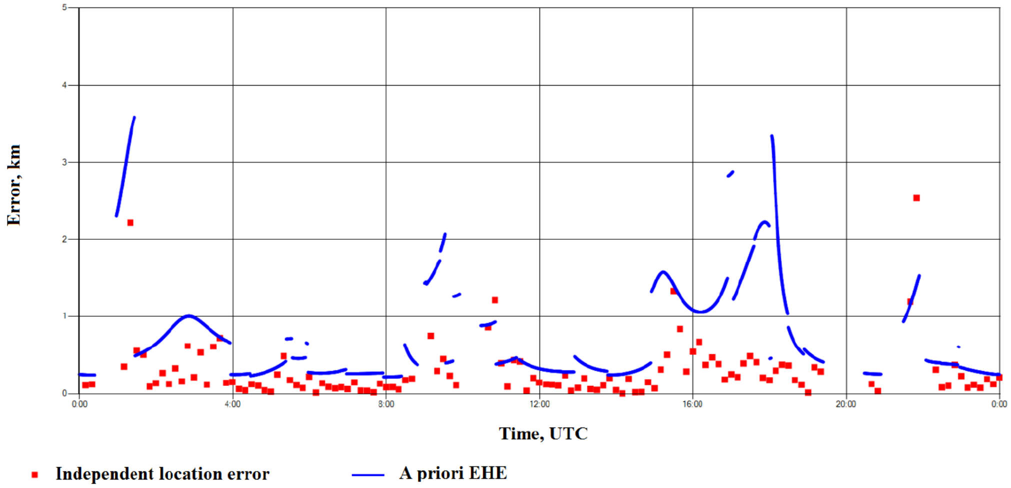


Figure 3-29: Beacon ID 2065E84560FFBFF (Norway) - Multi-Burst Solutions over 10 Minutes

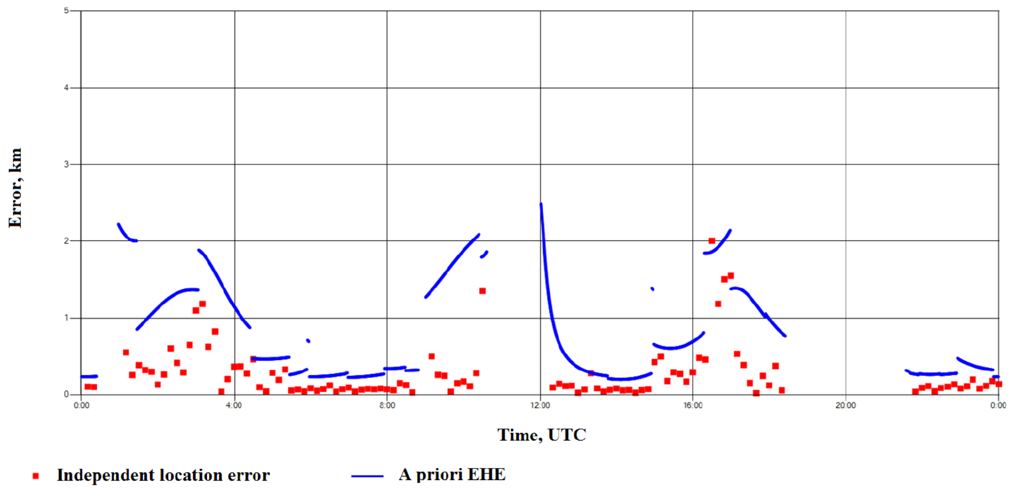


Figure 3-30: Beacon ID 1EFC6A87D0FFBFF (Italy) - Multi-Burst Solutions over 10 Minutes

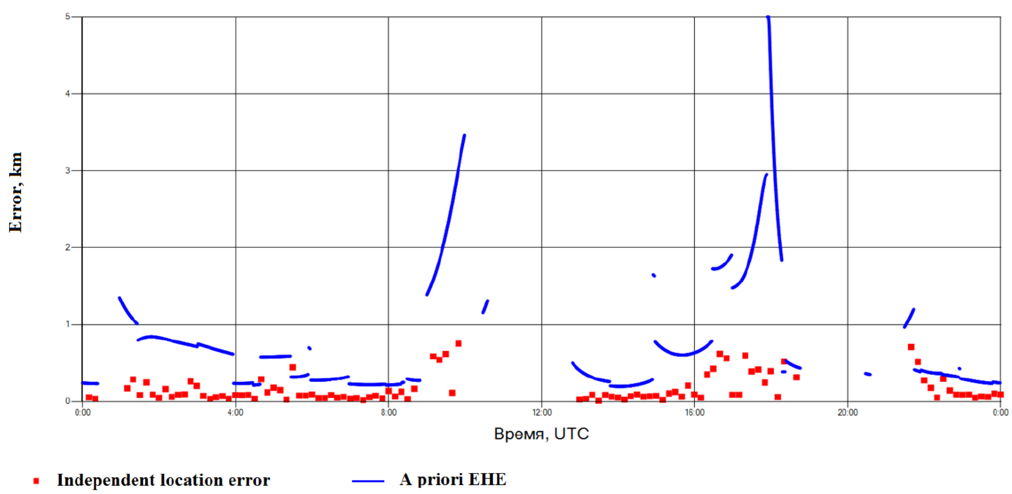


Figure 3-31: Beacon ID 1C7C084B20FFBFF (France) - Multi-Burst Solutions over 10 Minutes

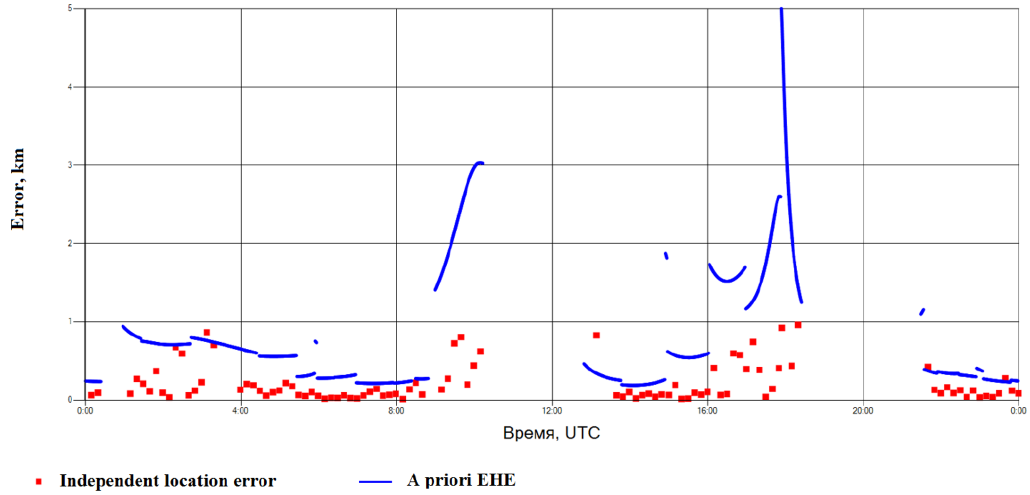


Figure 3-32: Beacon ID 1C7C8C8880FFBFF (France) - Multi-Burst Solutions over 10 Minutes

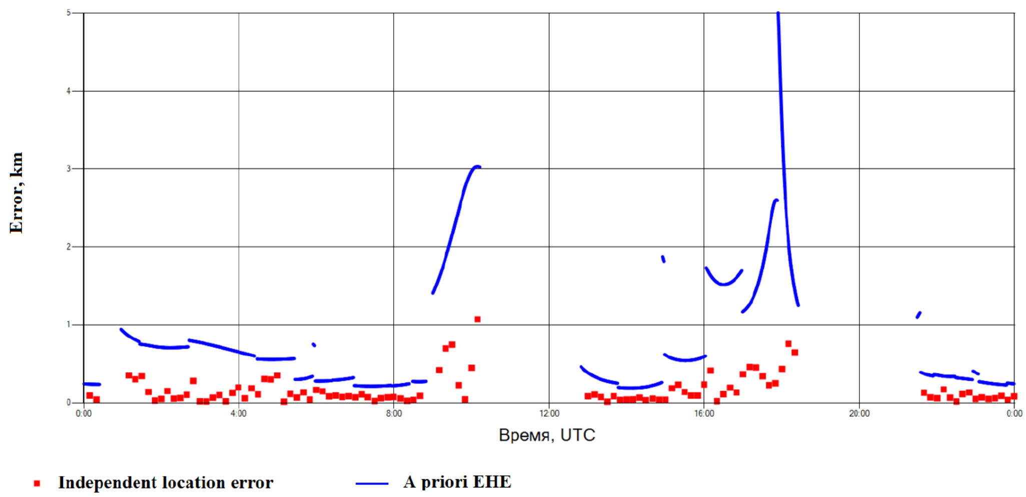


Figure 3-33: Beacon ID 1C7C0CF1E6FFBFF (France) - Multi-Burst Solutions over 10 Minutes

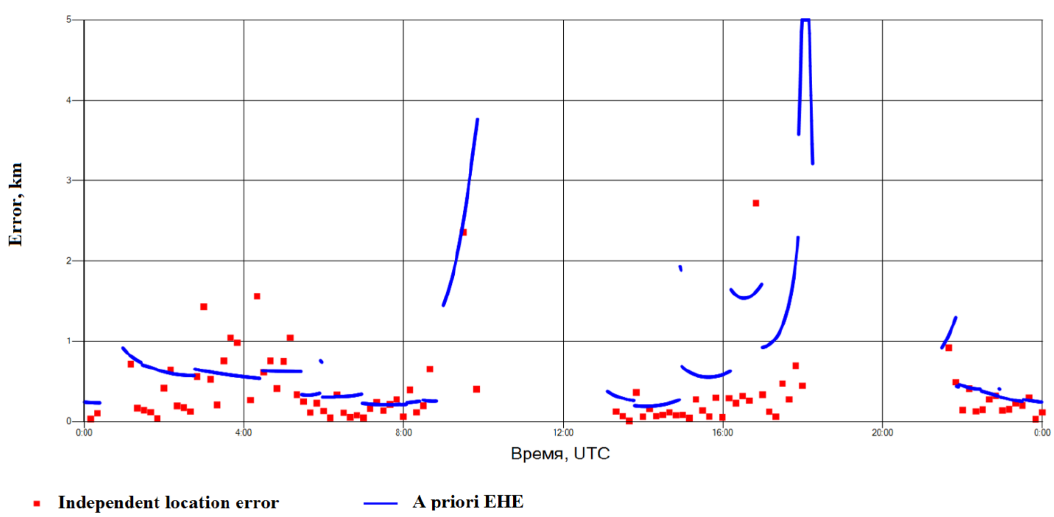


Figure 3-34: Beacon ID 1C7DF3800CFFBFF (France) - Multi-Burst Solutions over 10 minutes

3.5.2 Interpretation

3.5.2.1 EC/France

The MEOLUT throughput is greater than 99%, except for Bari-Italy-scenario #2. However, the single-channel throughput and C/N_0 of operational beacons are lower than those observed with beacon simulator.

The single-burst location probability is nearly compliant with MEOSAR IOC requirement (90%) for all static beacons. The Location Accuracy is compliant to MEOSAR IOC requirement (5 km at 95%) for all static beacons.

The high number of antennas (12) and the coordinated tracking allows optimizing the performances over all of the SAR/Galileo Ground Segment (SGS) coverage area. S-band payloads were still required, because fewer than 12 L-band satellites are simultaneously visible.

For slow-moving beacons, the location accuracy was strongly degraded compared to static beacon results, which confirm the need for specific processing implementation to take advantage of the high number of channels.

Recommendations

QMS beacons should have a transmitted power not higher than 35 dBm to better reflect the operational beacon performances.

3.5.2.2 France

The MEOLUT throughput is sufficient to have a real-time detection. However, the single-channel throughput and C/N_0 of operational beacons were lower than those observed with a beacon simulator.

For L-band satellite only in D&E configuration, the single-burst location probability is generally below the MEOSAR EOC requirement, and with large variations depending on beacon type (ELT and EPIRB are usually better than PLB). This demonstrates that the S-band payloads are still necessary to meet the required performances.

For static beacons, the location accuracy performance did not meet the requirement (95% below 9 km) but had been improved compared to Phase II results (95% below 20 km).

For slow-moving beacons, the location accuracy was strongly degraded compared to static beacons results, which confirmed the need of specific processing implementation. In addition, it was observed that encoded positions matched very well with the actual beacon track.

Recommendations

QMS beacons should have a transmitted power not higher than 35 dBm to better reflect the operational beacon performances.

3.5.2.3 USA

The Maryland MEOLUT report provides detailed results for each beacon and each method. Table 3-46 to Table 3-49 summarize the totals for all beacons.

Maryland inadvertently neglected to modify the tracking schedule to utilize only L-band satellites for this test. However, more L-band satellites were included in the testing than in previous D&E testing. The results vary from beacon to beacon making it difficult to draw any general conclusions.

Table 3-46 - Static Beacons Method 1

All							
	1 Burst	**2 Bursts**	**3 Bursts**	**4 Bursts**	**5 Bursts**	**6 Bursts**	**7 Bursts**
Cumulative Bin Count							
Error 1 km	3	4	6	11	18	19	15
Error 5 km	37	91	133	213	301	312	269
Error 10 km	67	138	205	303	409	421	349
Total	88	171	231	336	427	440	355
Cumulative Probability (%)							
Error 1 km	3.4	2.3	2.6	3.3	4.2	4.3	4.2
Error 5 km	42	53.2	57.6	63.4	70.5	70.9	75.8
Error 10 km	76.1	80.7	88.7	90.2	95.8	95.7	98.3
Percentile Error (km)							
50 Percentile	5.4	4.9	4.4	4.2	3.8	3.7	3.3
75 Percentile	10.8	8.7	7.3	6.7	5.4	5.4	4.9
95 Percentile	20.2	17.2	14.1	12.6	9.4	9.7	8.2

Table 3-47 - Static Beacons Method 2

All							
	1 Burst	**2 Bursts**	**3 Bursts**	**4 Bursts**	**5 Bursts**	**6 Bursts**	**7 Bursts**
Cumulative Bin Count							
Error 1 km	42	49	61	72	70	81	85
Error 5 km	689	975	1135	1233	1317	1404	1444
Error 10 km	1131	1550	1744	1867	1965	2007	2039
Total	1378	1796	1985	2089	2159	2204	2245
Cumulative Probability (%)							
Error 1 km	3	2.7	3.1	3.4	3.2	3.7	3.8
Error 5 km	50	54.3	57.2	59	61	63.7	64.3
Error 10 km	82.1	86.3	87.9	89.4	91	91.1	90.8
Percentile Error (km)							
50 Percentile	5	4.6	4.5	4.3	4.1	4	4
75 Percentile	8.4	7.4	7	6.7	6.5	6.3	6.2
95 Percentile	17.6	15.6	14.8	14.5	13	12.6	12.2

Table 3-48 - Moving Beacons Method 1

All							
	1 Burst	**2 Bursts**	**3 Bursts**	**4 Bursts**	**5 Bursts**	**6 Bursts**	**7 Bursts**
Cumulative Bin Count							
Error 1 km	2	0	0	1	0	0	0
Error 5 km	13	8	16	19	5	10	1
Error 10 km	30	17	21	22	11	11	2
Total	44	23	28	25	13	12	2
Cumulative Probability (%)							
Error 1 km	4.5	0	0	4	0	0	0
Error 5 km	29.5	34.8	57.1	76	38.5	83.3	50
Error 10 km	68.2	73.9	75	88	84.6	91.7	100
Percentile Error (km)							
50 Percentile	7.9	6.4	4.9	2.8	6.7	4.1	5.5
75 Percentile	12.3	13.5	13	6.5	10.2	5.3	5.5
95 Percentile	33.6	31.4	29	31.4	13.9	11.6	5.5

Table 3-49 - Moving Beacons Method 2

All							
	1 Burst	**2 Bursts**	**3 Bursts**	**4 Bursts**	**5 Bursts**	**6 Bursts**	**7 Bursts**
Cumulative Bin Count							
Error 1 km	2	6	4	4	3	4	3
Error 5 km	25	47	58	66	71	77	80
Error 10 km	54	85	102	112	116	126	129
Total	67	105	125	139	147	159	166
Cumulative Probability (%)							
Error 1 km	3	5.7	3.2	2.9	2	2.5	1.8
Error 5 km	37.3	44.8	46.4	47.5	48.3	48.4	48.2
Error 10 km	80.6	81	81.6	80.6	78.9	79.2	77.7
Percentile Error (km)							
50 Percentile	6.6	5.8	5.8	5.5	5.4	5.2	5.3
75 Percentile	9.3	9	8.7	9.3	9.4	9	9.8
95 Percentile	27.8	27.8	27.4	28.4	27.5	26.7	27.3

3.5.2.4 Russia

The objective of test T-5 was to determine characteristics of MEOSAR System for operational beacons spread on Earth, thus this test was the closest to the real-world scenario. It was noted that main performance parameters were somewhat worse (about 1.5 times) for operational beacons than for beacon simulator in test T-4.

Independent location probability (with any error) requirement was not met for all beacons involved in the test due to partial space segment and insufficient number of antennas on the Moscow MEOLUT.

Independent location accuracy requirement was met for all static beacons with good margin (5-10 times). With expanded L-band space segment location accuracy will be even better and it will be possible to make tracking schedule so as to keep a priori EHE value constant enough within MEOLUT DCA.

3.6 Test T-6 (MEOSAR System Capacity)

Test Objectives

According to document C/S R.018, test T-6, "MEOSAR System Capacity", is defined as the maximum number of beacons operating simultaneously that can be successfully processed without degradation of performance.

The system performance parameters used to assess the system capacity are:

- The probability of detection of a valid/complete message, over a given period of time after beacon activation (after 1, 2, 4 or 7 bursts); and
- The error for both a single-burst location and for a composite location calculated from the full 7 bursts of each beacon ID.

Table 3-50 - Maryland Beacon Simulator Transmission

Slot	Date	Time 1st Tx (UTC)	Date	Time last Tx (UTC)
1	2017-10-02	16:35:00.000	2017-10-02	17:40:00.000
2	2017-10-02	18:17:00.000	2017-10-02	19:22:00.000
3	2017-10-02	20:00:00.000	2017-10-02	21:05:00.000
4	2017-10-02	21:40:00.000	2017-10-02	22:45:00.000
5	2017-10-03	18:05:00.000	2017-10-03	19:10:00.000
6	2017-10-04	16:39:00.000	2017-10-04	17:44:00.000
7	2017-10-04	17:49:50.000	2017-10-04	18:54:50.000
8	2017-10-04	19:37:00.000	2017-10-04	20:42:00.000
9	2017-10-04	21:17:00.000	2017-10-04	22:22:00.000
10	2017-10-05	17:10:00.000	2017-10-05	18:15:00.000
11	2017-10-05	19:25:00.000	2017-10-05	20:30:00.000
12	2017-10-05	21:06:00.000	2017-10-05	22:11:00.000

Table 3-51 - France Beacon Simulator Transmission

Slot	Date	Time 1st Tx (UTC)	Date	Time last Tx (UTC)
01	2018-01-08	12:51:00	2018-01-08	13:55:22
02	2018-01-08	14:36:00	2018-01-08	15:40:22
03	2018-01-09	12:21:00	2018-01-09	13:25:22
04	2018-01-09	14:26:00	2018-01-09	15:30:22
05	2018-01-09	16:06:00	2018-01-09	17:10:22
06	2018-01-10	12:06:00	2018-01-10	13:10:22
07	2018-01-10	14:16:00	2018-01-10	15:20:22
08	2018-01-10	15:56:00	2018-01-10	17:00:22
09	2018-01-11	11:46:00	2018-01-11	12:50:22
10	2018-01-11	14:01:00	2018-01-11	15:05:22
11	2018-01-11	15:46:00	2018-01-11	16:50:22
12	2018-01-12	12:06:00	2018-01-12	13:10:22

France conducted preliminary analysis of the T-6 beacon scripts to make sure that there were no problems with the SARP-3 processing and to limit the risk of producing false alert messages.

Hawaii and Florida transmissions were not conducted due to simulator limitations.

Transmission Slot Selection

As the test coordinator, France provided an optimized tracking plan suggested for each MEOLUT avoiding SARP3 LEOSAR passes.

Each 12 test slots were selected with at least four MEOSAR satellites continuously in view of the beacon simulator with at least a 5-degree elevation angle, taking into account the maximum number of MEOLUT's in co-visibility with the simulator.

3.6.1 Analysis

The following test reports were provided by the participants:

Table 3-52 - T-6 Test Reports Provided by Participants

Administration	Test report reference
France	See below
USA	P3_T6_2018_09_24_USA_Maryland_Report

3.6.1.1 France

The French MEOLUT results focus on the ones obtained during the French simulator transmission in order to maximize the co-visibility between the test beacons and the MEOLUT antennas, and consequently to stimulate each reception chain.

System Capacity Using Detection Performance

Figure 3-35 shows the MEOLUT throughput depending on the number of simultaneous beacons NB. It can observe that the valid message curve is very close to the theoretical maximum curve, and the complete message curve is slightly lower. The throughput values are also higher than the ones from D&E Phase II. Consequently, the system capacity in term of MEOLUT throughput is at least NB = 200.

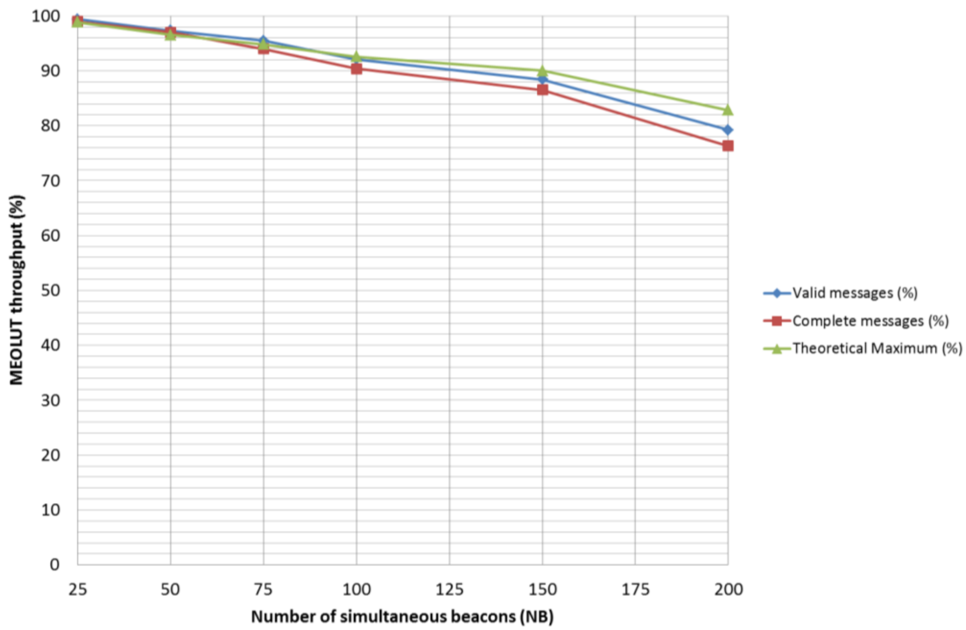


Figure 3-35: Valid/Complete Message Detection Probability

Figure 3-36 and Figure 3-37 represent Time to first Valid and Complete messages, respectively. Their trend and values are very similar. The probability to receive a message within 50 s is almost 100% up to NB = 75. Above NB = 75, the probability of valid message within 50 s is slightly degraded between 91% and 95%, whereas the probability of valid message within 100 s is still closed to 100%. As in Phase II, the system capacity is at least NB = 200 but the high number of beacons seems to delay only the short terms detections (i.e., first and/or second transmitted burst is not received).

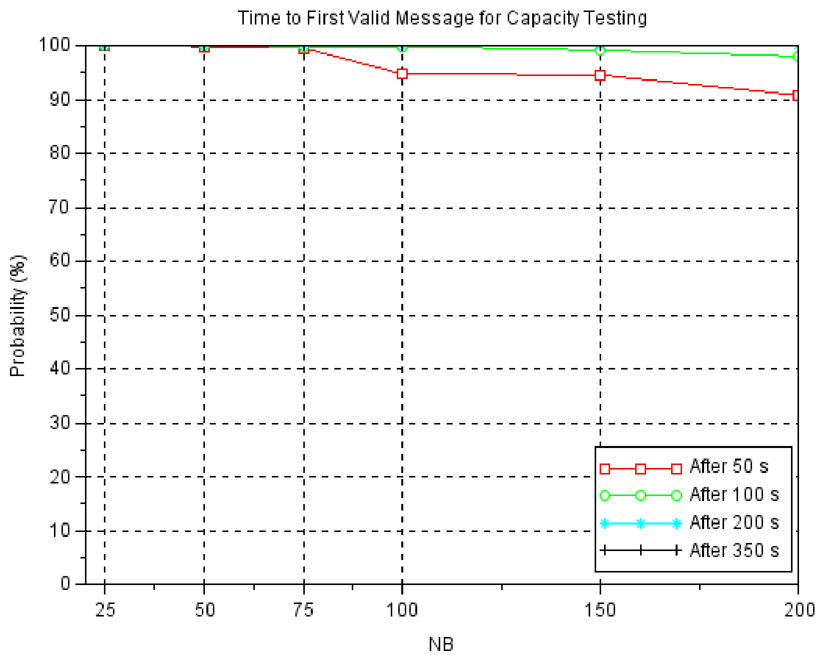


Figure 3-36: Time to First Valid Message for Capacity Testing

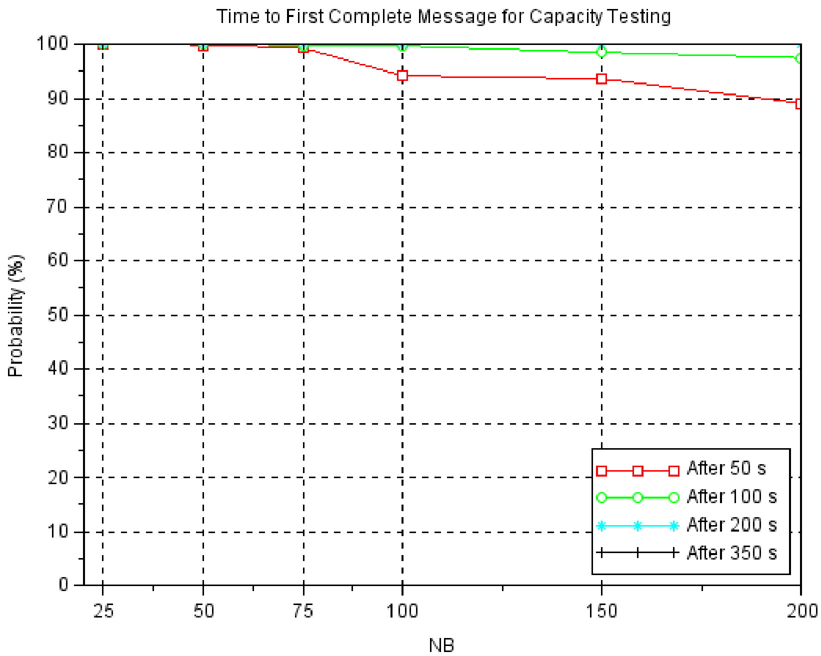


Figure 3-37: Time to First Complete Message for Capacity Testing

System Capacity Using Location Performance

Figure 3-38 shows the location probability (single locations and composite locations) depending on the number of simultaneous beacons NB. The probability continuously decreases from 92% to 46% and from 96% to 38% for single locations and composite locations respectively. Two effects were identified:

- L-band signal processing (demodulation, decoding) overload; a received message buffer is overfilled,
- Saturation of the TOA/FOA FTP link between the L-band active antenna and CNES.

For single location probability, the EOC requirement is 75% which implies that the system capacity in term of single location probability is limited to NB = 50.

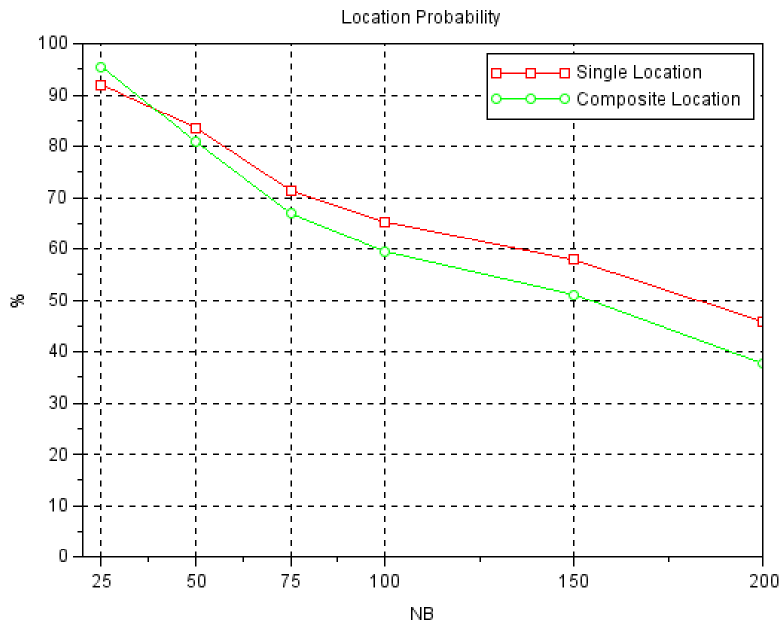


Figure 3-38: Independent Location Probability

Figure 3-39 shows the location errors depending on the number of simultaneous beacons NB. For the single-burst location, the accuracy decreases from NB = 25 to 100, then the accuracy is relatively stable from NB = 100 to 200. The location ratio with error less than 5 km is higher than the MEOSAR IOC requirement of 90%. For the composite locations, the location ratio is higher than 98% for any NB, which is better than the MEOSAR IOC target (95%).

Consequently, the system capacity in term of location accuracy is at least NB = 200.

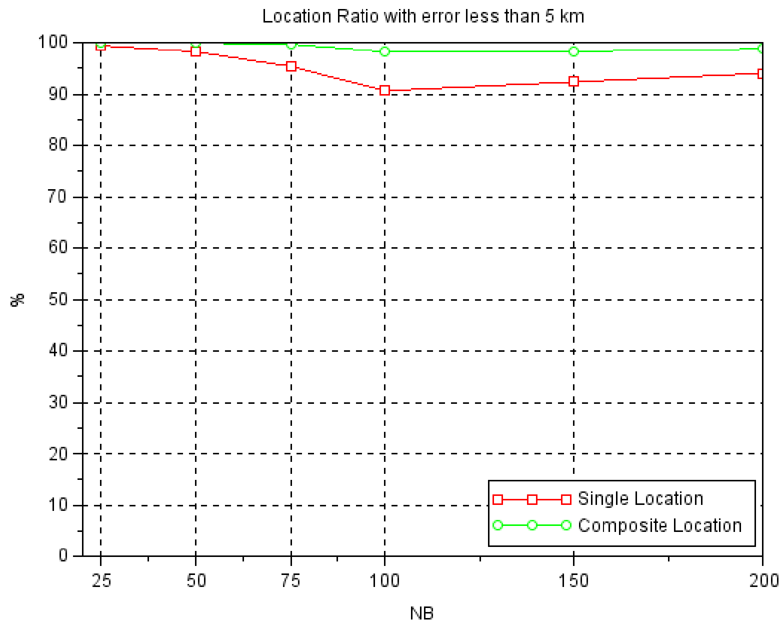


Figure 3-39: Location Ratio with Error Less than 5 km

3.6.1.2 USA

Configuration

During test T-1 Phase III, the Maryland MEOLUT was configured to track only L-band satellites, Galileo 401, 402, 403, 408, 409, 419, 422, 424, 426, 430. During test T-6, the Maryland MEOLUT was configured in stand- alone, non-networked mode. All six channels were operational during the test.

Maryland Beacon Simulator Transmission

The following results are for the Maryland beacon simulator transmission only. Due to the distance of France, Maryland did not process that data collected.

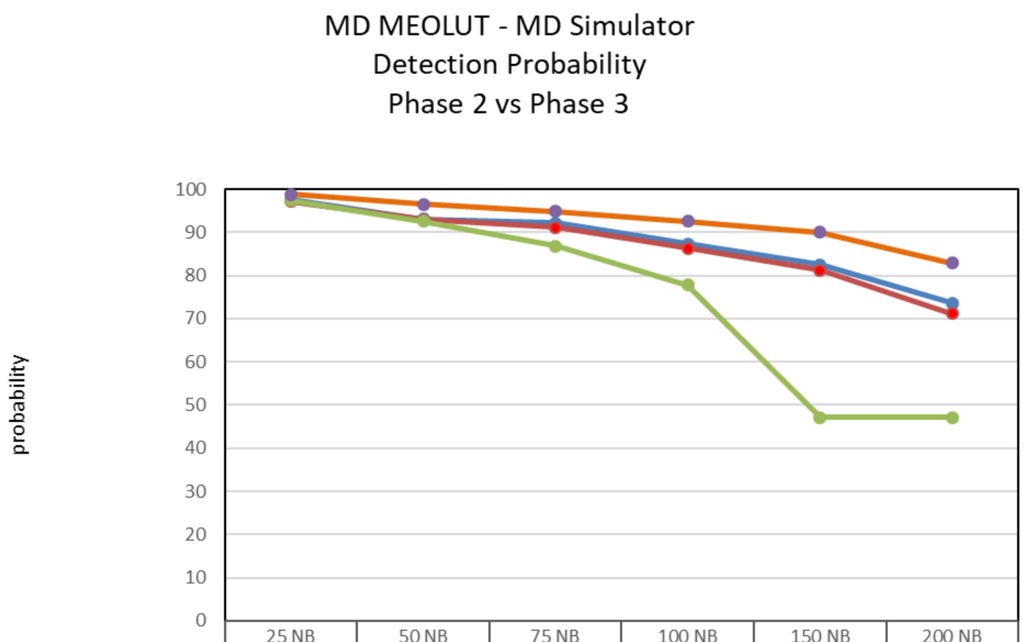
Based on the Galileo satellites that were available for use by the Maryland MEOLUT, there were multiple test slots where only two or three satellites were visible as shown in the Table below. During many time slots, even though all six channels were tracking, often two or three channels were tracking the same satellite, which obviously impacted the overall results

Table 3-53 provides the breaks down of the number of satellites tracked per time slot.

Table 3-53 - T-6 Maryland Satellite Visibility

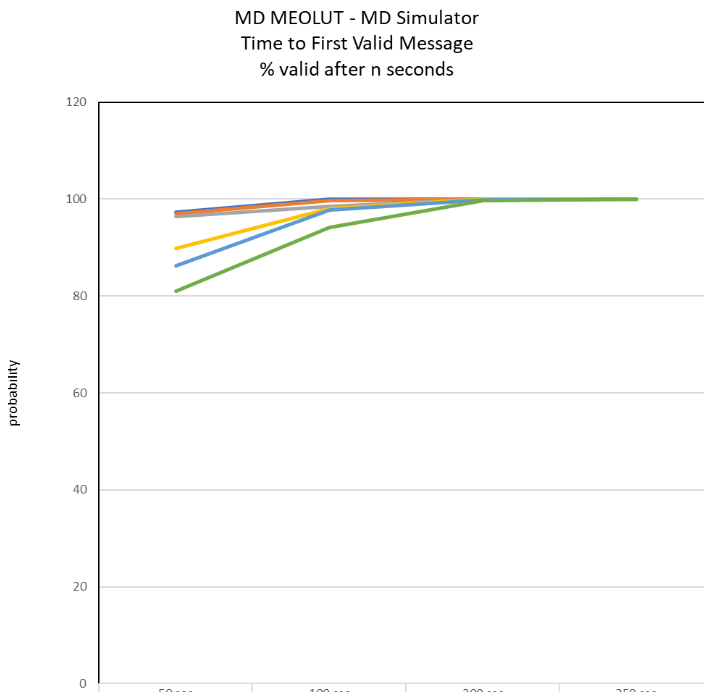
Satellite Visibility for Maryland								
Slot#	**Start Time**	**End Time**	**NB25**	**NB50**	**NB75**	**NB100**	**NB150**	**NB200**
1	10/2/2017 16:35	10/2/2017 17:39	5	4	3	3	3	2
2	10/2/2017 18:17	10/2/2017 19:21	2	2	2	2	2	1
3	10/2/2017 20:00	10/2/2017 21:04	2	2	3	3	3	3
4	10/2/2017 21:41	10/2/2017 22:45	4	4	4	4	3	4
5	10/3/2017 18:05	10/3/2017 19:09	3	3	3	3	3	3
6	10/4/2017 16:39	10/4/2017 17:43	3	3	3	3	3	3
7	10/4/2017 17:49	10/4/2017 18:54	3	3	3	3	3	4
8	10/4/2017 19:37	10/4/2017 20:41	3	3	3	3	4	4
9	10/4/2017 21:17	10/4/2017 22:21	6	6	5	5	5	5
10	10/5/2017 17:10	10/5/2017 18:14	3	2	2	2	2	2
11	10/5/2017 19:25	10/5/2017 20:29	3	3	3	3	3	3
12	10/5/2017 21:06	10/5/2017 22:10	4	4	4	4	4	4

Results



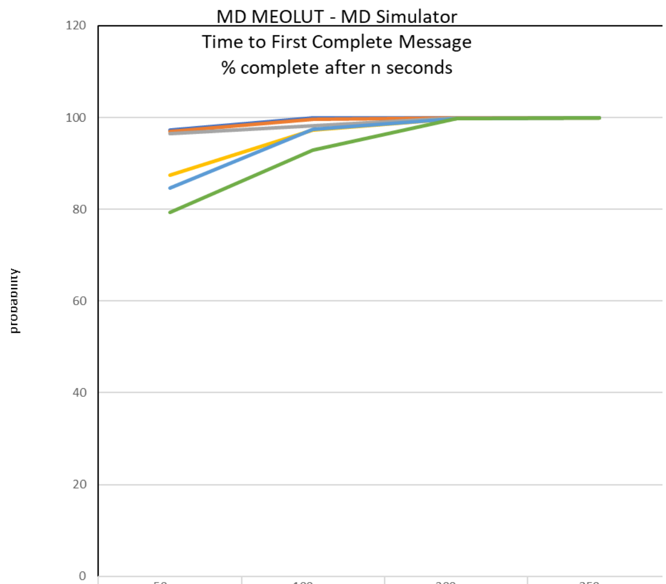
	25 NB	50 NB	75 NB	100 NB	150 NB	200 NB
Phase3 Valid	97.52	93.12	92.24	87.33	82.54	73.58
Phase 3 Complete	97.19	92.90	91.22	86.39	81.22	71.20
Phase 2 Valid	97.43	92.60	86.89	77.81	47.10	47.18
Theoretical Max	98.86	96.57	94.86	92.57	90	82.86

Figure 3-40: Detection Probability



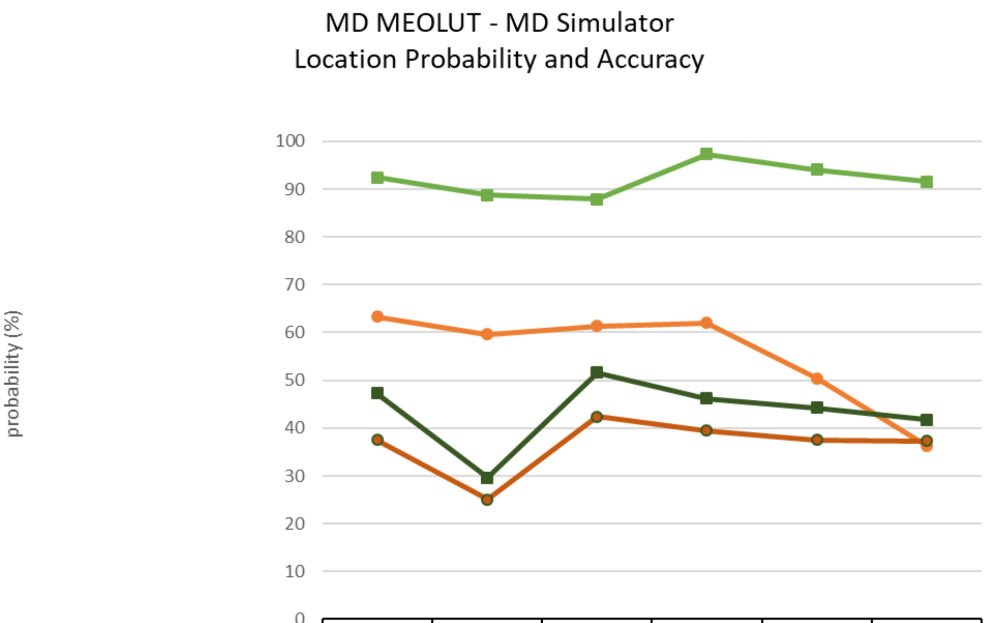
	50 sec	100 sec	200 sec	350 sec
25 NB	97.33	100.00	100.00	100.00
50 NB	97.00	99.67	100.00	100.00
75 NB	96.44	98.44	100.00	100.00
100 NB	89.83	98.08	100.00	100.00
150 NB	86.22	97.78	99.78	100.00
200 NB	81.04	94.13	99.75	100.00

Figure 3-41: Time to First Valid Message



	50 sec	100 sec	200 sec	350 sec
25 NB	97.33	100.00	100.00	100.00
50 NB	97.00	99.67	100.00	100.00
75 NB	96.44	98.22	100.00	100.00
100 NB	87.50	97.25	99.83	100.00
150 NB	84.67	97.39	99.78	100.00
200 NB	79.29	92.96	99.71	100.00

Figure 3-42: Time to First Complete Message



	25 NB	50 NB	75 NB	100 NB	150 NB	200 NB
Single burst solutions	63.30	59.60	61.30	62.00	50.40	36.30
Single burst with error < 5km	37.50	25.05	42.42	39.44	37.54	37.31
Merged solutions	92.40	88.70	87.90	97.30	94.10	91.60
Merged with error < 5km	47.25	29.67	51.63	46.15	44.27	41.77

Figure 3-43: Location Probability and Accuracy

3.6.2 Interpretation

3.6.2.1 France

The Phase III results are more significant than the ones from Phase II since the MEOSAR space segment contains more satellites and the MEOLUT is in operational mode.

The system throughput performance shows no particular correlation with the number of simultaneous beacons NB, and the expected performance drop-off with the system saturation has never occurred. The high number of beacons NB seems to delay only the short-term detections of beacon activation. The MEOSAR system capacity in term of detection is then considered higher than NB = 200.

The independent location probability is the most sensitive parameter. This parameter continuously decreases with respect to NB. The MEOSAR system capacity in term of single-burst location probability is NB = 75 as the performance is below 75% (MEOSAR EOC target) for higher NB value. This limitation is related to the L-band stage which can be improved by adding memory resources.

Regarding the independent location accuracy, the performance is upper the MEOSAR IOC requirements for any NB value. Consequently, the MEOSAR system capacity in term of independent location accuracy is then considered higher than NB = 200.

Considering the intersection of any assessment parameter and the MEOSAR EOC requirement targets, the MEOSAR system capacity of the French MEOLUT is then NB = 75.

3.6.2.2 USA-Maryland

Based on the Galileo satellites that were available for use by the Maryland MEOLUT, there were multiple test slots where only two or three satellites were visible. During many time slots, even though all six channels were tracking, often two or three channels were tracking the same satellite, which obviously impacted the overall results.

However, results from Phase III testing still seem to indicate increased capacity over previous results. Due to the nature of the test, the amount of data is limited but the increased detection performance seems evident as shown in the chart Detection Probability.

3.7 Test T-4/T-7 (Networked MEOLUT Advantage)

While document C/S R.018 (MEOSAR D&E Plan) required that this test be completed by at least one participant during the MEOSAR D&E Phase III, the participants did not have the resources to conduct the networked MEOLUT test at the time required for Phase III, due to other priority work or lack of available test resources due to operations.

MEOLUT networking has been achieved by some participants showing significant performance improvement for operational distress beacon cases. MEOLUT networking test have been conducted during the MEOSAR D&E Phase II and reported in document C/S R.023.

3.8 Test T-5/T-7 (Networked MEOLUT Advantage)

While document C/S R.018 (MEOSAR D&E Plan) requires that this test be completed by at least one participant during the MEOSAR D&E Phase III, the D&E participants did not have the resources to conduct the networked MEOLUT test at the time required for Phase III, due to other priority work or lack of available test resources due to operations.

MEOLUT networking has been achieved by some participants showing significant performance improvement for operational distress beacon cases.

MEOLUT networking test have been conducted during the MEOSAR D&E Phase II and reported in document C/S R.023.

3.9 Test T-8 (Combined MEO/GEO Operation Performance (Optional))

Optional test T-8 had not been conducted during Phase III because of limited resources available.

- END OF SECTION 3 -

4 RESULTS OF THE OPERATIONAL TESTS AND DISCUSSION

For each operational test conducted, the following sections provide:

- test periods and MEOLUT mode of operation expected,
- a description of each MCC configuration, per Administration,
- operational test results provided by each Administration, and
- a summary of the interpretation of the test analyses, as provided by each Administration.

4.1 Expected MEOLUT Configuration and Time Periods

MEOSAR D&E Phase III Operational Tests were carried out in two parts. During this phase of the test the MEOLUTs were configured in a nominal status of operation that could be either stand-alone or networked.

Table 4-1 - Phase III Operational Data Collection Period

Start	End
15 January 2018 00:00 UTC	15 April 2018 00:00 UTC

4.2 MCC Configuration

The following information on LGM MCC configuration was provided by the participants.

4.2.1 FMCC

The operational data was collected and analyzed for the whole period allocated for operational tests of the D&E Phase III from 15 January 2018 to 22 April 2018.

The means used at the FMCC were:

- the French MEOLUT 2276 (standalone),
- the operational LGM-FMCC v2.2 connected to the LGM USMCC, the LGM NMCC and the other operational (LG) MCCs.

The following 39 MEOSAR satellites were available during the MEOSAR D&E Phase III:

- DASS/GPS: 301, 302, 303, 306, 308, 309, 310, 312, 315, 316, 317, 318, 319, 323, 324, 326, 327, 329, 330, 332,
- GALILEO: 401, 402, 403, 404, 405, 407, 408, 409, 411, 412, 414, 418, 419, 420, 424, 426, 430,
- GLONASS: 501, 502 (not used in the operational configuration).

4.2.2 USA

4.2.2.1 Data Collection Periods

The primary data collection period applied for Phase III operational tests at the operational LGM USMCC was 15 January 2018 00:00 UTC to 15 April 2018 00:00 UTC (13 weeks).

The data set used for test O-7 comes from another study with an extended data collection period, 1 January 2018 00:00 to 15 July 2018 00:00 UTC, and does include the 13 weeks noted above. Also, additional data collection periods (detailed below) were applied in July and August of 2018 to provide follow-up analysis for tests O-2 and O-7.

4.2.2.2 Collection

Data collected at the USMCC Operational LGM MCC was used for all test results. In addition, the backup USMCC supplied data to support O-3 and O-4 test results. The USA Hawaii and Florida MEOLUTs were operated in networking mode for the entire period. Other MEOLUTs contributing to this alert data include France and all three EU MEOLUTs (Norway, Spain and Cyprus) via the data received from the Norway MEOLUT.

4.3 Test O-1 Potential Time Advantage

The test O-1 measures the elapsed time between the receipt at an MCC of MEOSAR distress alert messages as compared to those from the existing system (LEOSAR and GEOSAR alert messages).

4.3.1 O-1 Test Result

The following test reports were provided by the participants:

Table 4-2 - O-1 Test Reports Provided by Participants

Administration	Test report reference
France	JC-32/Inf.26
USA	JC-32/8/3

4.3.1.1 France

4.3.1.1.1 Results of Run

FMCC Service Area

The results of test O-1 for the FMCC service area are presented in .

Table 4-3 - PTA Summary Results in Minutes (AOI = FMCC Service Area)

PTA Summary Results for All Data (in minutes)								
	PTAE	PTAL	PTAA	PTAC	PTAO	PTAU (compared with LEO)	PTAU (compared with GEO)	PTAU (both)
Mean:	6,45	35,59	21,19	39,83	7,05	81,76	-16,31	-2,95
Median:	0,73	13,13	7,05	16,53	1,87	16,47	1,37	1,63
Standard Deviation:	34,72	164,59	130,42	184,02	78,66	395,28	265,74	256,20
Skewness:	1,29	0,97	-2,30	1,49	-7,48	-3,85	-12,22	-10,75
N:	113	302	345	241	648	215	352	450

Where "N" is the size of the statistical sample.

FMCC Service Area and Participating MEOLUT Coverage Area

The results of test O-1 for the FMCC zone and MEOLUT coverage are presented in Table 4-4.

Table 4-4 - PTA Summary Results in Minutes (AOI = FMCC Service Area + MEOLUTs Coverage)

PTA Summary Results for All Data (in minutes)								
	PTAE	PTAL	PTAA	PTAC	PTAO	PTAU (compared with LEO)	PTAU (compared with GEO)	PTAU (both)
Mean:	2.31	28.49	20.65	27.06	3.97	64.65	-7.14	-6.73
Median:	0.65	10.58	6.43	12.87	1.58	15.32	1.11	1.19
Standard Deviation:	24.95	118.10	109.74	133.41	72.99	434.54	252.43	236.63
Skewness:	-3.37	-0.36	-0.20	-0.52	-11.69	-3.97	-14.50	-14.88
N:	89	241	276	191	488	161	272	336

Where "N" is the size of the statistical sample.

The following map illustrates beacon locations and the delimitations of the AOIs.

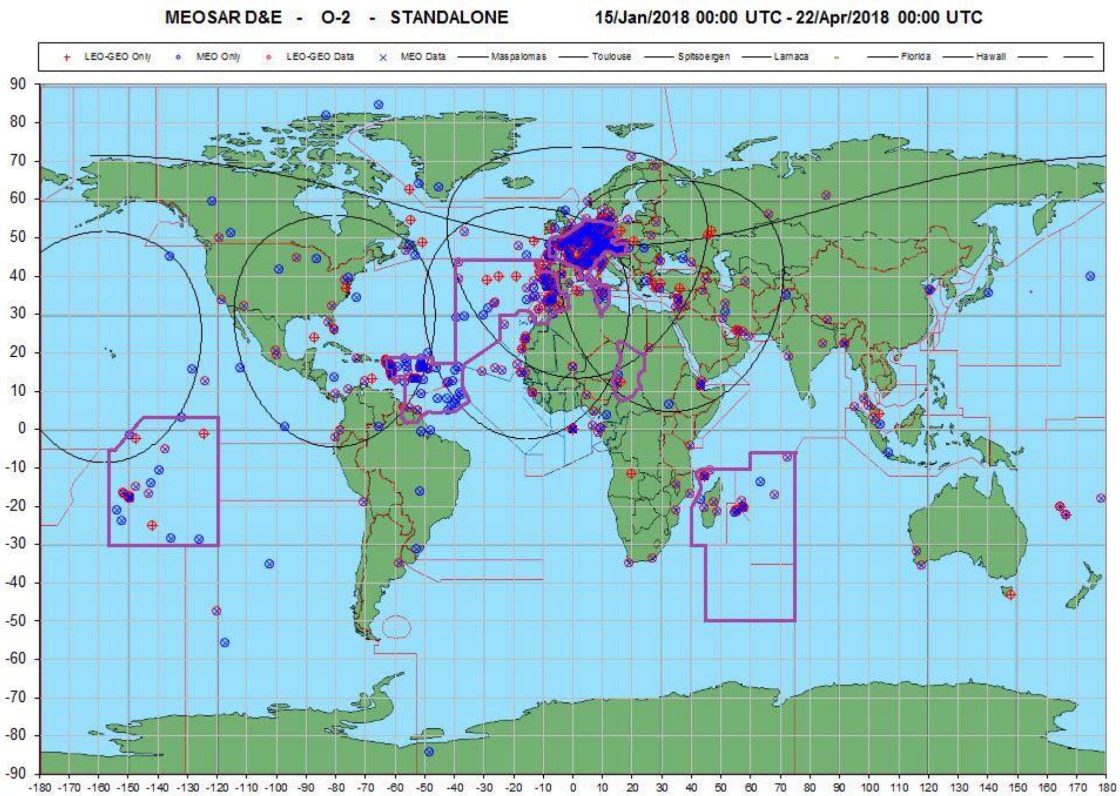


Figure 4-1: Participating MEOLUT Coverage and Geographical Repartition of Samples (FMCC Service Area in Purple and Participating MEOLUTs Coverage in Black)

As observed in the D&E Phase II test campaign, the difference in the results obtained for the two AOI approaches (i.e., FMCC service area only and FMCC service area plus participating MEOLUTs with 3,000 km radius circles) is low. Indeed, a large amount of the detection/location event data occurring inside the FMCC service area is also covered by the D&E participating MEOLUTs (the map in Figure 4-1 illustrates this observation).

For most of the cases the MEOSAR system provides a time advantage over LEOSAR/GEOSAR for any type of alerts.

Over all the alerts processed by both systems (up to 648 samples), the time advantage PTAO is more than 7 minutes on average for MEOSAR. Nonetheless, it is worth noticing that the associated standard deviation is of about 79 minutes, which suggests cases of much higher difference for which LEOSAR/GEOSAR data still arrives before the MEOSAR data.

The greatest time advantage of the MEOSAR system seems to be on the Location Confirmation (PTAC) with around 40 minutes on average. The standard deviation is also very high for this figure (about 3 hours), which implies here again a high variability that can be either related to space segment configuration or ground segment performance. The number of samples used for this computation is 241 cases, which seems to be sufficient for enough representativeness of those results.

Statistics for Unlocated beacon events presented in and Table 4-4 show that the PTA of the MEOSAR system compared with the LEOSAR system is about 81 minutes on average, but it has almost no advantage over the GEOSAR system. Indeed, according to these figures, unlocated beacons are detected by the GEOSAR system 16 minutes on average before the MEOSAR system. However, having a close look at the data set, two cases have been identified with significant advantage for the GEOSAR system (2,600 and 4,000 minutes respectively). Some further analysis showed that for these two cases the MEOSAR system located the alert at the same time as the GEOSAR system detected it, but that the MEOSAR system did not generate an unlocated alert prior to the position alert.

Table 4-5 shows the results obtained for PTAU of the MEOSAR system when these two cases are not taken into account. The MEOSAR system provides eventually a time advantage of 2.5 minutes in average over the GEOSAR system instead of a time disadvantage of 16 minutes approximately:

Table 4-5 - PTA Summary Results in Minutes
(AOI = FMCC Service Area) Without Extreme Cases

PTA Summary Results for All Data (in minutes)								
	PTAE	PTAL	PTAA	PTAC	PTAO	PTAU (compared with LEO)	PTAU (compared with GEO)	PTAU (both)
Mean:	6.51	30.74	21.30	33.70	7.07	100.66	2.47	11.78
Median:	0.78	13.13	7.07	16.40	1.88	17.07	1.38	1.64
Standard Deviation:	34.87	140.98	130.79	157.82	78.78	282.50	77.19	121.65
Skewness:	1.28	-2.26	-2.29	-0.99	-7.47	3.12	2.91	0.53
N:	112	300	343	239	646	214	350	448

4.3.1.1.2 Complementary Analysis

Figure 4-2 shows that the Overall Time Advantage for the MEOSAR system (all alert types considered) is between 0 and 5 minutes for almost 60% of the samples. The left-hand side of this histogram illustrates the events for which the LEOSAR/GEOSAR data was available before the MEOSAR data, which represent about 15% of the cases. Cases for which the difference is beyond 10 minutes only occurred for alert beacons that were first notified by the MEOSAR system. Complementary graphs detailing the distribution of the difference in time between systems are presented in the attachment to this document.

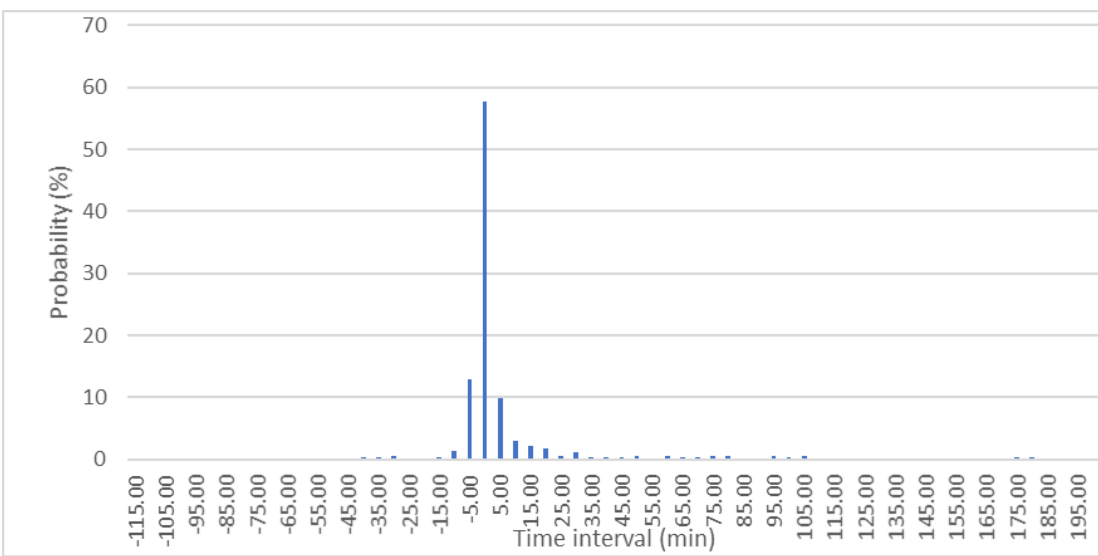


Figure 4-2: MEOSAR Overall Time Advantage (FMCC Service Area) - Histograms of Samples Repartition

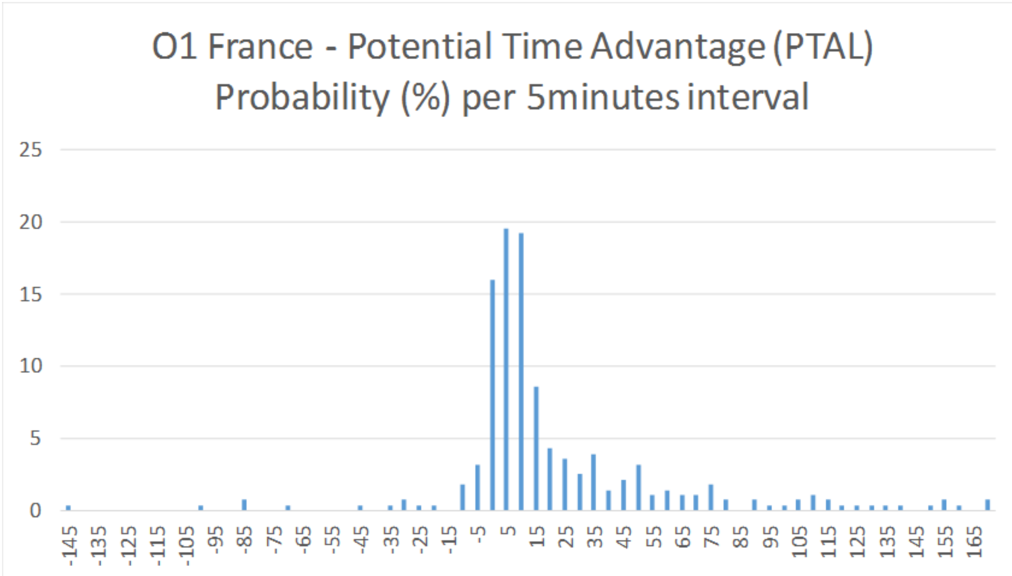


Figure 4-3: Potential Time Advantage All Locations (FMCC Service Area)

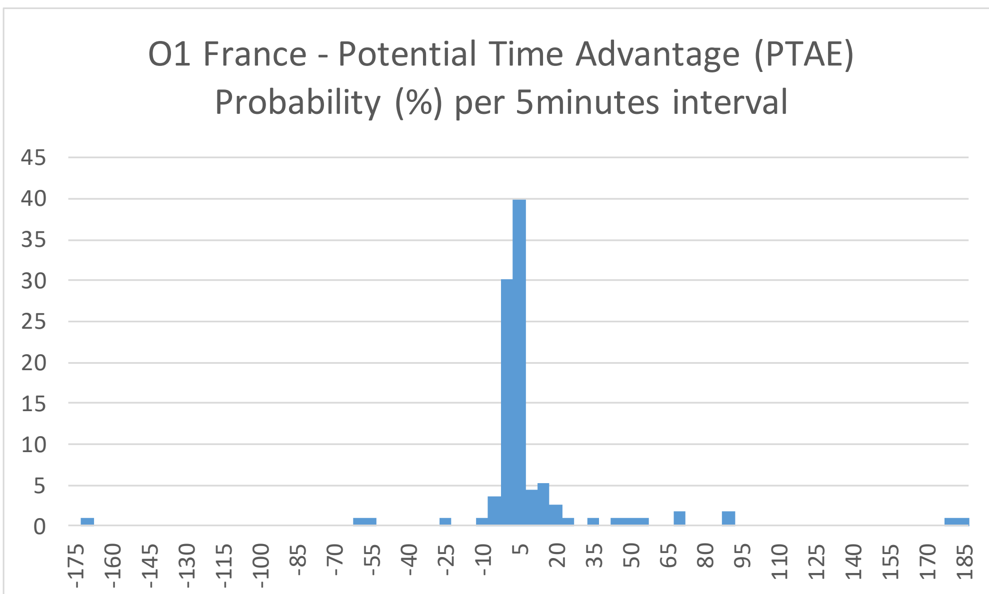


Figure 4-4: Potential Time Advantage for Encoded Positions (FMCC Service Area)

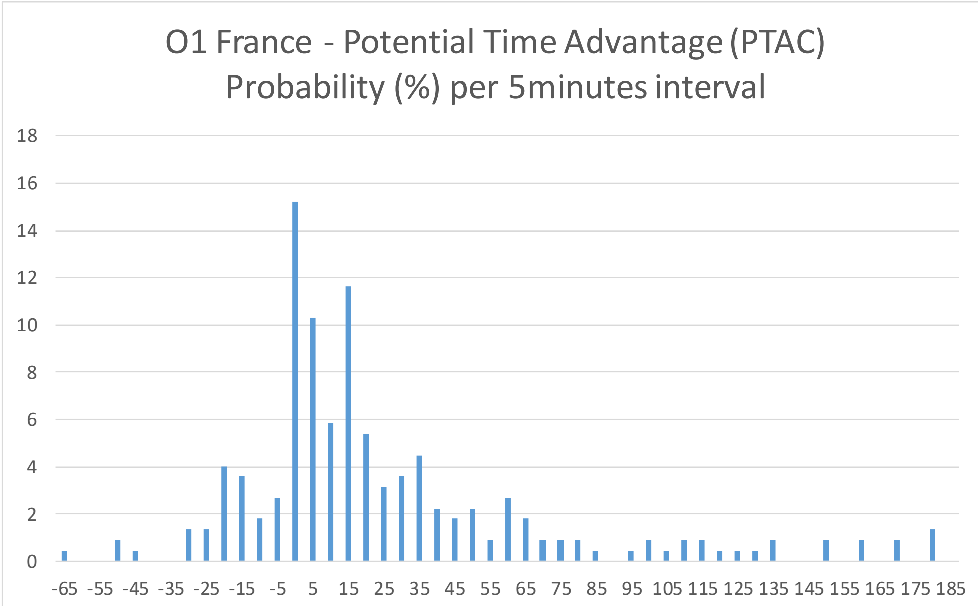


Figure 4-5: Potential Time Advantage for Confirmed Positions (FMCC Service Area)

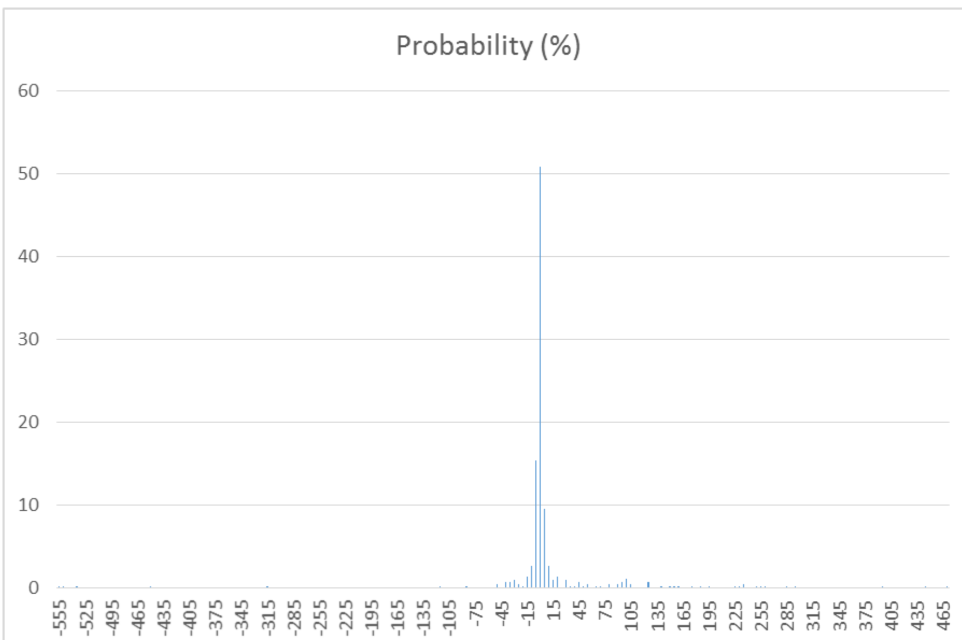


Figure 4-6: Potential Time Advantage for Unlocated Alerts (FMCC Service Area)

4.3.1.1.3 Summary

With the samples collected during MEOSAR D&E Phase III, the following were noted:

- a potential time advantage of the MEOSAR system for detection,
- a potential time advantage of the MEOSAR system for location,
- a potential time advantage of the MEOSAR system for location confirmation,
- a slight advantage of the MEOSAR system for encoded alert messages.

The trend of the analyses shows some potential time advantage for the MEOSAR system that reaches a few minutes in most of the cases. Although the timing is sometimes better for LEOSAR/GEOSAR alerts, this is expected to occur rather less with an extended MEOSAR ground segment.

4.3.1.2 USA

The objective of analyzing the Potential Time Advantage (PTA) is to provide a comparison between the new MEOSAR system and the existing LEOSAR/GEOSAR system with respect to the timeliness in the receipt of various alert notifications at the MCC. Per section 5.1.5 of document C/S R.018, for Phase III, rather than using the times of outgoing notifications it is more appropriate to collect the time that the data was received at the MCC, and as only one system can actually be responsible for position confirmation, the comparison based on that criterion was dropped from the analysis. Other criteria for the reception times of the first unlocated, the first encoded position, and first independent position as well as separating LEOSAR data from GEOSAR data were all retained.

However, in attempting the analysis, the USA found that keeping all these criteria, as well as separate values for LEOSAR and GEOSAR data was cumbersome and made the interpretation of the results difficult. Noting that there was already going to be divergence from the data collection, analysis and reporting mechanisms outlined in section 5.1 of document C/S R.018, the USA decided to take these changes a step further and simplify the data collected and improve the interpretation of the results.

For all sites processed at the LGM USMCC during the 13-week data collection period, in addition to the USMCC site ID and the beacon ID the following data in Table 4-6 was collected.

Table 4-6 - LGM USMCC Phase III O-1 PTA Time Values Collected

Name (in Spreadsheet)	Description
FirstMeoDetectOnly	Receive time at MCC for the first MEOSAR detect only alert, unlocated or with encoded position
FirstMeoLocation	Receive time at MCC for the first MEOSAR DOA position
FirstMeoData	Receive time at MCC for the first MEOSAR alert data of any type
FirstLeoGeoDetectOnly	Receive time at MCC for the first LEOSAR or GEOSAR detect only alert, unlocated or with encoded position
FirstLeoLocation	Receive time at MCC for the first LEOSAR Doppler position
FirstLeoGeoData	Receive time at MCC for the first LEOSAR or GEOSAR alert data of any type

The FirstMeoData and FirstLeoGeoData times will be redundant with at least one of the other respective times, but having it recorded directly improves the clarity of results. Table 4-7 shows a portion of the spreadsheet used to perform the analysis in similar fashion to the spreadsheet defined and discussed in document C/S R.018.

Table 4-7 - Extract from LGM USMCC Phase III O-1 Analysis Spreadsheet

Data								Indicates which system was first			Gaps in minutes (Meo first > 0)		
USMCC Id	Beacon Id	FirstMeoDetectOnly	FirstMeoLocation	FirstMeoData	FirstLeoGeoDetectO	FirstLeoLocation	FirstLeoGeoDData	FirstDetectOnly	FirstLocation	FirstData	GapFirstDetectOnly	GapFirstLocation	GapFirstData
91528	9D0D90F17840001	2018/01/15 00:07:03	2018/01/15 00:07:03	2018/01/15 00:07:03	2018/01/15 00:07:36	2018/01/15 00:17:53	2018/01/15 00:07:36	M	M	M	0.6	10.8	0.6
91529	A78D4024680034D	2018/01/15 00:10:55	2018/01/15 00:08:05	2018/01/15 00:08:05	2018/01/15 00:13:16	2018/01/15 00:17:53	2018/01/15 00:13:16	M	M	M	2.3	9.8	5.2
91531	3EE6F8D97CFFBFF	2018/01/15 00:13:29	2018/01/15 00:15:12	2018/01/15 00:13:29	2018/01/15 00:14:48	2018/01/15 00:20:53	2018/01/15 00:14:48	M	M	M	1.3	5.7	1.3
91533	ADCE014E2440C01	2018/01/15 00:25:54	2018/01/15 00:28:05	2018/01/15 00:25:54	2018/01/15 00:24:22	2018/01/15 00:40:11	2018/01/15 00:24:22	LG	M	LG	-1.5	12.1	-1.5
91540	C6E8D34D29974D1	2018/01/15 02:12:15		2018/01/15 02:12:15	2018/01/15 02:11:24	2018/01/15 02:08:11	2018/01/15 02:08:11	LG		LG	-0.9		-4.1
91535	B389570304334D1	2018/01/15 01:06:12		2018/01/15 01:06:12	2018/01/15 01:04:05	2018/01/15 02:08:10	2018/01/15 01:04:05	LG		LG	-2.1		-2.1
91538	3384D12E40FFBFF	2018/01/15 01:44:15		2018/01/15 01:44:15		2018/01/15 02:43:27	2018/01/15 02:43:27			M			59.2
91537	C0C8A28C34D34D1	2018/01/15 01:42:12	2018/01/15 01:42:22	2018/01/15 01:42:12	2018/01/15 01:42:45	2018/01/15 01:53:21	2018/01/15 01:42:45	M	M	M	0.6	11.0	0.6
91539	D228341D34D34D1	2018/01/15 01:59:28		2018/01/15 01:59:28	2018/01/15 06:57:55	2018/01/15 03:57:15	2018/01/15 03:57:15	M		M	298.5		117.8
91542	C7C9D65028154D1	2018/01/15 02:34:37		2018/01/15 02:34:37		2018/01/15 03:26:53	2018/01/15 03:26:53			M			52.3
91541	ADCD02047544801	2018/01/15 02:36:42	2018/01/15 02:34:37	2018/01/15 02:34:37	2018/01/15 02:34:59	2018/01/15 03:03:13	2018/01/15 02:34:59	LG	M	M	-1.7	28.6	0.4

In Table 4-7, the data is to the left and the results generated by Excel formulas are on the right (green shading). The first three result columns identify which system was first, and the next three provide the actual applicable gap in minutes, for each of the three categories, first detect only, first location and first data of any type.

The summary results are provided in Table 4-8. The total number of sites analyzed was 8,323. Counts by data type are provided on the left and statistics for the gaps in minutes are provided on the right.

Table 4-8 - LGM USMCC Phase III O-1 Results

	First System		Gaps in Minutes	
	Count MEO	**Count LEO/GEO**	**Median**	**Standard Deviation**
FirstDetectOnly	5427	1838	1.80	179.8
FirstLocation	2286	640	17.73	190.4
FirstData	6679	1644	2.05	96.6

4.3.2 O-1 Test Result Interpretation and Conclusion

As demonstrated in previous phases of the D&E, the MEOSAR system provides a clear time advantage over the LEOSAR/GEOSAR system for the independent locations, and while performance relative to previous phases remains similar for detection, Phase III results do demonstrate some additional time advantage that was not previously as clear.

4.3.2.1 France

MEOSAR D&E Phase III testing allowed the comparison of timing of message receipt between the LEOSAR/GEOSAR and the MEOSAR systems with the limitations of:

- the MEOSAR space segment (not fully deployed),
- the MEOSAR ground segment very partially deployed with most of the MCC connected to the FMCC having only the LEOSAR/GEOSAR capability (only three LGM MCCs with their MEOLUTs and the rest of the data provided by LG MCCs),
- the duration of the measurement campaign.

However, in comparison to the MEOSAR D&E Phase II test campaign, the current results provide higher confidence in the MEOSAR system time advantage compared to the LEOSAR/GEOSAR system.

4.3.2.2 USA

The counts by data type are the best indicator for a clear time advantage for the MEOSAR system over the LEOSAR/GEOSAR system. The values for the gap in minutes demonstrate a similar advantage, also showing that for detect only data the actual median gap is relatively small, but for independent locations the time advantage is significant.

As has been seen before in USA results for both Phases I and II of the MEOSAR D&E, the time data has a wide range (as indicated by the standard deviation) and hence the median, rather than the average, is provided as a clearer measure of relative performance.

As demonstrated in previous phases of the D&E, the MEOSAR system provides a clear time advantage over the LEOSAR/GEOSAR system for the independent locations, and while performance relative to previous phases remains similar for detect only data, Phase III results do demonstrate some time advantage here as well that was not previously as clear.

4.4 Test O-2 Unique Detections by MEOSAR System as Compared to Existing System

4.4.1 O-2 Test Result

The following test reports were provided by the participants:

Table 4-9 - O-2 Test Reports Provided by Participants

Administration	Test Report Reference
France	JC-32/Inf.27
USA	JC-32/8/3

4.4.1.1 France

4.4.1.2 Methodology and Data Collection

The methodology as described in document C/S R.018 has been applied for the analysis presented in this document.

Two Areas of Interest have been taken into account for filtering beacon data. France reports test O-2 results for beacons located in:

a) an AOI defined as the FMCC service area; and
b) another AOI that corresponds to the portion of the FMCC service area that is covered by participating MEOLUTs (a MEOLUT coverage area is assumed to be the 3,000 km radius circle).

The MEOLUT configuration worksheet provides information regarding MEOLUT availability and is taken into account in the Excel macro.

The default settings for MEOLUT coverage are:

a) a 7,000 km radius around the MEOLUT for detection capability (which also applies to encoded location capability); and
b) a 3,000 km radius around the MEOLUT for independent location capability (which also applies to position confirmation capability).

4.4.1.3 Data and Analyses

All data have been collected for all beacons regardless of reception through MEOSAR, LEOSAR or GEOSAR satellites. The following table provides abbreviations referenced in the data collection spreadsheet.

Table 4-10 - Abbreviations Referenced in the Data Collection Spreadsheet

LGST	LEO/GEO Start Time
LGET	LEO/GEO End Time
LGDT	LEO/GEO Data Type (U=Unlocated, E=Encoded, D=Doppler, C=Confirmed)
MST	MEO Start Time
MET	MEO End Time
MDT	MEO Data Type (U=Unlocated, E=Encoded, D=DOA, C=Confirmed)
Latitude	Based on encoded position, independent position or ground truth information
Longitude	Based on encoded position, independent position or ground truth information

4.4.1.4 Results and Analysis

FMCC Service Area

The test O-2 results for the FMCC service area are presented in Table 4-11.

Table 4-11 - Unique Detections on Compared Systems (AOI = FMCC Service Area)

	Any Detection		Unlocated		Encoded Position		Independent Position		Confirmed Position	
	Count	%	Count	%	Count	%	Count	%	Count	%
LEO/GEO only	128	8.91%	36	2.51%	7	0.49%	69	4.81%	16	1.11%
MEO only	660	45.96%	409	28.48%	102	7.10%	107	7.45%	42	2.92%
Both Systems	648	45.13%	41	2.86%	6	0.42%	154	10.72%	447	31.13%
Neither System	0	0.00%	950	66.16%	1321	91.99%	1106	77.02%	931	64.83%
Total Beacon Events	1436		1436		1436		1436		1436	

FMCC Service Area and Participating MEOLUT Coverage Area

The test O-2 results for the FMCC zone and MEOLUT coverage are presented in Table 4-12.

Table 4-12 - Unique Detections on Compared Systems
(AOI = FMCC Service Area + MEOLUTs Coverage)

	Any Detection		Unlocated		Encoded Position		Independent Position		Confirmed Position	
	Count	%	Count	%	Count	%	Count	%	Count	%
LEO/GEO only	114	9.33%	36	2.95%	7	0.57%	60	4.91%	11	0.90%
MEO only	619	50.65%	409	33.47%	98	8.02%	86	7.04%	26	2.13%
Both Systems	489	40.02%	41	3.36%	5	0.41%	66	5.40%	377	30.85%
Neither System	0	0.00%	736	60.23%	1112	91.00%	1010	82.65%	808	66.12%
Total Beacon Events	1222		1222		1222		1222		1222	

The map in Figure 4-7 illustrates beacon locations and the delimitations of the AOI.

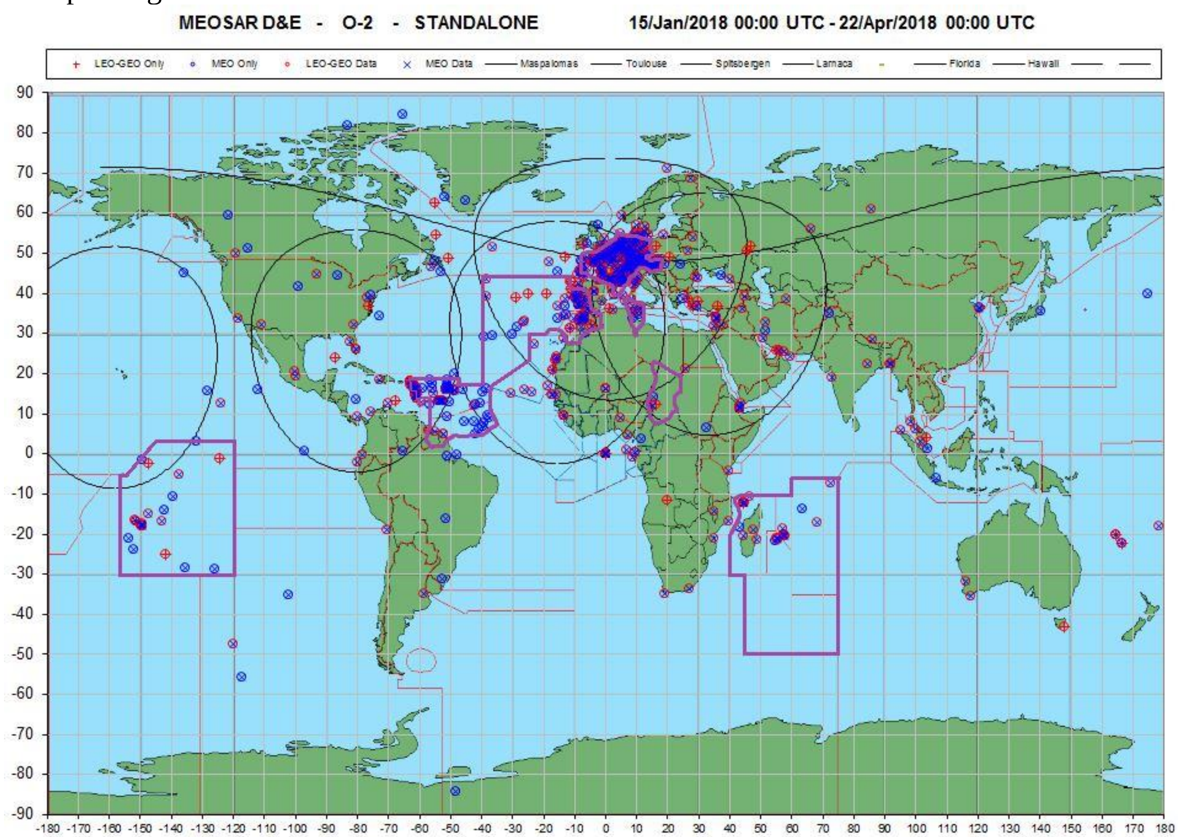


Figure 4-7: World Map Showing FMCC Service Area (Purple) and Coverage Area of Participating MEOLUTs (Black)

4.4.1.5 Analysis

4.4.1.6 Global Analysis

What can be observed is that the difference in the results obtained for the two AOI approaches (i.e., FMCC service area only and FMCC service area plus participating MEOLUTs with 3,000 km radius circles) is very low. Indeed, a large amount of the detection/location event data occurring inside the FMCC service area is also covered by the D&E participating MEOLUTs (see map in Figure 4-7 that illustrates this fact).

Table 4-12 and Table 4-13 show an excessive number of detections only for the MEOSAR system when compared to the LEOSAR/GEOSAR system. The number of unlocated alerts for the MEOSAR system is 11 times higher than for the LEOSAR/GEOSAR system. This difference was also observed in the analyses of D&E Phase II test campaign.

Based on these numbers, Figure 4-8 illustrates the type of events for each system. This histogram highlights the difference in the number of events detected by the MEOSAR system only. It also strikes out that 62% of the events in the case of the MEOSAR are unlocated beacons, whereas these events represent fewer than 30% of the alerts in the case of the LEOSAR/GEOSAR system.

Figure 4-9 shows that, regardless of the type of detection received, the unique detections by MEOSAR represent approximately 46% of the total messages received by FMCC. The unique detections by LEOSAR/GEOSAR only represent 9%, and co-detections 45%.

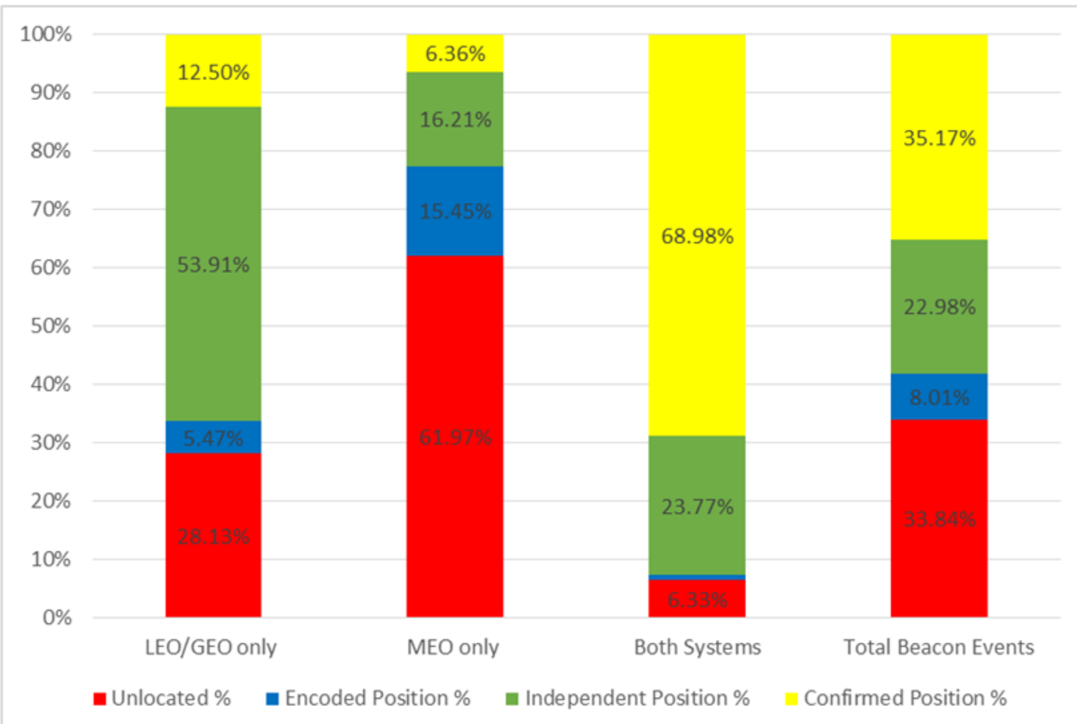


Figure 4-8: Events Type Distribution for Each System (AOI = FMCC Zone)

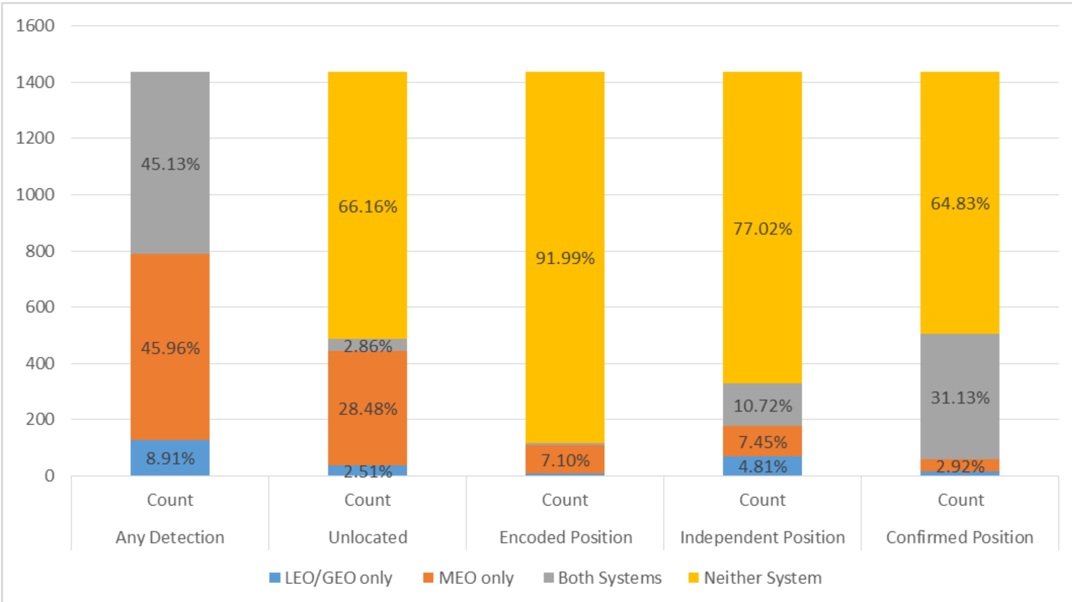


Figure 4-9: Test O-2 Histogram Results (AOI = FMCC Zone)

4.4.1.7 Analysis Isolating "Corroborated" Alerts

Table 4-13 shows the data analyses results when suspect alerts are discarded from the data set. The number of alerts detected by the MEOSAR system only is approximately divided by 2 (from 660 to 303). The count of MEOSAR only alerts is then two times higher than the number of alerts detected by LEOSAR/GEOSAR system only (128 alerts).

Table 4-13 - Unique Detections on Compared Systems (AOI = FMCC Service Area) without Suspect Alerts

	Any Detection		Unlocated		Encoded Position		Independent Position		Confirmed Position	
	Count	%	Count	%	Count	%	Count	%	Count	%
LEO/GEO only	128	11.86%	36	3.34%	7	0.65%	69	6.39%	16	1.48%
MEO only	303	28.08%	52	4.82%	102	9.45%	107	9.92%	42	3.89%
Both Systems	648	60.06%	41	3.80%	6	0.56%	154	14.27%	447	41.43%
Neither System	0	0.00%	950	88.04%	964	89.34%	749	69.42%	574	53.20%
Total Beacon Events	1079		1079		1079		1079		1079	

Figure 4-10 illustrates the repartition of alerts type for each system. For the MEOSAR only alerts the amount of Independent Location Alerts and Encoded Position Alerts is approximately 35%, the Unlocated Alerts represent 17% and the Confirmed Position Alerts represent 14% of the total number of alerts.

When considering all beacon events, the distribution completely changes; Confirmed Position Alerts represent ~47% of the alerts, Independent position alerts represent ~30% of the alerts, Unlocated alerts 12% and finally Encoded position alerts ~11% of the alerts.

Figure 4-10 shows that, regardless of the type of detection received, the unique detections by MEOSAR represent approximately 28% of the total messages received by FMCC. The unique detections by LEOSAR/GEOSAR only represent 12%, and co-detections 60%.

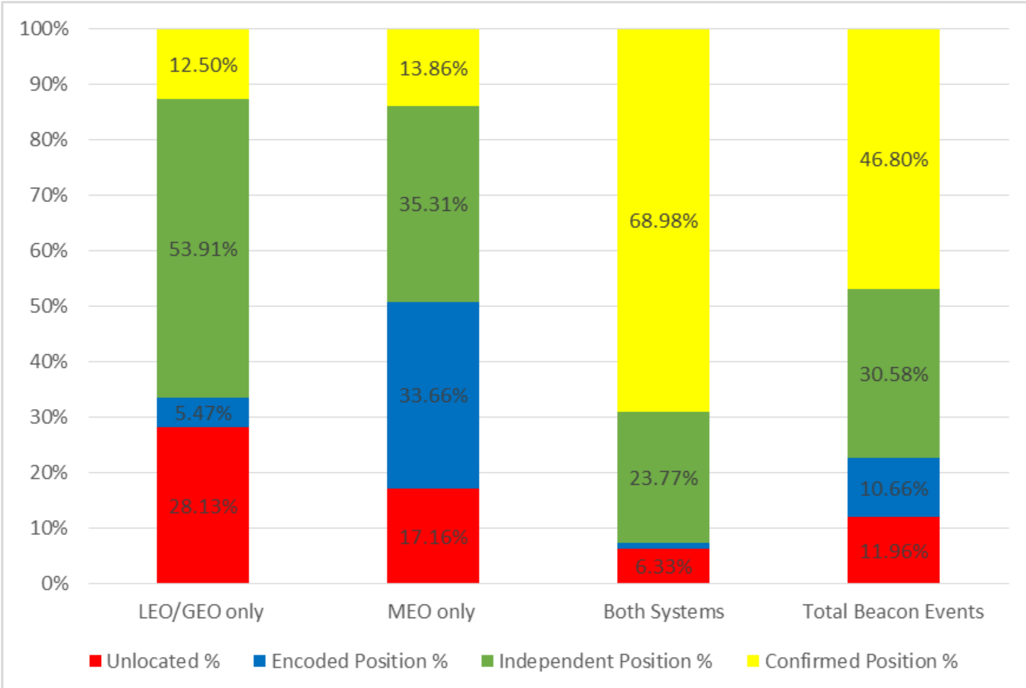


Figure 4-10: Events Type Distribution for Each System (AOI = FMCC Zone) Without Suspect Alerts

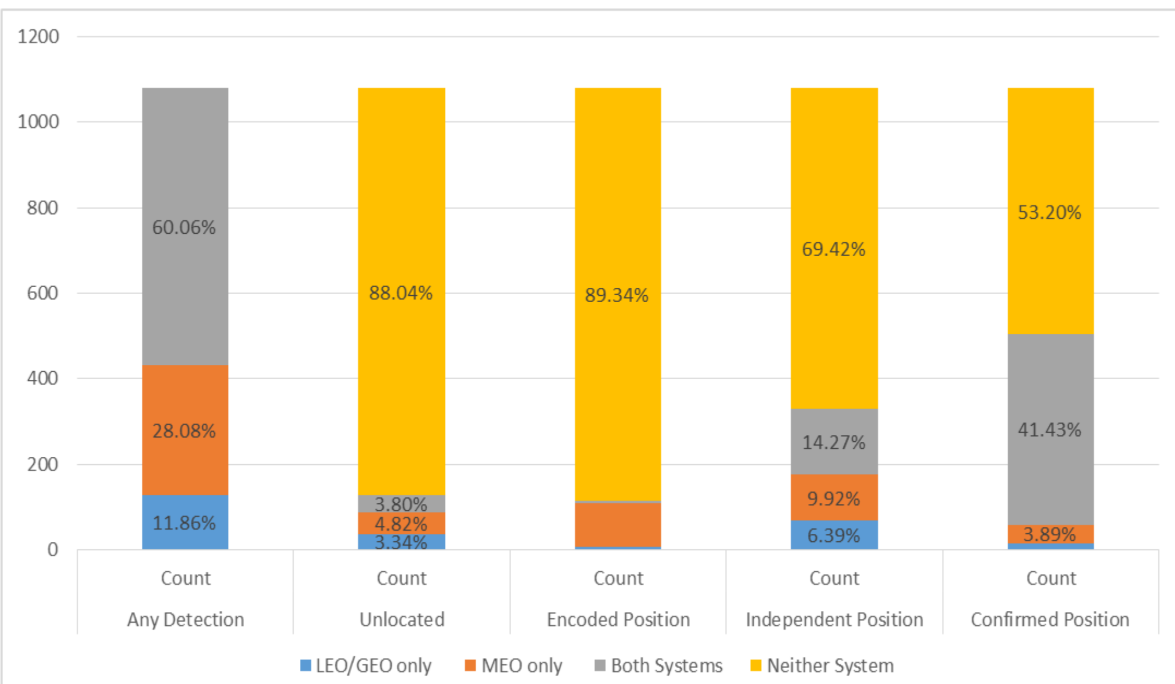


Figure 4-11: Test O-2 Histogram Results (AOI = FMCC Zone) Without Suspect Alerts

4.4.1.8 Summary

Results show that there is low difference when considering an area of interest defined by the FMCC service area or an area of interest defined by the FMCC service area extended by MEOLUT coverage. A detailed analysis of the MEOSAR data indicates that half of the MEOSAR-only alerts are suspect alerts (single-packet alerts with no other corroborated alert).

Once all suspect alerts are discarded from the analysis, we can observe that:

- the MEOSAR system has similar results to the LEOSAR/GEOSAR system with regard to detection,
- the MEOSAR system has a higher percentage of alerts with encoded position and alerts with independent position than the LEOSAR/GEOSAR system,
- in 12% of the cases the LEOSAR/GEOSAR system was the unique system to detect the beacons, and in more than half of the time providing an independent location.

4.4.1.9 USA

The LGM USMCC processed 20,605 alert sites during the 13-week test period. Of those sites, 7,880 were MEOSAR suspect alerts (i.e., the only alert was a single packet MEOSAR alert not corroborated by another C/S alert). The USA recently identified an issue where the networked USA MEOLUT sends a 3 BCH error single packet alert to the MCC (because the number of BCH-1 errors was not indicated in the networked data) when the originating MEOLUT properly filters the alert. Corrected this is expected to result in a reduction by about 90%. Reducing the number of alert sites by a corresponding amount (i.e., 90% of 7880), the adjusted total number of suspect alert sites and suspect alerts would be 13,513 and 788 respectively, with 5.8% of remaining sites being suspect.

Of the 20,605 sites processed by the LGM USMCC, 11,773 were detect only (i.e., with no independent position), and of those 10,375 were unlocated and 1,398 had encoded position. All 7,880 MEOSAR suspect alert sites are in the detect only data group. Noting that the vast majority of suspect alert sites are likely system generated anomalies, as well as the expected improvement mentioned above, suspect alert sites are excluded from the rest of the primary analysis discussed below. As discussed below, further analysis was performed to re-evaluate after the improvement was installed. Table 4-14 provides a breakdown of detect only results (i.e., with suspect alert sites excluded):

Table 4-14 - LGM USMCC Phase III O-2 Detect Only Results

	Sites on Both Systems	MEOSAR Only Sites	LEOSAR/GEOSAR Only Sites	Total Sites
Unlocated	1149	1242	1036	3427
Encoded Position	195	187	84	466
All Detect Only	1344	1429	1120	3893

Both systems performed similarly with respect to detect only data, each received data for approximately 60 to 70% of the total number of alert sites, and each received data for the 30 to 40% of alert sites uniquely. Looking at the full data set, perhaps the most interesting observation is that while half the data (per the median) has only a one-minute duration, the average duration is 14 minutes, with the duration for 250 sites over 60 minutes and for about 20 sites over 5 hours. While blockages or very low beacon power outputs are the expected causes, it would be interesting to analyze why these beacons were active for periods exceeding 60 minutes without achieving any independent location (DOA or Doppler).

As noted above, the LGM USMCC O-2 analysis focuses on an AOI which contains most of the USMCC service area, specifically, a rectangle from -10 to 60 degrees in latitude and from -180 to -40 degrees in longitude. There were 3642 sites in this area with some location (encoded, DOA or Doppler) excluding suspect alerts. Figure 4-12, Figure 4-13, Figure 4-14, and Figure 4-15 show the distribution of these sites over the AOI, broken down into the categories of "all data", "data received by both systems", MEOSAR only data and LEOSAR/GEOSAR only data.

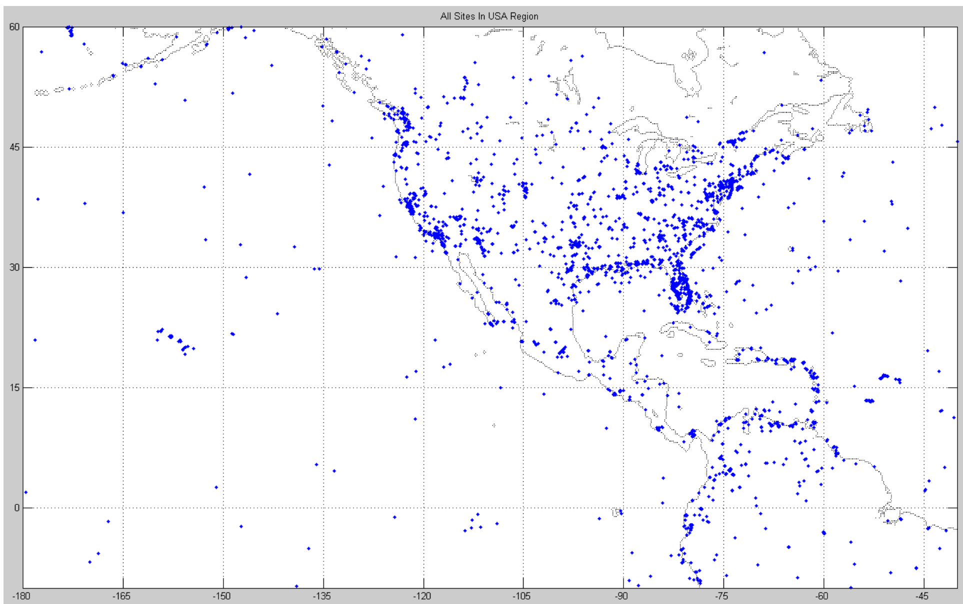


Figure 4-12: LGM USMCC AOI - All Data (3,642 Sites)

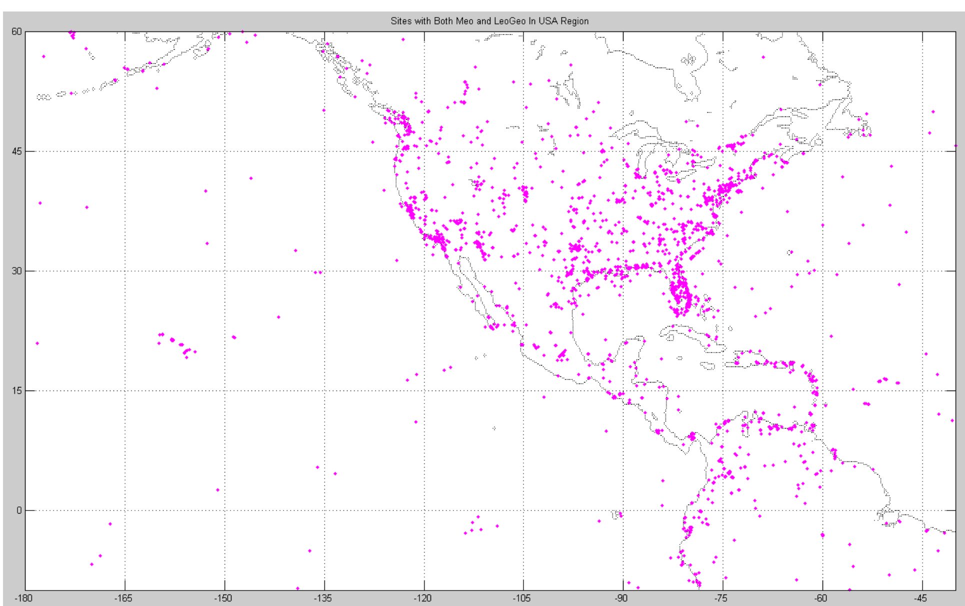


Figure 4-13: LGM USMCC AOI – Received by Both System (3,054 sites)

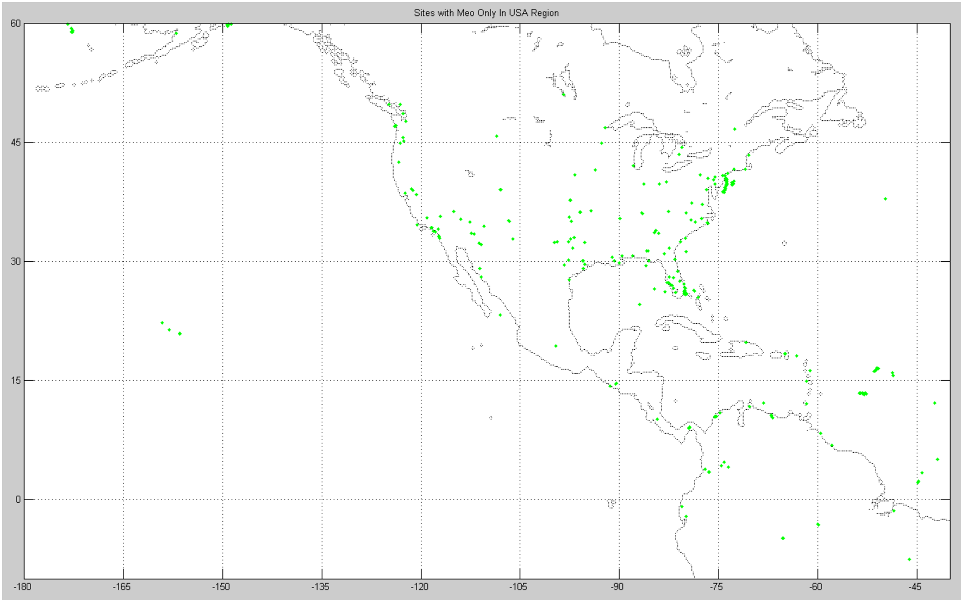


Figure 4-14: LGM USMCC AOI - MEOSAR Only (314 sites)

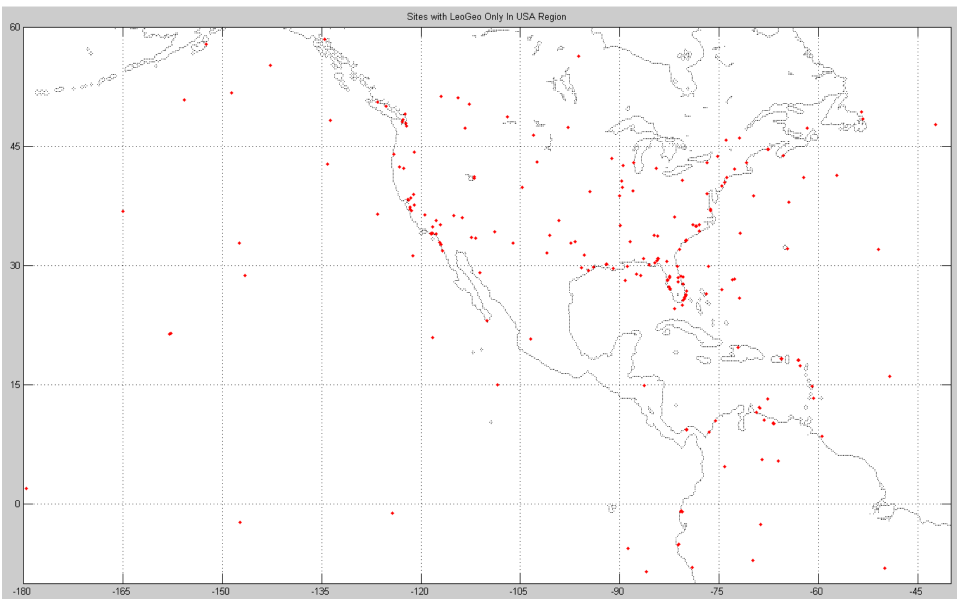


Figure 4-15: LGM USMCC AOI - LEOSAR/GEOSAR Only (274 sites)

There is very little difference in the geographical distribution for the categories of sites. A summary of alert data with locations (including encoded position only sites) broken down by category is provided in Table 4-15.

Table 4-15 - LGM USMCC Phase III O-2 - Located Sites - Inclusion of GEOSAR

Sites on Both Systems		LEOSAR/GEOSAR Only Sites	
Total	**Includes GEOSAR Data**	**Total**	**Includes GEOSAR Data**
3,054	2,767	274	9

While 91% (2767/3054) of sites seen by both systems included GEOSAR data, only 3.3% (9/274) of LEOSAR/GEOSAR only sites included GEOSAR data. The two most likely explanations for this behavior are blockages or beacons transmitting at low power (i.e., with a low signal to noise ratio); low power is more likely. While the MEOSAR (i.e., medium earth orbiting) satellite system is fairly resilient to blockages (due to the visibility of many MEOSAR satellites at diverse positions to most beacon locations), like the higher altitude GEOSAR system, its detection capability is more dependent on the power of beacon transmissions than the LEOSAR (i.e., low earth orbiting) satellite system.

While due to data distribution rules there is some limitations to the interpretation, it is informative to expand the AOI to include coverage by EC and France MEOLUTs as well as further west of the Hawaii MEOLUT (latitude from -10° to 75°, longitude from -180° to 60° and from 150° to 180°). The behavior, in particular with respect to the relative numbers and the geographical distribution is essentially the same. Specifically, the behavior is very consistent with the above analysis which uses the AOI (i.e., focused on the LGM USMCC service area). Table 4-16 provides parallel statistics and Figure 4-16 shows the result for the LEOSAR/GEOSAR only case.

Table 4-16 - LGM USMCC Phase III O-2 - Located Sites - Expanded AOI - Inclusion of GEOSAR

Sites on Both Systems		LEOSAR/GEOSAR Only Sites	
Total	**Includes GEOSAR Data**	**Total**	**Includes GEOSAR Data**
4623	3,185	563	17

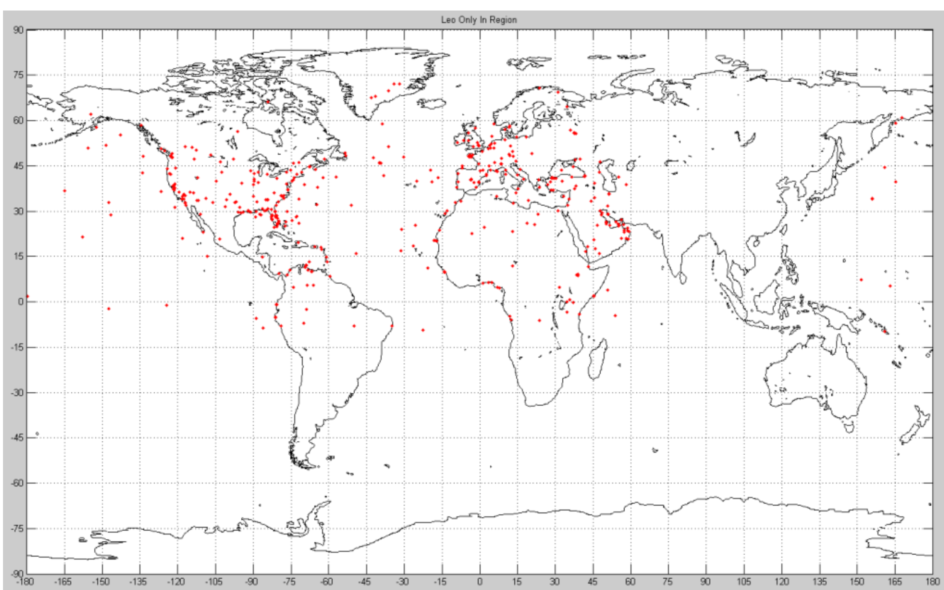


Figure 4-16: Expanded AOI - LEOSAR/GEOSAR Only (563 sites)

As reported above, after the primary data collection period the USA identified an issue that was creating significantly more suspect alerts than should have occurred. As such, after the software was fixed an additional data set was collected between 15 July 2018 00:00 UTC to 15 August 2018 00:00 UTC (4 weeks). Analysis of this data set follows.

The total number of sites opened during this time period was 5,300, and 446 (8.4%) were suspect alerts (previously 38.2% of all the data (7880/20605 were suspect alerts)). Of those 5,300 sites, 2,031 were detect only sites and Table 4-17 and Table 4-18 provide breakdowns including and excluding suspect alerts respectively.

Table 4-17 - LGM USMCC Phase III O-2 (Follow-on) Detect Only Results Including Suspect Alerts

	Sites on Both Systems	MEOSAR-Only Sites	LEOSAR/GEOSAR-Only Sites	Total Sites
Unlocated	435	961	432	1,828
Encoded Position	58	106	39	203
All Detect Only	493	1,0 67	471	2,031

Table 4-18 - LGM USMCC Phase III O-2 (Follow-on) Detect Only Results (No Suspect Alerts)

	Sites on Both Systems	MEOSAR Only Sites	LEOSAR/GEOSAR Only Sites	Total Sites
Unlocated	435	548	432	1,415
Encoded Position	58	73	39	170
All Detect Only	493	621	471	1,585

Of the 5,300 sites, 1,337 were within the AOI (a rectangle from -10° to 60°in latitude and from -180° to -40° in longitude), and Table 4-19 and Table 4-20 provide breakdowns including and excluding suspect alerts respectively. While plots are not provided, it is noted that these categories of sites also demonstrated very little difference in geographical distribution.

Table 4-19 - LGM USMCC Phase III O-2 (Follow-on) Locations in AOI Including Suspect Alerts

Sites on Both Systems	MEOSAR Only Sites	LEOSAR/GEOSAR Only Sites	Total Sites
1,153	112	72	1,337

Table 4-20 - LGM USMCC Phase III O-2 (Follow-on) Locations in AOI (No Suspect Alerts)

Sites on Both Systems	MEOSAR Only Sites	LEOSAR/GEOSAR Only Sites	Total Sites
1,153	97	72	1,322

And finally, per Table 4-21 the same characteristics with regards to GEOSAR data can be observed when including suspect alerts, further supporting the interpretation that many sites that MEOSAR does not detect, may be due to blockages or low power output at the beacon.

Table 4-21 - LGM USMCC Phase III O-2 (Follow-on) Location in AOI – Inclusion of GEOSAR

Sites on Both Systems		LEOSAR/GEOSAR Only Sites	
Total	Includes GEOSAR Data	Total	Includes GEOSAR Data
1,153	1,017	72	5

4.4.2 O-2 Test Result Interpretation and Conclusion

4.4.2.1 France

MEOSAR D&E Phase III testing allowed with test O-2 the comparison of detection of beacon activation by the LEOSAR/GEOSAR and the MEOSAR systems with the limitations of:

- the MEOSAR space segment (not fully deployed),
- the MEOSAR ground segment very partially deployed with most of the MCCs connected to the FMCC having only the LEOSAR/GEOSAR capability (only 3 LGM MCCs with their MEOLUT and the rest of the data provided by LG MCCs).

The current results provide good confidence in the MEOSAR system beacon detection capability, although it points out the need to limit the generation of suspect alerts by the MEOSAR system. This test also highlights the importance of maintaining the LEOSAR/GEOSAR system operational since for one out of eight of the beacon events this was the only system to detect and/or locate the beacon.

4.4.2.2 USA

As with results in previous phases of the MEOSAR D&E, most notably Phase II, the MEOSAR system produces a large number of suspect alerts (uncorroborated single packet MEOSAR alerts). Even with improvements at USA MEOLUTs in this regard, the percentage of 8.4% of all data is still high (although close to the projected value of 5.8% for the improvement).

With respect to other detect only data (not suspect), MEOSAR and GEOSAR/LEOSAR have similar performance with roughly one third of the data recorded uniquely by each system when omitting suspect alerts. Including suspect alerts (per the follow-on analysis) does drive the portion of detect only data up to about 50% of the total. Returning to data without suspect alerts, nearly half of these alert sites had durations of only one minute, and so a missed detection by either system is not surprising. However, many beacons were active much longer and further investigation into the lack of independent locations as well as the missed detections by either system would be beneficial.

The continuous availability and numerous visibility opportunities presented by MEOSAR appear to account for most of the MEOSAR only sites, which represent about 8% to 9% of all the data. A similar but lower portion, about 6% to 7%, of LEOSAR/GEOSAR only sites were found, but these actually turn out to be almost all *LEOSAR only* sites. The two most likely explanations for this behavior are blockages or beacons transmitting at low power (i.e., with a low signal to noise ratio), and the more likely cause is low beacon power. While MEOSAR is fairly resilient to blockages, like GEOSAR, it is sensitive to low beacon power transmissions.

4.5 Test O-3 Volume of MEOSAR Distress Alert Traffic in the Cospas-Sarsat Ground Segment Network

4.5.1 O-3 Test Result

The following test reports were provided by the participants:

Table 4-22 - O-3 Test Reports Provided by Participants

Administration	Test Report Reference
USA	JC-32/8/3

4.5.1.1 USA

The objective of this test is to compare message volume between the LEOSAR/GEOSAR and MEOSAR systems in order to determine the potential increased load due to MEOSAR data. Using the operational LGM USMCC alone for Phase III D&E testing would not normally have provided an opportunity to obtain a result for this testing.

However, the USMCC maintains a backup USMCC that continuously receives USA LUT alert data in parallel. The backup USMCC is an LGM MCC, but US MEOLUT data is not routinely received there due to the load on the supporting communications. Also, incoming data from other MCCs is not sent to the backup USMCC while in standby mode. The lack of foreign LEOSAR/GEOSAR (and MEOSAR) data introduces some discrepancy from what would be seen in a full USMCC. However, the backup USMCC processes essentially only LEOSAR/GEOSAR (LG) data and hence provides a reasonable means for comparison. Table 4-23 provides the counts by alert message type, and Table 4-24 provides the summary results.

**Table 4-23 - LGM USMCC Phase III O-3 –
Counts by Alert Message Type: LG MCC vs. LGM MCC**

	#122	#123	#124	#125	#126	#127							
LG	2820	511	22	4051	1847	10088							
	#122	**#123**	**#124**	**#125**	**#126**	**#127**	**#142**	**#143**	**#144**	**#145**	**#146**	**#147**	**#915**
LGM	1651	144	21	3569	1814	9951	3721	117	16	823	270	442	16497

**Table 4-24 - LGM USMCC Phase III O-3 –
Summary Results: LG MCC vs. LGM MCC**

	#Total	Data Volume	Bandwidth
LG	19339	19803136	0.0204
LGM	39036	56865792	0.0547

The message type counts in Table 4-23 are limited to alert data, and the final column for the LGM MCC provides the count for messages sent to MCCs that are not MEOSAR capable, a SIT 185 message encapsulated in a SIT 915 narrative format. In Table 4-24 the data volume is in bytes, with the SIT 915 messages contributing an average value of 2048 bytes and all other formats contributing 1024 bytes per message. The bandwidth is provided in kilobits per second (kbps).

4.5.2 O-3 Test Result Interpretation and Conclusion

4.5.2.1 USA

In general, the counts for LEOSAR/GEOSAR alert formats (SITs 122 to 127) are lower on the LGM system, but still relatively close. The counts for the MEOSAR alert formats (SITs 142 to 147) are comparatively very low, but this is due to the limited number of operational LGM MCCs (other Nodal

MCCs or those in the Western DDR), and most of the output to these MCCs shows up in the last column under the SIT 915 formats (which contain MEOSAR alert data encapsulated in the SIT 185 format).

Although somewhat higher, the overall volumes and bandwidths are similar to USA results from previous phases of D&E testing. Relative to previous phases, the increased numbers for the LG result are due predominately to the current LGM driven data distribution procedure of sending after position confirmation. An additional increase in the LGM system is caused by the larger message sizes for the SIT 915 formats, which in turn represent the majority of the load caused by MEOSAR alert data.

The key result here lies in the size of the increased load due to MEOSAR data. In previous phases, this factor has been determined to be about 2.5. In this testing the apparent increase is similar, with a value around 2.8 (a little more for volume, a little less for bandwidth), and when most MCCs have LGM capability (and the SIT 915 traffic is eliminated), that will likely return to a factor of about 2.5. And regardless, the bandwidth remains at an extremely low demand for modern communication systems.

4.6 Test O-4 406 MHz Alert Data Distribution Procedures

4.6.1 O-4 Test Result

The following test report was provided by the participant.

Table 4-25 - O-4 Test Results Provided by Participants

Administration	Test report reference
USA	JC-32/8/3

4.6.1.1 USA

The purpose of this test is to evaluate the initial concept of operations for alert data distribution and recommend modifications, as needed, for an operational MEOSAR system. Per section 5.4.5 of document C/S R.018, while the original design for this testing focused on *MEOSAR only* data, the same type of data can still be compiled for LGM MCCs providing a similar analysis of the new data distribution procedures. This has been done here, but modifications were made to the data collection and analysis to better reflect some aspects of the most recently defined data distribution procedures.

More importantly, as was done for O-3 testing, the backup USMCC again provides an opportunity to compare the LGM system to a largely LG only system. Specifically, the backup USMCC is a full LGM MCC, but US MEOLUT data is not routinely received there due to the load on the supporting communications. However, data from other MCCs is also not received, and while the backup USMCC is useful for observing categorical differences between an LG system and an LGM system, comparing the specific numbers is not always as meaningful.

Also, as was noted in the USA reporting for test O-2, during the period for the primary 13-week data collection a very large number of MEOSAR suspect alerts were recorded on the LGM system. As also reported there, this number was vastly reduced after a software update at the MEOLUTs. Similar to the primary analysis for the O-2 test, suspect alert data was entirely removed from this analysis, noting that other than significantly increasing the number of first alerts with no independent location (a single subset of this analysis), the impact is otherwise negligible to these results. Finally, it should also be noted that as this analysis pertains to data distribution, only sites that resulted in the generation of output messages are considered.

Data was collected from both systems, LG and LGM, for the primary data collection period and stored in a spreadsheet. Although similar, there are differences from the spreadsheet defined in document C/S R.018, and as such the columns applied here are defined in Table 4-26. An example extracted of the data collected is provided in Table 4-27. Each incoming alert was counted most often in exactly one of the columns of the spreadsheet.

Table 4-26 - LGM USMCC Phase III O-4 – Column Definitions for O-4 Results

Column Header	Comments
Site#	USMCC active site number/reference
Beacon Id	The 15 Hex beacon identification
Time First Data	The detect time of the first data for the site
Time Last Data	The detect time of the last data for the site
Num Sols	The number of solutions for the site
FA UNL	First Alert, no location
FA ENC	First Alert with location, encoded position only
FA IND	First Alert with location, independent position only
FA IND ENC CFM	First Alert with location, independent/encoded position confirmation (same event)
FA IND ENC DIF	First Alert with independent /encoded Position Conflict (same event)
NC IND IND DIF	position Not Confirmed, independent/independent position conflict
NC IND ENC DIF	position Not Confirmed, independent/encoded position conflict
NC ENC ENC DIF	position Not Confirmed, encoded/encoded position conflict/update
CA IND IND CFM	Confirmation Alert, new independent position to previous independent
CA ENC IND CFM	Confirmation Alert, new independent position to previous/new encoded position
CA IND ENC CFM	Confirmation Alert, new encoded to previous independent position
CT CFM	Continued Transmission alert with a matching updated independent and/or encoded positions, no position conflict
CT IND DIF	Continued Transmission alert for an independent position conflict
CT ENC DIF	Continued Transmission alert for an encoded position conflict
CT ENC UNL UPD	Continued Transmission alert for an unlocated or encoded position update
RD IND	Redundant Data with an independent location
RD UNL ENC	Redundant Data, unlocated or encoded position only

Table 4-27 - LGM USMCC Phase III O-4 – Example Extract from O-4 Results (LGM Data)

Site#	Beacon Id	Time First Data	Time Last Data	Num Sols	FA UNL	FA ENC	FA IND	FA IND ENC CFM	FA IND ENC DIF	NC IND IND DIF	NC IND ENC DIF	NC ENC ENC DIF	CA IND IND CFM	CA ENC IND CFM	CA IND ENC CFM	CT CFM	CT IND DIF	CT ENC DIF	CT ENC UNL UPD	RD IND	RD UNL ENC
91528	9D0D90F17840001	2018/01/15 00:05:40	2018/01/15 00:36:18	121	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	43	18
91529	A78D4024680034D	2018/01/15 00:07:20	2018/01/15 00:42:47	98	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	41	18
91531	3EE6F8D97CFFBFF	2018/01/15 00:12:40	2018/01/15 00:25:56	42	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	6
91533	ADCE014E2440C01	2018/01/15 00:22:20	2018/01/15 00:36:31	38	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	8	16
91535	B389570304334D1	2018/01/15 00:57:55	2018/01/15 03:49:57	82	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	31	35
91536	ADC6499C0599F81	2018/01/15 01:08:17	2018/01/15 01:09:07	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
91537	C0C8A28C34D34D1	2018/01/15 01:41:18	2018/01/15 01:53:57	48	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	21	13
91538	3384D12E40FFBFF	2018/01/15 01:40:56	2018/01/15 04:35:20	31	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	17
91539	D228341D34D34D1	2018/01/15 01:56:13	2018/01/15 06:34:44	62	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	28	21
91540	C6E8D34D29974D1	2018/01/15 00:50:44	2018/01/15 17:16:19	236	0	0	1	0	0	0	0	0	1	0	0	8	1	0	0	31	120
91541	ADCD02047544801	2018/01/15 02:33:34	2018/01/15 05:03:45	424	0	0	1	0	0	0	0	0	1	0	0	12	0	0	0	42	73
91542	C7C9D65028154D1	2018/01/15 02:31:16	2018/01/15 03:32:18	33	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	24	3
91545	2DCC813AE2FFBFF	2018/01/15 02:43:16	2018/01/15 12:21:34	1493	0	0	1	0	0	0	0	0	0	0	1	43	5	0	1	23	336
91547	9D8D41E53400271	2018/01/15 02:57:54	2018/01/15 02:57:54	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91548	2DC7507EACFFBFF	2018/01/15 03:04:54	2018/01/15 03:04:54	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
91549	2224D49554FFBFF	2018/01/15 03:07:48	2018/01/15 07:39:13	537	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	332	184

The basic results are provided in Table 4-28 and Table 4-29, for the LG and LGM systems respectively. In Table 4-28 and Table 4-29 the totals from the data columns (per Table 4-27) are provided on the first row of information, and then the data is grouped into various categories with the applicable total for that category provided in the first column (blue text). The percentages provided on each category row are relative to this total and the pie charts that follow in Figure 4-17, Figure 4-18, Figure 4-19, and Figure 4-20 provide a more informative view of these results which are then further discussed in the interpretations and conclusion section further below.

Table 4-28 - LGM USMCC Phase III O-4 – Results – LG System

LG Results By Categorey	APPLICABLE TOTAL	FA_UNL	FA_ENC	FA_IND	FA_IND_ENC_CFM	FA_IND_ENC_DIF	NC_IND_IND_DIF	NC_IND_ENC_DIF	NC_ENC_ENC_DIF	CA_IND_IND_CF	CA_ENC_IND_CFM	CA_IND_ENC_CFM	CT_CFM	CT_IND_DIF	CT_ENC_DIF	CT_ENC_UNL_UPD	RD_IND	RD_UNL_ENC
Totals From Data Columns	299636	4768	780	2360	520	48	721	513	337	2079	1014	21	11589	1646	166	5112	102298	165664
First Alerts	8476	56.25%	9.20%	27.84%	6.13%	0.57%												
Confirmation Alerts	3114									66.76%	32.56%	0.67%						
Pre-Confirmation Conflicts	1571						45.89%	32.65%	21.45%									
Continued Transmission	18513												62.60%	8.89%	0.90%	27.61%		
Redundant Data	267962																38.18%	61.82%

Table 4-29 - LGM USMCC Phase III O-4 – Results – LGM System

LGM Results By Categorey	APPLICABLE TOTAL	FA_UNL	FA_ENC	FA_IND	FA_IND_ENC_CFM	FA_IND_ENC_DIF	NC_IND_IND_DIF	NC_IND_ENC_DIF	NC_ENC_ENC_DIF	CA_IND_IND_CFM	CA_ENC_IND_CFM	CA_IND_ENC_CFM	CT_CFM	CT_IND_DIF	CT_ENC_DIF	CT_ENC_UNL_UPD	RD_IND	RD_UNL_ENC
Totals From Data Columns	1084865	8137	1153	2829	277	27	2596	519	293	4068	1342	163	33116	7324	434	3568	466000	553019
First Alerts	12423	65.50%	9.28%	22.77%	2.23%	0.22%												
Confirmation Alerts	5573									72.99%	24.08%	2.92%						
Pre-Confirmation Conflicts	3408						76.17%	15.23%	8.60%									
Continued Transmission	44442												74.52%	16.48%	0.98%	8.03%		
Redundant Data	1019019																45.73%	54.27%

The categories are considered in two groups, the first two at the "site level" (First Alerts and Confirmed Alerts) and the other three at the "solution level". Specifically, for the duration of the active site there is only one possible outcome for the type of data that generated the first alert or confirmed the position. The other categories occur multiple times throughout the duration of the site.

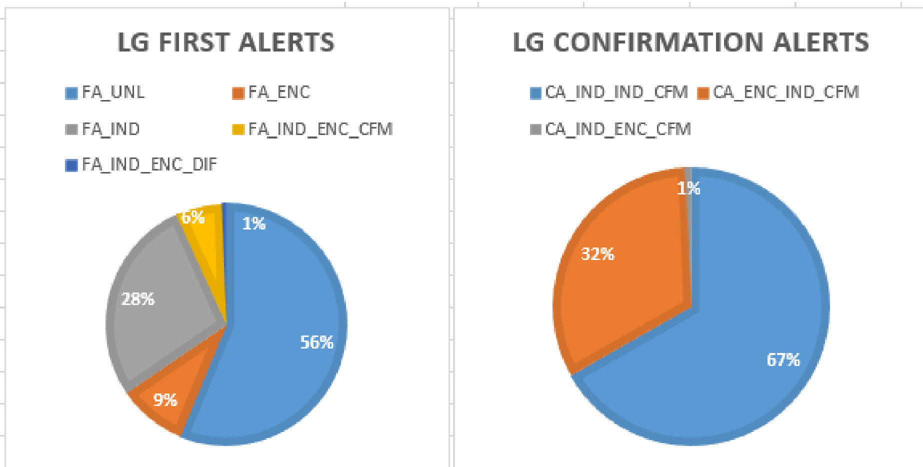


Figure 4-17: LGM USMCC Phase III O-4 – LG Site Level Results

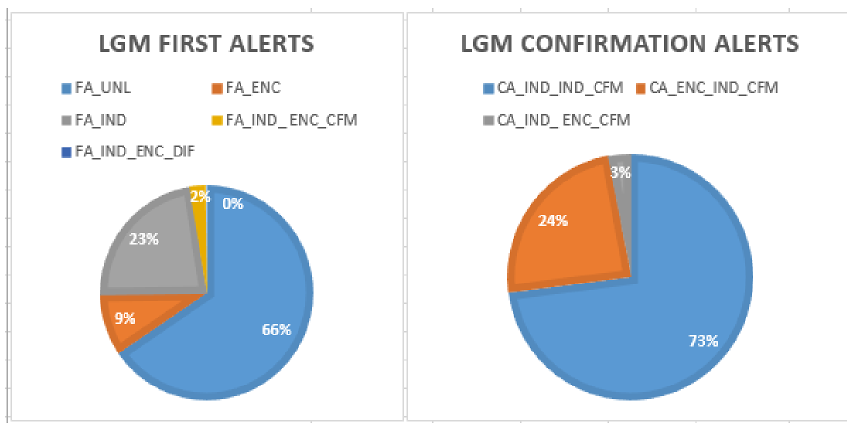


Figure 4-18: LGM USMCC Phase III O-4 – LGM Site Level Results

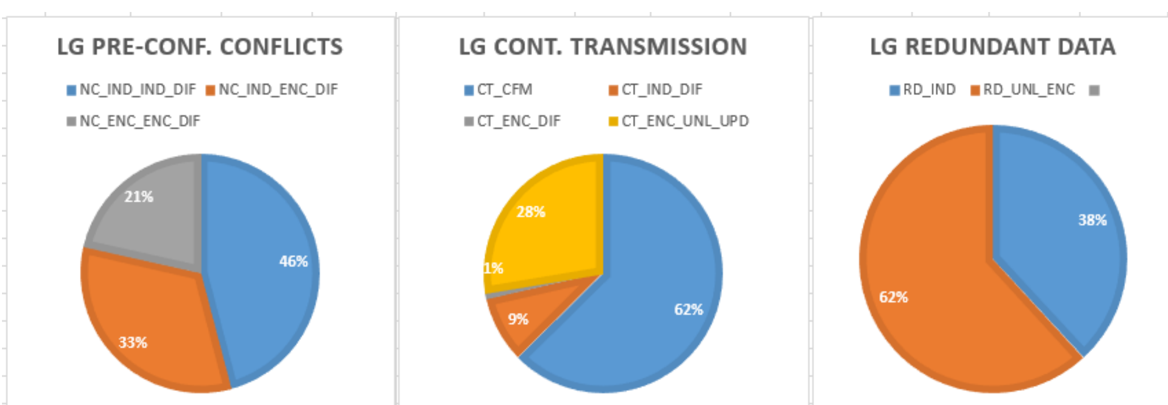


Figure 4-19: LGM USMCC Phase III O-4 – LG Solution Level Results

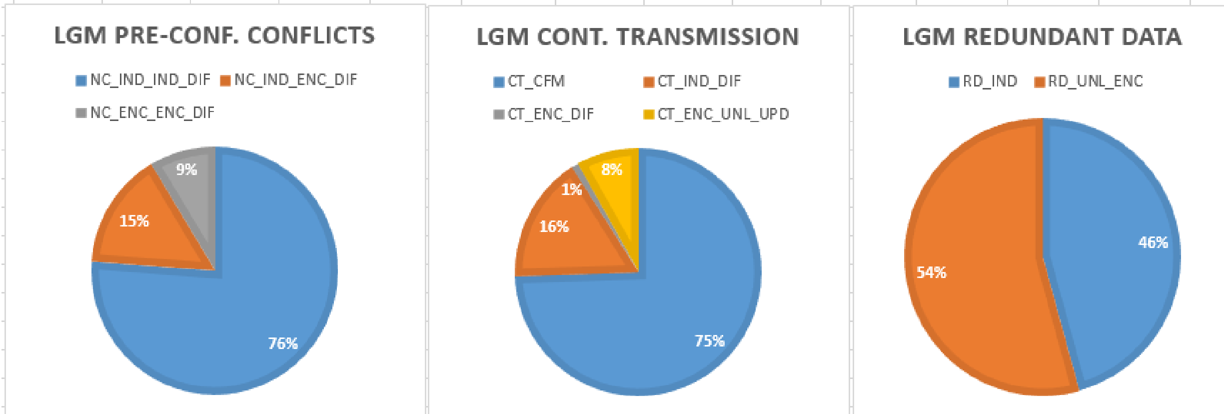


Figure 4-20: LGM USMCC Phase III O-4 – LGM Solution Level Results

4.6.2 O-4 Test Result Interpretation and Conclusion

4.6.2.1 USA

The breakdowns in First Alerts and Confirmation Alerts in Figure 4-17 and Figure 4-18 provide relatively similar results. As the USA observed in O-4 Phase II analysis, MEOSAR data does increase the number of unlocated alerts, first alerts in particular, which would be higher with suspect alerts (albeit now reduced) included. The other noticeable difference shows up in the higher percentage of Confirmation Alerts achieved specifically for the case of a new independent position confirming a previous independent position. This behavior is attributed to the increased data flow and hence the number of opportunities provided by the MEOSAR system.

The increased data flow from MEOSAR shows up much more significantly in the next set of charts, Figure 4-19 and Figure 4-20, most notably in the much higher percentage for pre-confirmation independent/independent position conflicts. A significant factor in the higher percentage is the poorer location accuracy for slow moving beacons for the MEOSAR system vs. the LEOSAR system, an issue that is actively being addressed by C/S participants. The increase in the number of independent alerts, as well as position conflicts, during continued transmission is attributed to the increase in opportunities (note that USA MEOLUTs send new solutions to the MCC on nearly every burst). The breakdown for redundant data is closer, but the same behavior can be observed.

In addition to the breakdown by categories, several overall statistics can be observed. While the number of sites differs due to the lack of both MEOSAR and foreign data in the LG system, the percentage of sites that achieve confirmed positions is similar, 36.7% (3114/8476) for the LG system and 44.9% (5573/12423) for the LGM system, with the increase attributed largely to the presence of MEOSAR data. It is also interesting to note the overall percentage of solutions that result in redundant data, representing 89.4% (267962/299636) for the LG system and 93.9% (1019019/1084865) for the LGM system.

In summary, the methodology used here to compare data distribution for an LG system versus an LGM system indicates that while similar overall, the key difference lies in the continuous opportunities to receive and process MEOSAR data, manifesting in more confirmed alerts, more data after position confirmation, but also more position conflicts. Finally, noting that a key goal of MCC data distribution procedures is to limit the data that goes to SPOCs and RCCs to that which is truly necessary, this analysis soundly demonstrates the success of the current C/S design as indicated by the very large percentages of data that falls into the category of redundant data.

4.7 Test O-5 SAR/Galileo Return Link Service

The following test reports were provided by the participants:

Table 4-30 - O-5 Test Reports Provided by Participants

Administration	Test report reference
France	TG-1/2018/6/1

4.7.1 Context

The Galileo program includes Search and Rescue transponders on board its satellites and a SAR/Galileo ground segment (SGS) to provide SAR service to the Cospas-Sarsat community. The SGS is responsible for ensuring the Cospas-Sarsat Forward Link Service for the SAR/Galileo Coverage (SGC) Area covering European countries.

The SAR/Galileo system also offers the possibility of a specific communication link from the Galileo Ground Segment to a distress beacon called RLS (Return Link Service), provided by the Return Link Service Provider (RLSP). The RLSP acts as the interface between the Cospas-Sarsat Ground Segment and the Galileo infrastructure, as illustrated in Figure 4-21. Bits dedicated to the SAR Service are available on the L1 navigation signal to broadcast Return Link Messages (RLM) to beacons allowing various services complementary to the existing Forward Link Alert Service. These complementary services currently consist of a confirmation of reception of the distress alert (Type-1 message), and other applications, such as a capability to remotely activate a specific beacon, could be implemented in the future (Type-2 message).

The RLM requests, encapsulated in the FLAM (Forward Link Alert Messages), will be received by the MEOLUTs and transmitted to the RLSP through a dissemination mechanism based on current Cospas-Sarsat alert data distribution procedures.

As the operational RLSP was under development in 2017, the D&E Test O-5 was conducted using a pre-operational version of the RLSP.

The French Space Agency (CNES), is responsible, as the SAR/Galileo Data Service Provider (SGDSP), for the coordination of the ground operations related to the SAR/Galileo Service. Moreover, it is also the Test Coordinator for the MEOSAR D&E Test O-5 campaign.

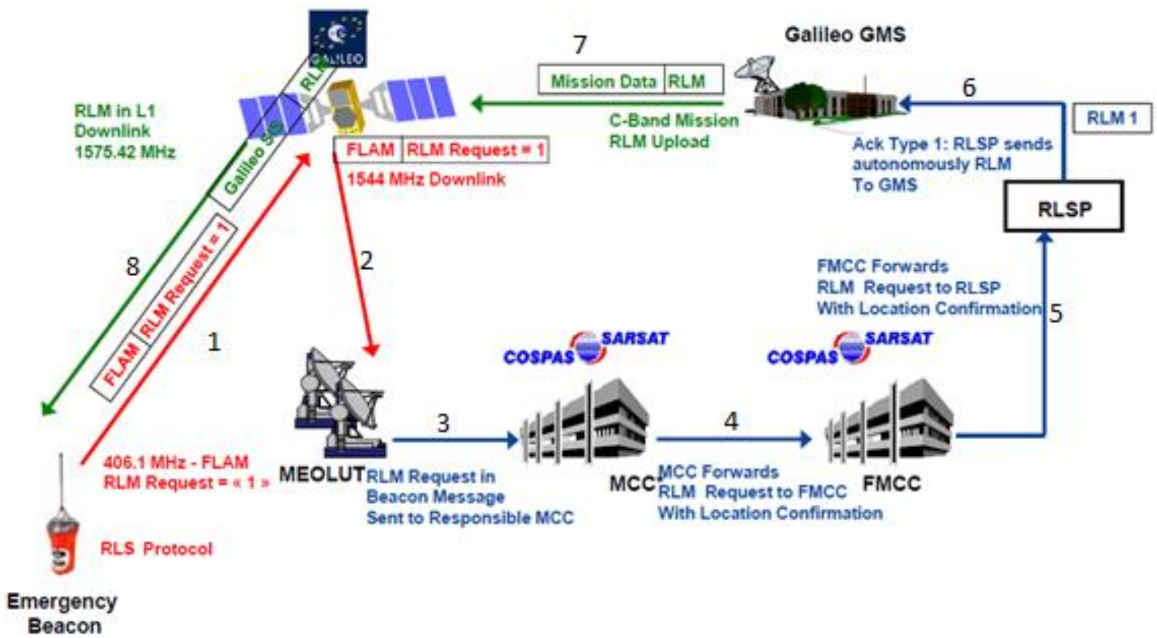


Figure 4-21: Overview of the SAR/GALILEO Return Link Service Architecture

4.7.2 D&E Test O-5 Objectives

The test O-5 campaign aimed to validate the overall readiness of the Return Link Service and to assess the D&E objectives defined in document C/S R.018, section 5.5.1 shown in Table 4-31.

Table 4-31 - Objectives of Test O-5

Objective	Description
RL-1: Validation of Return Link Service Interfaces	Validate the different interfaces for a Return Link Service from the MCC responsible for the service area where the beacon is located and confirm that there is no erroneous definition in the SIT message format between the involved equipment (SIT138, SIT139 and SIT185).
RL-2: RLM Transfer Time Measure	Assess the waiting time between the RLM request transmission by the originating MCC and the reception of the RLM by the beacon. The test will characterize both the latency of the Cospas-Sarsat System to disseminate the RLM request and the overall latency of the RLS in the context of the acknowledgment service.
RL-3: RLM Detection Probability	Determine the probability of detecting the transmission of the RLM from the Galileo system and recovering at the 406 MHz beacon with return link capability a valid RLM within 15 minutes of the RLM transmission request sent by the RLSP to the Galileo system. This is the maximum delay permitted by the SAR/Galileo Return Link User Requirements for first Return Link Message notification.

4.7.3 RLM Request Distribution Procedure Evaluation and Test Scenarios

Figure 4-22 presents the operational interfaces evaluated in the frame of the Test O-5 for the RLM request distribution.

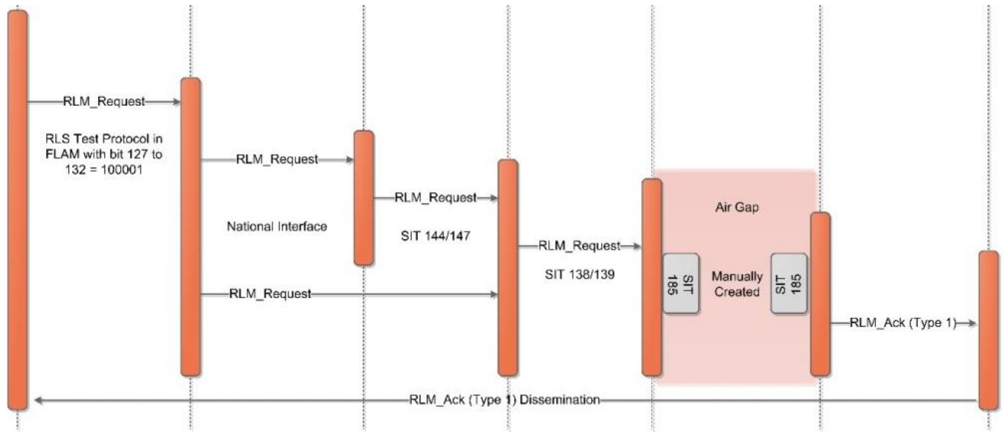


Figure 4-22: RLM Distribution Process Under Test

The test O-5 was run under high-level security constraints due to the fact that the pre-operational RLSP was connected to the Galileo Mission Segment (GMS). As a consequence, a manual "Air Gap" was necessary between the FMCC and the RLSP.

In order to have various representative dissemination paths, four different scenarios were defined (see Table 4-32).

Table 4-32 - Test O-5 Scenarios

Event	Description
Test O-5: Scenario 1	FMCC is responsible for the service area (MCC*) where the alert is located: beacon activation in the FMCC service area.
Test O-5: Scenario 2	One MCC of the Central DDR is responsible for the service area (MCC*) where the alert is located: beacon activation in the NMCC and ITMCC service areas.
Test O-5: Scenario 3	One MCC of another DDR is responsible for the service area (MCC*) where the alert is located: beacon activation in the SPMCC and USMCC service area.
Test O-5: Scenario 4	One MCC of another DDR that is not directly connected to the FMCC is responsible for the service area (MCC*) where the alert is located.

4.7.4 Participants

The following participants were involved in preparation and execution of test O-5:

- MCCs and Centers: ITMCC, FMCC, NMCC, USMCC, SPMCC and ESTEC.

  Note: Due to shipment issues caused by customs policy, the BRMCC never received the RLS beacon to test scenario 4 dissemination path.

- 4 manufacturers in active mode (for beacon prototype testing): Mobit, McMurdo/Orolia, ACR Electronics and a Russian branch of JSC "URSC" - "ISDE".
- 1 manufacturer in passive mode (receive-mode only): Ursa Minor.

4.7.5 RLS Beacon Deployment

Six RLS beacons were shipped to participants in 2016 and 2017. A transmission script has been provided with a procedure for powering the RLS beacon and running the script. When activated, the beacon transmits five different beacon IDs (with an encoded position included in the transmitted messages), chosen to cover the three types of REBs alternatively (ELT, EPIRB, and PLB). The list of the beacon IDs transmitted during the test O-5 is provided in the test report, available in the "Other Documents" section of the TG-1/2018 meeting webpage.

4.7.6 Ground and Space Segment Status

The ground segment configuration applied during test O-5 is available in the test report. It was stable throughout the campaign. The following numbers of satellites were used during the campaign: 16 Galileo (L-band), 20 GPS DASS (S-band) and 1 Glonass (L-band, non-operational).

4.7.7 Methodology and Changes with Respect to Document C/S R.018

In order to gain consistency with the current configuration ("Air Gap", time out, only automatic type 1 acknowledgement assessed, etc.), tests were conducted with changes with regard to document C/S R.018 (as described in document JC-31/Inf.14 (France/EC)).

4.7.8 RLM Requests Distribution Procedure Evaluation

Each test participant collected data to support the evaluation of the RLM request distribution procedures as documented the test plan provided before the tests. The evaluation methodology entails collecting information on SIT content and time. Data post-processing is detailed in the test report.

4.7.9 As-Run Schedule

A first dry-run was organized in July 2017 in order to test the various equipment before the official test O-5 campaign. The as-run schedule is presented in Table 4-33.

Table 4-33 - Test O-5 As-Run Schedule

Date	Event	Entities involved
November 16, 2017	Dry-Run	RLSP, GMS, FMCC
November 22, 2017	Test O-5: Scenario 2	RLSP, GMS, NMCC, ITMCC, Mobit, McMurdo/Orolia
November 29, 2017	Test O-5: Scenario 3 (+ Scenario 1)	RLSP, GMS, SPMCC, USMCC, ACR Electronics, FMCC, ACR Electronics
December 6-7, 2017	Test O-5: Scenario 4 (+ Scenario 1)	RLSP, GMS, ESTEC, JSC "URSC" - "ISDE", NMCC (2nd run), ACR Electronics (2nd run), Mobit (2nd run)

4.7.10 D&E Test O-5 Results

The statistics of this test O-5 are based on results of 83 beacon activations considered significant and nominal. Three scenario configurations were tested out of four, and the test O-5 campaign results are summarized in the following tables.

4.7.10.1 RL-1: Return Link Service Interfaces

Table 4-34 - RLS Interfaces Objectives

Parameter	Expected Results	Comments	Results (OK/NOK)
MCC*-FMCC	RLM_Request (SIT138/SIT139) transmission	After resolving the beacon position (Position Confirmation) either from SIT144/SIT147 reception or own location determination. The RLM request (SIT138/SIT139) will transit through different MCCs on the path from MCC* to FMCC.	Partially OK Scenario 2: For Norway, 2 detections out of 5 beacons were done with LEO/GEO, which triggered 4 SIT135 Scenario 3: For Spain and ACR Electronics, 5 detections out of 8 beacons were done with LEO/GEO, which triggered 5 SIT134/SIT135 Scenario 4: For Mobit, the detection was done with LEO/GEO, which triggered a SIT135
MCC*-RCC	SIT 185 with updated text informing on beacon RLS_Capability_Notification	The MF#62 will include the following text: "WARNING THIS BEACON HAS A RETURN LINK CAPABILITY"	OK All the SITs 185 processed during the Test O-5 entailed the Statement “THIS BEACON HAS GALILEO RETURN LINK CAPABILITY”
FMCC-RLSP	RLM_Request (SIT 185) Transmission	Upon reception of SIT138/SIT139 from MCC* or after resolving the beacon position if FMCC is the MCC responsible for the service area where the distress is located	OK All the SITs 185 were transmitted to the RLSP.
RLSP-GMS VAL_CHAIN	RLM_Acknowledgement Transmission	Upon reception of SIT 185 from the FMCC, the RLSP should generate and send to the GMS the beacon acknowledgment with a list of usable satellite.	Manual action (“Air Gap”): OK

4.7.10.2 RL-2: RLM Transfer Time

Concerning the assessment of objective RL-2, there is no target in terms of expected probability value. <u>Note:</u> The time needed for the “Air Gap” manual handling has been retrieved from the time measurements in order to get the most representative value of the RLS performances.

Table 4-35 - RLM Transfer Time Objectives

Item	Probability	Expected Performance / Requirement	Result: Probability
C/S System Latency	M/N with M the number of beacons for which the RLM_Request is received by the RLSP within 10 and 20 min. after the REB first burst transmission and N, the total number of beacons.	The latency between the confirmation of a RLS capable beacon position into the MCC* and the reception of the RLM request in the RLSP shall be less than 10 min. Assuming that the beacon position confirmation can be achieved within 10 min (MEOSAR requirements), the total C/S System latency to transmit a RLM request to the RLSP will be 20 min.	At 10 min: 82.7% Scenario 2: For Norway, 2 detections out of 5 beacons were done with LEO/GEO, which took longer than a MEO detection Scenario 3: For Spain and ACR Electronics, 5 detections out of 8 beacons were done with LEO/GEO, which took longer than a MEO detection Scenario 4: For Mobit, the detection was done with LEO/GEO, which took longer than a MEO detection
			At 20 min: 85%
Delivery Time by RLSP to Galileo System	M/N with M the number of beacons for which the RLM_Ack is received by the GMS within 5 min after the SIT 185 reception by the RLSP and N, the total number of beacons at the RLSP side.	The RLSP shall deliver a RLM request to the Galileo system within 5 minutes after reception of confirmed distress information from a beacon with RLS capability, provided by the Cospas-Sarsat Ground Segment	At 5 minutes: 97 % Nominally, it takes about 3 seconds for the RLSP to send the RLM request to the GMS. Only when the Galileo network was saturated, this transfer time could reach up to 8 minutes.
Delivery Time by Galileo System to distress beacon	M/N with M the number of beacons for which the RLM_Ack is received within 0 to 5 minutes after RLM first transmission by GMS and N, the total number of RLM_Ack received by GMS.	The Galileo system shall deliver the RLM to the appropriate beacon within 15 minutes of its reception from the RLSP	At 5 minutes: 69.7%
			At 15 minutes: 80.7 %
Total Transfer Time	M/N with M the number of beacons for which the RLM_Ack is received within 15 to 40 minutes after the REB first burst transmission, and N, the total number of beacons.	The RLM acknowledgment shall be delivered to the GMS-OPE_CHAIN within 40 minutes of its transmission by the originated MCC	At 15 minutes: 72.7%
			At 40 minutes: 82.7%

4.7.10.3 RL-3: RLM Detection Probability

Table 4-36 - RLM Detection Probability Objectives

Parameter	Expected Results	Comments	Results (OK/NOK)
RLM Detection Probability	> 99%	The delay established at 15 minutes from the RLM transmission by the RLSP to the Galileo system until the RLM reception at the 406 MHz beacon.	96.3 %: NOK 2 RLMs sent out of the 83 RLS beacons were never received For 1 transmission during Scenario 4 the RLM took 63 minutes to reach the beacon.

4.7.11 Conclusion

The SGDSP, as D&E Test O-5 Coordinator, thanks all MCCs, participants and manufacturers for their active and collaborative participation in this very useful international test campaign.

In spite of many issues encountered, the D&E Test O-5 campaign was partly successful and was an opportunity for validating for the first time the end-to-end RLS system in real conditions.

The three objectives of the D&E Test O-5 were assessed based on statistics made on the basis of 83 beacons' transmissions. Moreover, 3 scenario configurations out of 4 were tested.

This test campaign mainly validated the pre-operational RLSP and Galileo part of the Return Link Service. Nevertheless, the Cospas-Sarsat part of the RLS system is not fully validated. In fact, even if the D&E Test O-5 campaign was delayed compared to its initial schedule (Q3 2014), MCCs are not all ready and several interpretations of the December 2016 specifications have been observed. The Return Link Service and performance specifications are based on the RLS beacon detection/localization by the MEOSAR system, which is supposed to be more rapid than the historical LEO system. During the test campaign, about 10% of the time, RLS alerts were made by LEO and GEO systems.

Several industrial partners took part in the test O-5 campaign in order to test their RLS beacon equipment. It was one of the rare opportunities to make full-scale tests before the decommissioning of pre-operational RLSP used for this campaign. Configuration tuning is still necessary for beacon manufacturers and MCCs before type approval and commercialization of RLS beacons. New tests with the operational RLSP are essential.

4.8 Test O-6 Evaluation of Direct and Indirect Benefits of the MEOSAR System

The following test reports were provided by the participants:

Table 4-37 - O-6 Test Reports Provided by Test Participants

Administration	Test report reference
Australia	See section 4.8.1.1 below
France	JC-32/8/5
New Zealand	JC-32/8/2 and JC-33/8/3

4.8.1 O-6 Test Result

4.8.1.1 Australia

The O-6 test differs from the other D&E tests in that it does not have specific pass/fail criteria, nor is it measuring specific performance. Instead, the test evaluates the direct and indirect benefits to SAR services from the use of MEOSAR data by collecting a set of incidents that illustrate the benefits (and any negative effects) experienced by SAR services.

54 incidents of interest were collected from the Australian and New Zealand JRCCs from June 2017 to July 2018. The incidents are listed in Attachment 1.

Each incident was classified by the beacon data received: L (LEO), M (MEO), LM (LEO/MEO), GM (GEO/MEO) and LGM (LEO/GEO/MEO).

Each incident was also tagged with descriptors to identify the benefits or disadvantages of the incident. The descriptors were:

Advantage – MEOSAR provided an advantage to the JRCC. For example, for incident 1, MEOSAR gave a 49-minute advantage in providing an encoded location in a distress incident.

No advantage – The MEOSAR data provided no advantage. For example, in incident 39, the MEOSAR data had no advantage (although providing an encoded and a MEOSAR Difference Of Arrival (DOA) location) as GEOSAR data received at the same time provided the same encoded location that was used by the JRCC.

Additional work – The MEOSAR data created additional work in the JRCC. For example, in incident 4, the JRCC responded to an inadvertent activation only detected by MEOSAR.

Reduced work – The MEOSAR data reduced the workload in the Australian or New Zealand JRCC. For example, MEOSAR data in incident 12 was used by the Australian JRCC to resolve two Doppler locations so that no SAR action was required by the JRCC.

MEOSAR question – There was a question about the MEOSAR data in this incident. For example, in incident 1, although the beacon was detected by MEOSAR with an encoded location, a confirming DOA location was not generated until 42 minutes later.

Each incident contains a summary Table with data about the incident, a description of the incident, some brief analysis (typically examining the beacon detections from MEOSAR, GEOSAR and LEOSAR), and a short conclusion.

4.8.1.2 Summary

Table 4-38 lists the incidents based on type of detection.

Table 4-38 - Summary of Incidents by Type of Detection

Detections	Number	Incidents
LEO-only	4	6, 15, 33, 50
MEO-only	22	3, 4, 5, 7, 8, 11, 14, 16, 20, 22, 25, 28, 31, 32, 34, 35, 36, 37, 38, 45, 46, 54
LEO-MEO	15	1, 2, 9, 12, 13, 17, 19, 23, 26, 27, 29, 47, 51, 52, 53
GEO-MEO	11	21, 24, 30, 39, 40, 41, 42, 43, 44, 48, 49
LEO-GEO-MEO	2	10, 18

Table 4-39 lists the incidents associated with the descriptors used in the analysis.

Note that incident 2 did not fit any classification but was included as an interesting incident.

Table 4-39 - Summary of Classifications for the Incidents

Descriptor	Number	Incidents
Advantage	27	1, 3, 5, 7, 8, 9, 10, 11, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 34, 35, 37, 41, 44, 45, 49
No advantage	10	30, 39, 40, 42, 43, 47, 48, 51, 52, 53
Additional work	9	4, 14, 27, 31, 32, 36, 38, 46, 53
Reduced work	3	12, 17, 54
MEOSAR question	17	1, 7, 9, 10, 11, 13, 19, 22, 26, 27, 29, 42, 47, 48, 51, 52, 53

4.8.1.3 Analysis

Some general comments can be derived by analysing the incidents collected for test O-6. Note however that the data collected was not comprehensive in that not all incidents were included for analysis; only incidents that demonstrated the benefits or challenges of MEOSAR were collected. See document JC 30/Inf.30, “An Analysis of Data from the Australian MEOSAR MCC”, for an analysis of MEOSAR data over a one-month period.

4.8.1.4 Benefits of MEOSAR Data

It is clear that MEOSAR data is useful to SAR agencies; there was an advantage in 27 incidents and reduced work in 3 incidents.

In some incidents, MEOSAR was the only beacon data used in a successful rescue (e.g., incident 5).

In many incidents, the MEOSAR data provides a significant time advantage over LEOSAR (e.g., incident 23).

The Australian and New Zealand regions did not have good GEOSAR coverage until late 2017 when data from the NZGEO2 tracking Louch-5A was used in the Australian and New Zealand JRCCs. The introduction of Louch-5A resulted in more incidents (e.g., incident 39) involving a beacon with an encoded location detected by both GEOSAR and MEOSAR, resulting in no advantage provided by MEOSAR.

MEOSAR and GEOSAR usually have similar detection times; however if the beacon does not have an encoded location, MEOSAR DOA location data provides a significant benefit to a SAR agency. A GEOSAR detection of an unregistered beacon without an encoded location cannot be processed by a SAR agency, but a MEOSAR detection of the same beacon with a DOA location is a benefit to SAR agencies (e.g., incident 41).

4.8.1.5 Additional Work Due to MEOSAR Data

In some incidents, the MEOSAR data created more work. Typically, this was an incident with an inadvertent activation of a beacon that was detected only by MEOSAR, resulting in a response by the JRCC. If the beacon was registered, the additional work was a phone call (e.g., incident 5). For unregistered beacons or if the emergency contacts could not be reached however, the additional work could involve expense and effort (e.g., incident 14).

Although the Australian and NZ JRCCs have noted the additional work created by MEOSAR, it has been managed at the operational level and has not resulted in staffing or resourcing changes.

4.8.1.6 Reduced Work Due to MEOSAR Data

The MEOSAR data reduced work in some incidents. During incident 17, the NZ JRCC received a Doppler location in NZ, but the Australian JRCC was able to advise that MEOSAR data resolved the incident to the other Doppler location in Australia. The NZ JRCC did not have to process the Doppler location in NZ any further, saving work.

4.8.1.7 Incidents Not Detected by MEOSAR

Some incidents were detected by LEOSAR but not by MEOSAR. Four incidents (6, 15, 33 and 50) were collected.

None of the LEO-only incidents was a real distress situation. Incident 6 was an activation in a warehouse which is consistent with a weaker reflected signal being transmitted and hence, not detected by the GEOSAR and MEOSAR satellites. Incidents 15 and 50 are believed to be in waste facilities where a beacon may activate with a weaker signal due to the antenna not being properly deployed. The reason for the activation of the beacon in incident 33 was not determined.

The issue of incidents not detected by MEOSAR is important for Search and Rescue authorities; for example, document TG-1/2018/Inf.4 (USA) found 7% of incidents in the LGM USMCC service area were not detected by MEOSAR.

4.8.1.8 Questions About MEOSAR Performance

In 17 incidents, there were questions about the performance of MEOSAR. In some of these incidents, MEOSAR still provided an advantage. For example, in incident 19, MEOSAR provided the first detection but there was a 44-minute delay between the detection and first DOA location. In other incidents, the MEOSAR performance affected the JRCC. For example, in incident 53, some of the MEOSAR locations were very inaccurate and almost resulted in the tasking of SAR assets unnecessarily.

Unfortunately, it is difficult to provide a comprehensive answer to the incidents that raise questions about the MEOSAR performance. Usually delay in the generation of a DOA location can be attributed to terrain shielding (see incident 7, for example) but could also be related to satellite geometry or due to tracking DASS S-band satellites with lower detection rates (than Galileo satellites).

4.8.1.9 The Value of Independent Locations

Various incidents demonstrate the value of independent locations.

In incidents 23 and 44, although the beacon had GPS capability, no GPS location was received until the rescue was almost complete. In both incidents it appears the GPS antenna was blocked during the incident.

In incident 1, the encoded location was generated 42 minutes before the first matching DOA location. Similarly, in incident 7 the encoded location was generated 30 minutes before the only DOA location.

In many other incidents, the encoded and DOA location combined to confirm the location within a few minutes (e.g., incidents 5, 8 and 11).

4.8.1.10 Conclusions

The 54 incidents collected (see Annex 3) illustrate the benefits and challenges that MEOSAR data presents to SAR services. The data collected should be incorporated into the MEOSAR D&E Phase III test report.

4.8.1.11 France

The observations provided in this section result mainly from analyses of the distress and rescue cases handled by the French MRCC Gris-Nez between February 2017 and July 2018. During that period MEOSAR alerts were generated by the USMCC Hawaii and Florida MEOLUT, the French MEOLUT and, after September 2017, the Spitsbergen EU/MEOLUT. The most part of this analysis, mainly based on the area of competence of Gris-Nez, concerns maritime distress SAR cases only.

It has to be noted that the Gris-Nez MRCC competence area contains locations that are sometimes less covered by MEOLUTs, and so MEOSAR performance is reduced there at this time. However, additional data and observations come from the FMCC.

4.8.1.12 Benefits of MEOSAR Data

From February 2017 to July 2018, the LEOSAR/GEOSAR/MEOSAR 406 MHz SAR system provided data for 503 distress events handled by Gris-Nez MRCC. Out of the 503 cases for which the 406MHz SAR system provided data, 360 alerts included the MEOSAR system.

Concerning the timing, over the 204 events for which the three types of data LEOSAR/GEOSAR and MEOSAR data were available, the MEOSAR was received earlier than LEOSAR/GEOSAR information in 146 cases and simultaneously to the LEOSAR/GEOSAR information in 15 cases. For the other cases the LEOSAR/GEOSAR alert data was provided before the MEOSAR data.

These statistics are reflected in Table 4-40.

Table 4-40 - Timing Comparison Between MEOSAR System Alerts and LEOSAR/GEOSAR System Alerts (Gris-Nez MRCC 406 MHz SAR Events from Feb.2017 to Jul. 2018)

MEOSAR only data	Only LEOSAR/GEOSAR data	MEOSAR earlier than LEOSAR/GEOSAR	MEOSAR and LEOSAR/GEOSAR simultaneously	MEOSAR later than LEOSAR/GEOSAR
156	143	146	15	43

The average time advantage between the MEOSAR system and the LEOSAR/GEOSAR for the events analyzed is 45 minutes.

As shown in Table 4-41, MEOSAR independent location was provided for 293 SAR events among the ones analyzed. For the other cases, 406 MHz detection alert was provided including MEOSAR and potentially encoded position.

Table 4-41 - Repartition of Alerts Providing Detection Only and Location Alerts from the 406 MHz SAR System (Gris-Nez MRCC 406 MHz SAR Events from February 2017 to July 2018)

Total number of events	MEOSAR independent location	Detection only
360	293	67

The Gris-Nez MRCC 406 MHz SAR event file also contained information on the difference between the position provided by the independent location performed by the 406MHz MEOSAR system and the actual distress position that allowed extracting some further statistics. The average error of the MEOSAR system for beacon position in this analysis is 2.6 NM (see evolution in Table 4-42).

Table 4-42 - Evolution of Percentage of Average Location Error of the 406MHz MEOSAR System for Beacon Position when Available (Gris-Nez MRCC 406 MHz SAR events from February 2017 to July 2018)

February 2017 – July 2018	February 2017 – December 2017	January 2018 – July 2018
2.6 NM	2.8 NM	2.2 NM

In about 50% of the cases, the MEOSAR independent location was less than 0.1 NM apart from the actual distress position. About 58% of the MEOSAR independent location provided were less than 1 NM away from the actual distress position. Six MEOSAR independent location were more than 20 NM away from the actual distress position. These figures are presented in Table 4-43.

Table 4-43 - Percentage of Events per Distance Between MEOSAR Independent Location and actual Distress Position when Available (Gris-Nez MRCC 406 MHz SAR Events from February 2017 to July 2018)

Distance ≤ 0.1 NM	Distance ≤ 1 NM	Distance ≤ 5 NM	Distance ≤ 10 NM	Distance ≤ 20 NM
49.3%	57.7%	81.9%	90.7%	95.2%

Although limited to maritime 406 MHz distress beacon events only, to a certain period of time and to a given Search and rescue region, the outcomes of the statistics provided in this section for the 406 MHz MEOSSAR system are very encouraging. Indeed, they confirm that the MEOSAR system is very efficient in detecting 406 MHz distress beacons. This system is also noticeably faster than the LEOSAR/GEOSAR system and performs a high level of precision for independent location.

The main part of SAR cases includes now MEOSAR data, as seen below.

The last months of data provided by Gris-Nez MRCC show indeed that lots of the files now contain MEOSAR data: July 2018, 23 files with MEOSAR data on 25 Cospas-Sarsat files; June 2018, 21 files with MEOSAR data on 27 Cospas-Sarsat files; May 2018, 23 files with MEOSAR data on 36 Cospas-Sarsat files.

4.8.1.13 Reduced Work Due to MEOSAR Data

In some SAR cases (all service areas data are considered below, Gris-Nez and FMCC data), the MEOSAR data help to significantly reduce search and rescue operation duration, then search costs, and to maximize the chance of saving human lives. The list below, evaluation on a case-by-case basis of interesting incidents, illustrates some SAR cases where MEOSAR was the first or only means of alert. Encoded positions are recorded below, but the value of independent location is highlighted.

- In July 2017, MEOSAR provided the only alert, giving a position 40 minutes before the LEO position (flooding of S/V Nozgwen, UK SRR, 3 POB, 3 people rescued),
- In October 2017, MEOSAR provided the first alert, giving a position 10 minutes before the LEO position, 1 NM of accuracy (sinking of F/V Petite Fanny, French SRR, 2 POB, 2 people rescued),
- In November 2017, MEOSAR position received 20 minutes before LEO position (dismasting of S/V Tokita, French SRR, 1 POB, 1 person rescued), encoded position provided by GEO one minute before MEO independent location,
- In November 2017, MEOSAR provided the only alert, giving a position one hour before the LEO position (evacuation of S/V Roll Over, Spanish SRR, 2 POB, 2 people rescued) – encoded position provided by GEO one minute after MEO,
- In December 2017, MEOSAR provided the only alert, giving a position 56 minutes before LEO position (capsizing of race vessel S/V Actual Ultim engaged in a world tour, Chile SRR, 1 POB, 1 person rescued), encoded position provided by MEO two minutes after independent location,

- In December 2017, MEOSAR provided the first alert, giving a position 35 minutes before the LEO position (evacuation of S/V Sunflower, Portuguese SRR, 2 POB, 2 people rescued), encoded position provided by MEO at the time of the independent location,
- In May 2018, MEOSAR position received 20 minutes before LEO position (evacuation of S/V Island Bird, Mauritius SRR, 4 POB, 4 people rescued) - encoded position provided by GEO at the time of the independent location,
- In July 2018, MEOSAR position received 1 hour before LEO position (sinking of S/V L'Epervier II, French SRR, 1 POB, 1 person rescued),
- In July 2018, MEOSAR position received 23 minutes before LEO position (PLB, France, sickness in mountain, 1 POB, 1 rescued), encoded position provided by MEO at the time of the independent location,
- In July 2018, MEOSAR position received 22 minutes before LEO position (aircraft, France, crash after take-off, 4 POB, 2 rescued, 2 dead), GEO provided the first detection 2 minutes before MEO first independent location.

The number of lives saved during SAR cases in which MEOSAR provided the only alert(s) (FMCC data, all service areas, February 2017 to July 2018) has to be highlighted: 94 SAR cases, 247 lives saved.

4.8.1.14 Disadvantages of MEOSAR Data

Operational Feedback – Additional Work Due to MEOSAR Data

French SPOC Gris-Nez MRCC did not notice a specific increase in the number of false alerts because of better detection or single-burst detection, nor an increase in the number of ceased alerts (beacon only turned on for a short time and then turned off, detected by the MEOSAR system, but not LEOSAR/GEOSAR system).

However, SPOC Gris-Nez noticed a large increase of data in each SAR case including a MEOSAR constellation, and so MRCC workload increased since MEOSAR EOC.

No MEOSAR Independent Location Availability or Incidents Not Detected by MEOSAR

In 67 MEOSAR cases, no DOA was available (Gris-Nez MRCC data, February 2017 to July 2018). This statistic could be due mainly to MEOSAR suspect alerts.

12,296 files, from February 2017 to July 2018, did not contain MEOSAR data, but only LEOSAR/GEOSAR ones (all service areas data).

When MEOSAR data were provided very late or never provided, it was due, most probably, to weak beacon emission (low battery or masking difficulty, e.g., beacon activation inside a house).

For instance, in a July 2017 SAR case, the beacon of S/V Nixwiweg was probably out of the vessel, which had been forfeited in Colombia (the EPIRB was probably in Panama). First detection was a LEOSAR one (at 07:47 UTC), then the first MEOSAR detection occurred at 14:53 UTC (French MEOLUT 2276), and the first MEOSAR position was obtained at 21:47 UTC (US MEOLUT 3385).

The evolution of global coverage of MEOSAR satellites and of the MEOLUTs visibility could be another explanation. It has to be noted that the increase of the number of MEOSAR satellites provides an increase of the MEOSAR detection as time passes.

In some real distress cases, the MEOSAR constellation did not allow to receive distress data. Six real SAR cases were only detected by LEO/GEO and not by MEOSAR (all service areas, February 2017-July 2018). Regarding this statistic, keeping a functional LEOSAR constellation remains crucial. The lack of beacon signal power could indeed become a difficulty in using the MEOSAR constellation, if GEOSAR and especially LEOSAR constellation were not maintained.

During the capsizing of maxi trimaran Banque Populaire IX in April 2018 (Morocco SRR, 3 POB, 3 people rescued), the EPIRB was first activated in the hull of the vessel. MEOSAR could only detect the beacon emission during a 4-hour period, but not give a position (first MEOSAR detection at 00:37 UTC– first Doppler location at 04:44 UTC, then first DOA at 05:49 UTC).

4.8.1.15 Questions About MEOSAR Performance

Search Costs and Reliability in MEOSAR Data

Some SAR cases raised questions about the performance of MEOSAR. At a minimum, quality and quantity of MEOSAR data have to be improved, to increase RCCs and SPOCs confidence in and reliance on the value of 406 MHz Beacons and provide a decrease in search costs. Improvement of MEOSAR regarding moving beacons is indeed necessary, as the location dispersion is very important in these cases.

In May 2018, the sailing vessel Black Baron suffered a flooding in the Mediterranean Sea (see Figure 4-23). Two people were evacuated by helicopter and rescue boat. Even though MEOSAR delivered a position less than one minute after the first detection, 34 minutes before LEO/GEO data, a lot of incoherent data were provided by MEOSAR. Encoded position, DOA and confirmed position were very different. MEOSAR data could jump for instance 10 km from the last position (positions were spread along 30 km in total length). Risks for SAR forces and costs are then increased in such cases. Despite the use of homing by search and rescue units, there is an important challenge to search, in a very extended area, for a moving object whose precise nature is unknown and which could be at a different position (i.e., not where the beacon is sending its signal).

In another SAR case, which took place close to India’s coast in July 2018 on a merchant vessel, the inaccurate MEOSAR location runs along 100 km (see Figure 4-24).

Figure 4-23: Illustration of the MEOSAR Location Dispersion in the S/V Black Baron SAR Case (FMCC) Mediterranean Sea, May 2018

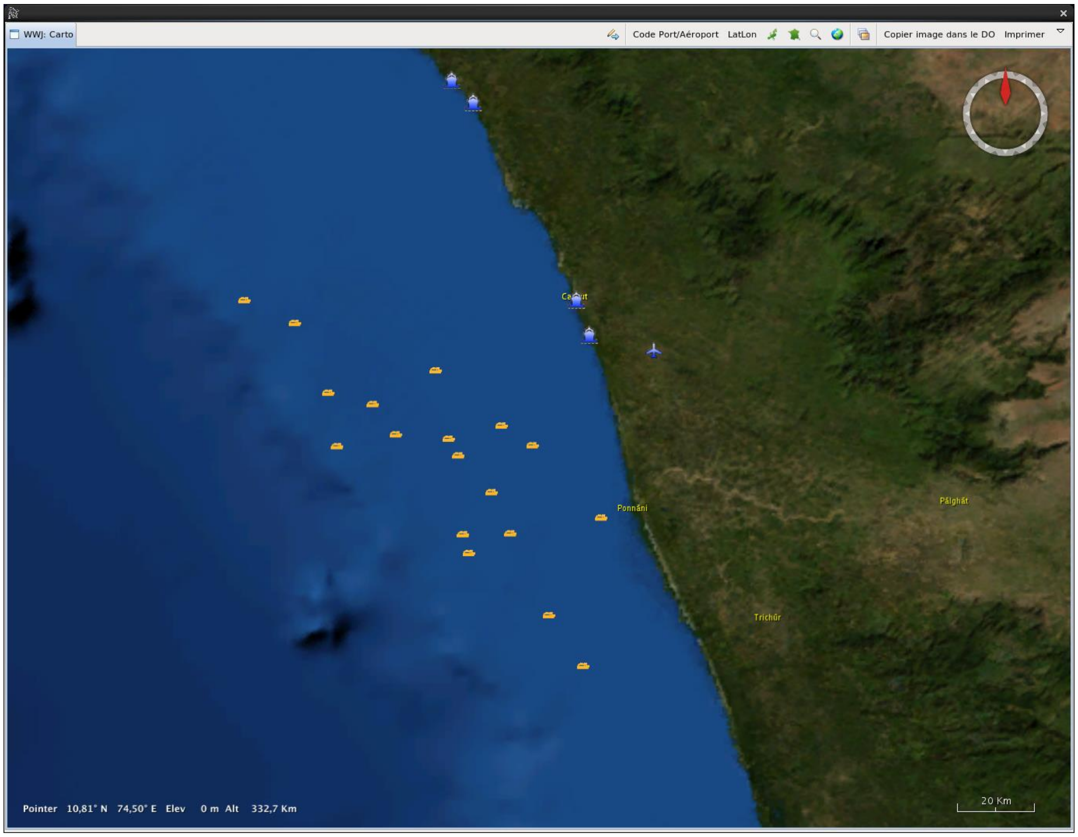


Figure 4-24: Illustration of the MEOSAR Location Dispersion Close to India Coast (FMCC) July 2018

Another issue regarding the high quantity of data is the management of a lot of simultaneous emissions, for example during a natural disaster.

During hurricane Irma for instance, the hurricane that destroyed Saint Martin and Saint Barthelemy Islands on 6 September 2017, 55 beacons' emissions, including 28 US beacons, were recorded in the Antilles between 08:40 UTC and 13:40 UTC (see Figure 4-25):

- Each beacon emission created the sending of several messages to French SPOC Antilles-Guyane MRCC. 264 messages were manually sent by FMCC operators,
- Each emission of a US coded beacon created a request for information toward USMCC, information forwarded to Antilles-Guyane MRCC,
- Each emission was specifically handled, and coordinated with Antilles-Guyane MRCC, to limit transmission of confirmed alerts.

FMCC proposes, as being more efficient in such cases, that the MCC involved ask quickly for stopping continuous transmission after a location confirmation in its service area, to decrease the number of messages overwhelming the RCCs/SPOCs.

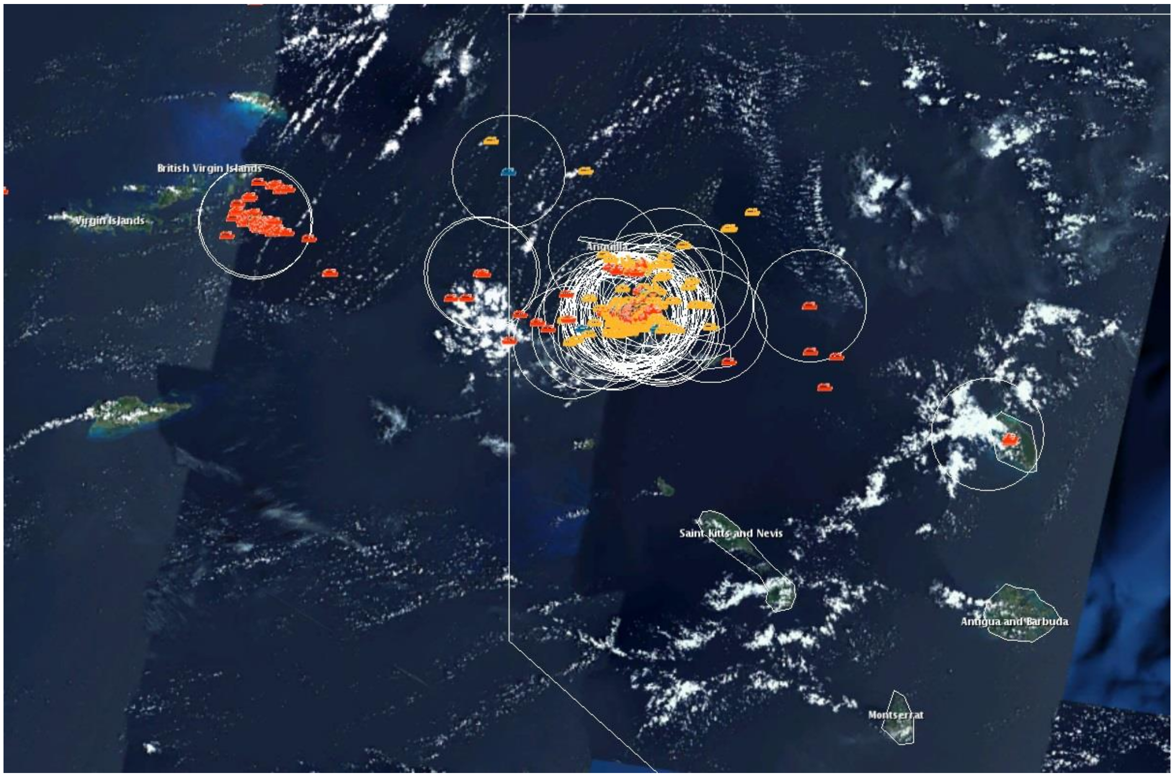


Figure 4-25: Illustration of the 406 MHz Data during Hurricane Irma St. Martin and St. Barthelemy Islands (6 September 2017)

At a minimum, regarding the quantity and quality of MEOSAR data produced, the suspect alerts issue should be considered.

Suspect Alerts Statistics in FMCC Service Area - 2017

***4,100 suspect alerts in 2017**
3,804 from US LUTs 3385 and 3669 (**92.78%**).
7.22% of suspect alerts come from FR and NM LUTs (note that at the end of 2017, an anomaly was detected and corrected on NM LUT).

97 % of suspects alerts with French country codes are manually filtered by FMCC operators. The remaining 3 % are distributed if the alert is confirmed with a registration in the French database.

***1,829 alerts for 2017 in the FMCC service area were French beacons (i.e., 50% of suspect alerts)**.

If these 4,100 alerts have been fully distributed by the FMCC in its service area, approximately 1,800 French suspect alerts would have been distributed in 2017 to the five French SPOCs, i.e., about 360 additional files per center.
For example, **360 Cospas-Sarsat files represent for Gris-Nez MRCC more than one year of C/S alerts (244 C/S alerts handled in 2017 by Gris-Nez MRCC), which highlight the need for filtering such data.**

54 beacons were registered (2.95% registered and 97.05% unregistered).

France understands from the recommendations of the DDP that it is the role of the source MCC to filter suspect alerts. This filtering is done at the French MEOLUT 2276 level, which already complies with MEOLUT IOC specification, especially with the anomaly rate of $<10^{-4}$ (see section 5 .11 of document C/S T.019). This process reduces the message traffic and prevents reception of suspect alerts by other MCCs' operators.

Whenever single-packet alerts are consistent, these alerts are correlated with other data that match with the initial single-packet alert. Therefore, there is no identification as “undetermined alert” and no need for specific processing. Otherwise, almost all of these alerts are suspect and classified as "undetermined alerts".

For France, redefining the distribution process of suspect alerts during MEOSAR IOC appears to be a priority. Indeed, the prerequisite should therefore be the setting of a deadline of compliance with the IOC MEOSAR standards for all the operational MEOLUTs, at least with respect to the anomaly rate of $<10^{-4}$. MEOLUTs complying with the processing anomalies rate for MEOSAR IOC standard requirement will be able to limit the anomalies and thus the majority of the suspect alerts (estimated at a 90% rate), and therefore confine the impact of these alerts on SPOCs and LG MCCs.

The issue of search and rescue units' costs, very important regarding investigation of suspect alerts cases, should not be discounted. For instance, as FMCC distributes to its SPOCs suspect alerts from registered beacons in the French database, RCCs have to investigate, perhaps at sea, if a location is available, and if the investigation by phone/on land of the contact for the registered beacon gives no result.

4.8.1.16 SAR Event

Such a SAR event as presented below confirms that the MEOSAR system is very efficient in detecting 406 MHz distress beacons and also noticeably faster than the LEOSAR/GEOSAR system. Moreover, it performs at a high level of precision for independent location.

On 24 July 2018, French sailing vessel Air Caress sunk after a fire on board in Ponta Delgada SRR, far away from the coast.

The skipper, alone on board, was rescued by two vessels sent by Ponta Delgada MRCC.

MEOSAR was the only means of alert. A first DOA position was given 30 minutes before LEO data, with 0.2 NM precision (an encoded position was provided by GEO at the same time).

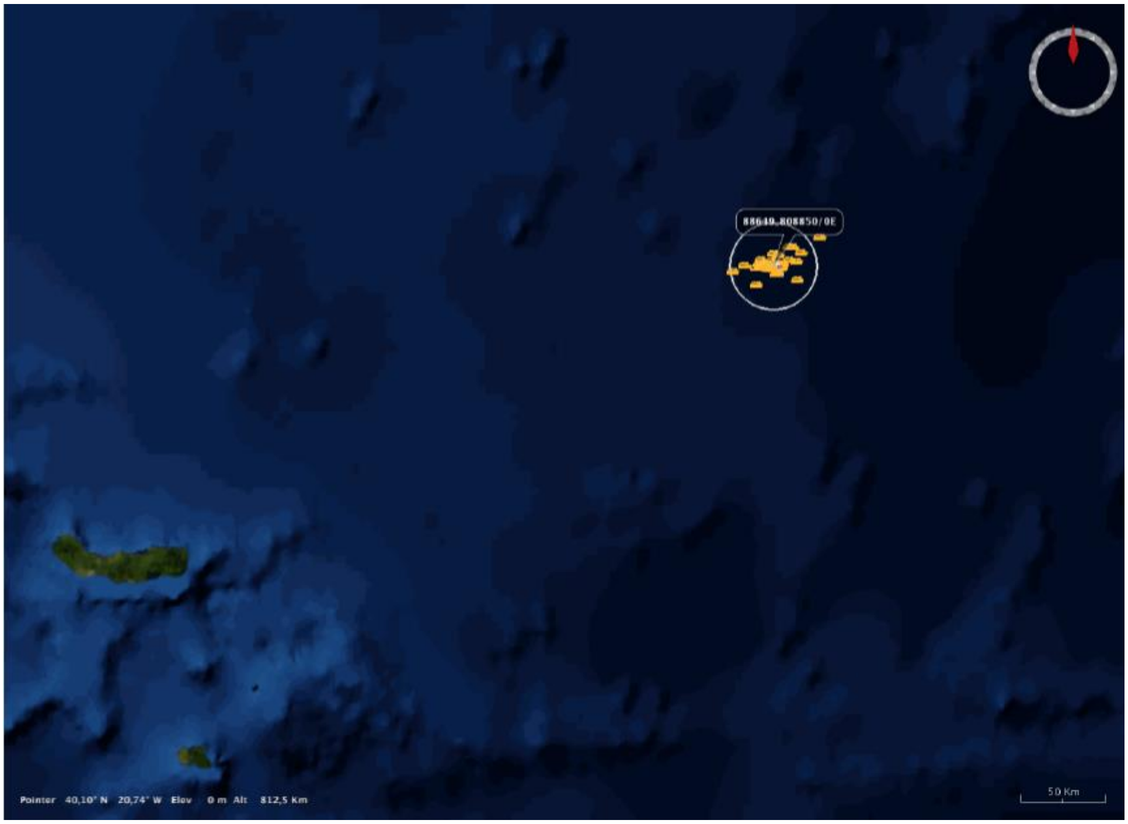


Figure 4-26: Illustration of the MEOSAR Locations in Ponta Delgada SRR (FMCC) July 2018

4.8.2 Test Result Interpretation and Conclusions

Interpretation and conclusions of test O-6 are provided in the sections above.

4.9 Test O-7 MEOSAR Alert Data Distribution – Impact on Independent Location Accuracy

4.9.1 O-7 Test Result

The following test reports were provided by the participants:

Table 4-44 - O-7 Test Reports Provided by Test Participants

Administration	Test report reference
France	See section 4.9.1.1 below
USA	JC-32/8/3

4.9.1.1 France

The purpose of this test is to evaluate the initial concept of operation for alert data distribution and recommend modifications, as needed, for an operational MEOSAR system. The goal is to ensure that the MCC data distribution procedures provide SPOCs and other MCCs with accurate independent DOA location data in a timely manner and to minimize the distribution of redundant data.

The key measure of performance is tied to the accuracy of the MEOSAR location data transmitted by MCCs. Specifically, the objective is to evaluate the accuracy of filtered location data versus the accuracy of distributed location data and to determine if a quality factor can be identified which provides SPOCs and other MCCs with more accurate location data in a timely manner.

The purpose of the O-7 analysis is to characterize the location Quality Factor versus the real horizontal location error in order to determine a proper definition and meaning of this value. This is why the actual positions of the analysed beacons had to be known previously.

This analysis was performed for every beacon which actual position is available.

France had collected specific data whenever MEOSAR data distribution procedures determine that new location data is for the same beacon event as existing data (see document C/S R.018 Annex E sections 3.2.3 and III/B.4). The intent was to capture a “snap-shot” of the location data and processing status when new data for the same beacon event is received and record this information for analysis.

The input data collected included at the minimum the columns shown in Table 4-45 provides notes on various input fields. Each record in the input data set represented a processing case where a redundant independent location was recorded and included the data from the existing (previous) solution with which it was redundant.

Table 4-45 - O-7 Processing Worksheet Input Data

	A	B	C	D	E	F	G	H	I
1	MCC#	DO#	BeaconId	ReceiveTime	NewLat	NewLon	RefLat	RefLon	EHE
2	7856695	74099	9D064AD8C31AA11	13/04/2018 15:07	53.538	9.880	53.548	9.842	5.23
3	7888805	74360	9EA6492D966CBE1	15/04/2018 17:58	39.679	-75.587	39.679	-75.587	58.34
4	7888846	74360	9EA6492D966CBE1	15/04/2018 18:03	39.682	-75.592	39.679	-75.587	44.74
5	7917038	74628	1B488A9312FFBFF	17/04/2018 12:53	50.369	8.716	50.347	8.638	7.99
6	7933382	74826	9E8DD215B54129D	18/04/2018 15:34	51.592	4.500	51.552	4.548	2.95
7	7933449	74826	9E8DD215B54129D	18/04/2018 15:36	51.561	4.598	51.552	4.548	8.52
8	7933462	74826	9E8DD215B54129D	18/04/2018 15:38	51.569	4.583	51.552	4.548	12.9
9	7933450	74826	9E8DD215B54129D	18/04/2018 15:39	51.565	4.608	51.552	4.548	6.05
10	7933425	74826	9E8DD215B54129D	18/04/2018 15:39	51.565	4.532	51.552	4.548	1.74
11	7933441	74826	9E8DD215B54129D	18/04/2018 15:43	51.541	4.575	51.552	4.548	2.8
12	7933471	74826	9E8DD215B54129D	18/04/2018 15:44	51.560	4.539	51.552	4.548	1.38
13	7933525	74826	9E8DD215B54129D	18/04/2018 15:47	51.544	4.566	51.552	4.548	4.31
14	7933485	74826	9E8DD215B54129D	18/04/2018 15:47	51.489	4.535	51.552	4.548	7.56
15	7943148	74934	9C8DCE3D56C01A5	19/04/2018 08:01	47.402	19.166	47.402	19.166	9.14
16	7943110	74934	9C8DCE3D56C01A5	19/04/2018 08:01	47.430	19.221	47.402	19.166	4.78
17	7947820	74984	ADC6498A3019EE1	19/04/2018 14:28	49.913	7.257	49.913	7.257	5.71
18	7959939	75096	1EEE688EF6FFBFF	20/04/2018 10:14	45.751	8.846	45.755	8.911	11.79
19	7959974	75096	1EEE688EF6FFBFF	20/04/2018 10:14	45.755	8.905	45.755	8.911	19.18
20	7959946	75096	1EEE688EF6FFBFF	20/04/2018 10:15	45.744	8.882	45.755	8.911	4.44

Table 4-46 - O-7 Processing Worksheet Acronyms

Field	Comment
MCC#	alert number on the FMCC
EHE	Expected Horizontal Error
DO#	site number
NewLat	the latitude for the redundant solution
NewLon	the longitude for the redundant solution
RefLat	the real latitude of beacon
RefLon	the real longitude of beacon

This test could be performed more than once, but it was recommended that at least some data for this test be collected in the later portion of the D&E period, when more MEOSAR satellites were expected to be available, so that MEOSAR D&E participants will populate the input data worksheet in the provided spreadsheet, and then run the embedded macro named *RunAnaylsisO7*. An example of the results generated by the macro, which include a summary table and a record for each solution record from the input example dataset is shown in Table 4-47.

Table 4-47 - O-7 Processing Worksheet Output Data

Category	Count	Percentage
Success	66	66.0%
Failure	31	31.0%
Total Analyzed	**100**	

MCC#	DO	BeaconId	ReceiveTime	NewLat	NewLon	RefLat	RefLon	Distance	EHE	Success/Failure	Outcome
6524591	60058	996648F0636CA61	15/01/2018 10:45	49.370	13.309	49.411	13.324	4.686	5.44	1	Success
6556179	60415	2DC6A90014FFBFF	17/01/2018 15:05	49.494	-2.667	49.494	-2.667	0.000	23.9	1	Success
6556180	60415	2DC6A90014FFBFF	17/01/2018 15:05	49.424	-2.582	49.494	-2.667	9.916	3.44	0	Failure
6616963	61009	99663C29AE95DD1	21/01/2018 22:19	48.226	14.268	48.274	14.133	11.331	4.26	0	Failure
6678089	61708	9C6810DD35034D1	25/01/2018 09:14	49.639	-1.669	49.639	-1.669	0.000	7.48	1	Success
6678099	61708	9C6810DD35034D1	25/01/2018 09:14	49.632	-1.601	49.639	-1.669	4.959	6.08	1	Success
6678135	61708	9C6810DD35034D1	25/01/2018 09:17	49.657	-1.630	49.639	-1.669	3.448	4.16	1	Success

In the results table, success is identified when distance between real location of beacon and estimated location of redundant data is smaller than Expected Horizontal Error of this alert. This test also provides an opportunity to evaluate the use of expected horizontal error within MCC processing.

France had collected and recorded counts for all MEOSAR events at the French operational FMCC-LGM. For the O-7 analysis, this represents a set of 52 deployed operational beacons.

The O-7 MEOSAR results are summarized in Table 4-48.

Table 4-48 - French MEO-Ready MCC O-7 Results Summary

Category	Count	Percentage
Success	66	66.0%
Failure	34	34.0%
Total Analyzed	**100**	

Over analysed MCC files, it appears that the number of successes is majority (66% as shown in Table 4-48). However, this is showing that the Expected Horizontal Error is enough accurate in two thirds of cases, which is not satisfactory according to section 5.10 of document C/S T.019 (it should be more than 95% of cases). Indeed, if the O-7 objective is to prove the reliability of Expected Horizontal Error, then results do not allow to fulfil completely this objective.

4.9.1.2 USA

Test O-7 considers the distribution of same beacon event data, specifically in the determination of “better quality”. While the intent was once more focused on evaluating potential quality factors for MEOSAR alert data that has been largely overcome by the selection of the Expected Horizontal Error (EHE) as the measure of data quality for MEOSAR. As such, to report on test O-7, the USA has analyzed the performance of the EHE, and to the extent possible, the corresponding ability to actually determine a better-quality location for the same beacon event.

In a separate study on the same topic, data was analyzed for solutions sent to the LGM USMCC by the Hawaii and Florida MEOLUTs for the first six months of 2018. The data set includes three reference beacons, Hawaii (AA5FC0000000001), Florida (ADDC00202020201) and Maryland (ADFFFFFFFFFFFFC) and all transmit at the nominal power of 37 dBm. The beacons are listed with the ground truth applied in the analysis in Table 4-49.

Table 4-49 - LGM USMCC Phase III O-7 – Reference Beacons Used for EHE Analysis

Reference	Beacon 15 Hex ID	Latitude	Longitude
FLBcn	ADDC00202020201	25.61628	-80.38390
HABcn	AA5FC0000000001	21.52075	-157.99640
MDBcn	ADFFFFFFFFFFFFC	39.00139	-76.84139

As indicated by document C/S T.020 (MEOLUT Commissioning Standard), the performance of EHE is measured by a simple comparison of the EHE to the actual error, and is considered successful if the distance from the actual location is less than or equal to the EHE. Per document C/S T.020, the required range of success for EHE performance is between 93% to 97%. Table 4-50 shows an example of the solution data used in the analysis.

Table 4-50 - LGM USMCC Phase III O-7 – EHE Performance Analysis – Example of Data

SolId	SourceId	BcnId15	NumBurst	NumSat	TimeLast	Latitude	Longitude	Distance	EHE	Err<=EHE
22155408	3669	ADFFFFFFFFFFFFC	36	6	2018/05/03 17:21:50	38.99797	-76.8499	0.827133	0.9	Yes
22155433	3385	AA5FC0000000001	1	3	2018/05/03 17:21:40	21.49985	-157.945	5.767969	12.4	Yes
22155435	3385	AA5FC0000000001	2	4	2018/05/03 17:22:30	21.50787	-157.981	2.160748	7.7	Yes
22155437	3669	ADDC00202020201	12	6	2018/05/03 17:22:35	25.61925	-80.3923	0.903721	1.7	Yes
22155438	3669	ADFFFFFFFFFFFFC	37	6	2018/05/03 17:22:40	38.99791	-76.8478	0.672865	0.9	Yes
22155441	3669	ADFFFFFFFFFFFFC	38	6	2018/05/03 17:22:40	38.99741	-76.8469	0.650057	0.9	Yes
22155453	3385	AA5FC0000000001	2	4	2018/05/03 17:22:30	21.50752	-157.979	2.309492	7.5	Yes
22155471	3385	AA5FC0000000001	3	5	2018/05/03 17:23:20	21.52224	-157.997	0.166723	5.6	Yes
22155479	3669	ADDC00202020201	14	6	2018/05/03 17:23:25	25.61899	-80.3918	0.850284	1.5	Yes
22155490	3385	AA5FC0000000001	3	5	2018/05/03 17:23:20	21.52729	-158.008	1.363484	5.3	Yes
22155502	3669	ADDC00202020201	15	6	2018/05/03 17:23:25	25.6198	-80.3939	1.077264	1.5	Yes
22155503	3669	ADDC00202020201	16	6	2018/05/03 17:24:15	25.62035	-80.3963	1.322137	1.4	Yes
22155518	3669	ADDC00202020201	17	6	2018/05/03 17:24:15	25.62047	-80.3974	1.433398	1.3	No
22155678	3385	AA5FC0000000001	10	5	2018/05/03 17:29:10	21.52757	-158.008	1.402889	2.8	Yes
22155679	3669	ADDC00202020201	28	6	2018/05/03 17:28:26	25.6183	-80.3946	1.095112	1	No
22155691	3669	ADDC00202020201	29	6	2018/05/03 17:29:15	25.6185	-80.3946	1.098911	1	No
22155850	3669	ADDC00202020201	36	6	2018/05/03 17:33:25	25.62099	-80.3966	1.372211	0.9	No
22156024	3385	AA5FC0000000001	8	6	2018/05/03 17:38:20	21.52891	-158.014	2.014708	3.6	Yes

The main results are provided below in Table 4-51, where “NC” stands for “number compliant” and “NL” stands for “number of locations”. The 86.5% value for single bursts was consistent with previous analysis, indicating that the USA MEOLUTs were close but still not achieving the requirement. However, the inclusion of all locations, most notably multiple burst locations resulted in the surprising result of only 45.6%.

Table 4-51 - LGM USMCC Phase III O-7 – EHE Performance Results

All Locations

	Florida	Hawaii	FLBcn	HABcn	MDBcn	All Data
NC	182699	45354	100377	45354	82322	**228053**
NL	438152	61941	237430	61941	200722	**500093**
Percentage	41.7%	73.2%	42.3%	73.2%	41.0%	**45.6%**

Single Burst Only

	Florida	Hawaii	FLBcn	HABcn	MDBcn	All Data
NC	20428	7512	11131	7512	9297	**27940**
NL	23999	8295	13025	8295	10974	**32294**
Percentage	85.1%	90.6%	85.5%	90.6%	84.7%	**86.5%**

It can be observed that Hawaii-only statistics match up explicitly with HABcn (Hawaii reference beacon). This is explained by the underlying configuration and software support, in that the error in distance is only recorded for explicitly configured pairings of beacons with MEOLUTs, which when conceived was based on the notion of stand-alone performance, not using networking. Hence, by the current configurations, the Hawaii MEOLUT data is only evaluated against the HABcn, while the Florida MEOLUT data is evaluated against both the FLBcn and MDBcn.

It is also interesting to note that the performance for the Hawaii reference beacon is overall better, in particular perhaps for the multiple-burst locations. More analysis was done to confirm the suspicion that adding more bursts progressively made the EHE less accurate. Table 4-52 shows that this EHE performance does indeed get worse as the number of bursts increases. And, that leads to the likely explanation of why Hawaii multiple-burst results are better. Hawaii resets location processing at 10-minute (13 burst) intervals, and Florida resets location processing at 20-minute (26 bursts) intervals (and for reasons unknown also often produces solutions with as many more bursts). If Florida were to use a 10-minute (13 burst) window, per Table 4-52 the overall EHE performance would improve from 46.5% to 64.3%.

Table 4-52 - LGM USMCC Phase III O-7 – EHE Performance as Burst Count Increases

#Bursts	<= #Bursts	= #Bursts	Average EHE
1		86.5%	11.82
2	83.7%	80.1%	7.16
3	80.1%	73.1%	5.2
4	77.6%	66.4%	4.58
5	75.5%	61.3%	4.01
6	75.0%	59.7%	3.64
7	73.2%	57.4%	3.24
10	68.3%	49.1%	2.37
13	64.3%	38.9%	2.07
26	51.7%	27.3%	0.8

There remains a mystery as to why the single-burst EHE performance for this data set associated with the Hawaii beacon is about 5% better than the Florida beacon, but if the explanation were due to differences in the underlying software, it is possible that the achievable 10 minute window performance could be improved to 73.2% (per the Hawaii "All Locations" result in Table 4-51). Nonetheless, 73.2% is still well below the requirement of 93% to 97% and an action to further investigate and improve this performance for the USA MEOLUTs ensued.

In August 2018, it was reported that significant progress had been made on EHE performance. During periods of re-commissioning for both the Hawaii and Florida MEOLUTs, data was once again collected at the USMCC. These data sets include the new USA reference beacon in California (ADFC000001D0033) and results are provided below in Table 4-53 and Table 4-54 for stand-alone cases (data from both MEOLUTs), and then for Hawaii and Florida networked as Hawaii was receiving networked data from the six commissioned Florida MEOLUT antennas while Florida re-commissioning was taking place. The specific dates for data collection were 26 July 2018 00:00 UTC to 2 August 2018 00:00 for Hawaii as stand-alone, and 15 August 2018 00:00 to 18 August 2018 00:00 for Florida as stand-alone and Hawaii as networked.

Table 4-53 - LGM USMCC Phase III O-7 – Improved EHE – Combined Stand-Alone MEOLUTs

	All Locations	Single Burst Only
NC	20514	2219
NL	22187	2482
Percentage	92.40%	89.40%

Table 4-54 - LGM USMCC Phase III O-7 – Improved EHE – Hawaii MEOLUT Networked

	All Locations	Single Burst Only
NC	11712	1364
NL	12632	1487
Percentage	92.7%	91.7%

Test O-7 results would ideally include an analysis of how well EHE works when applied in the "better quality" algorithm specified for LGM MCCs. However, reference beacons not only limit the range of values and hence opportunities to apply an algorithm, this data is not routinely processed beyond data ingestion at the USMCC. Working with operational data is the answer, but this requires first having validated ground truth, and then a rather formidable effort to look the processing history for each candidate site in detail. Several cases were studied when the EHE logic was first implemented, and one or two cases were recently analyzed using the encoded position for ground truth, and while these case do indicate that the algorithm works, no full blown study has been attempted for this report. At this time the USA can only report the following underlying statistics. Over the primary data collection time period, the MCC algorithm for sending a better quality MEOSAR location (per DDP section 3.2.3.3) resulted in success 2,797 times. 1,620 of those cases had an EHE of 5.0 km or larger.

4.9.2 O-7 Test Interpretation and Conclusion

4.9.2.1 France

The results of the O-7 test, even slightly better in networking mode, depend on the proper use and definition of the Quality Factor, which differs from the one manufacturer to another.

Despite the results obtained during the O-7 test do not show complete compliance with the requirements, since the execution of this test, several improvements have been made on MEOLUT software which now allows to rely on EHE as a viable quality indicator for MEOSAR alert data.

Several MEOLUT commissioning reports have demonstrated these improvements in several occasions and for French MEOLUT the software refinements have been achieved during 2019 and 2020.

4.9.2.2 USA

While the improved USA MEOLUT performance is still just outside the specification, the implication is clear that the requirement is achievable, and that the EHE can be used as a viable quality indicator, for both single-burst and multiple-burst solutions. However, it is very important to note that this data only applies to static beacons. It is well established that current location algorithms for processing MEOSAR data yield poor accuracy when a beacon is slowly moving, and hence at present in these situation EHE values are often smaller than the actual error. However, given improved moving beacon algorithms now being developed, along with potential associated adjustments in the EHE computation, the expectation is EHE will hold as a viable quality factor for MEOSAR alert data.

- END OF SECTION 4 -

5 CONCLUSIONS AND RECOMMENDATIONS

This section provides the conclusions commonly agreed by participants in the MEOSAR D&E tests and their recommendation for the implementation of the MEOSAR system.

5.1 Conclusions

5.1.1 Test T-1 (Processing Threshold and System Margin)

5.1.1.1 General Conclusions

The processing threshold and system margin are "figures of merit" for a MEOLUT. The processing threshold is the value of the minimum beacon transmit power for which the valid/complete message throughput at the MEOLUT is equal to or greater than the expected performance. The system margin is a measure of how far below the nominal beacon transmit power of 5 W (i.e., 37 dBm) a MEOLUT can process beacon signals and produce valid/complete messages with a throughput meeting expected performance. The range of beacon transmit power for which the MEOSAR system can consistently produce valid messages increases with the system margin which characterises the robustness of the system to signal degradation.

The objectives of the tests were to determine the minimum value of the beacon output power for which a single MEOLUT satellite channel and multiple channels are able to produce a valid/complete message for each beacon burst 70% of the time to meet the expected threshold performance. The system margin is the difference between the nominal output power of a beacon and this processing threshold.

The Processing Threshold in a Standalone MEOLUT configuration with four channels was better than 26 dBm and reached down to 22-24 dBm in some cases. System Margin, therefore, was better than 11 dB.

With respect to the single-satellite channel statistics, the System Margin in most cases was better than 6-8 dB, with surging to 12-15 levels for some MEOLUTs.

Overall, in terms of the Processing Threshold and System Margin the MEOSAR system performed adequately in comparison with LEOSAR (although a direct comparison would be inappropriate as the power budgets are different due to orbit heights) and demonstrated its robustness to signal degradation.

5.1.2 Test T-2 (Impact of Interference)

5.1.2.1 General Conclusions

Although no interference monitoring was performed in Phase III, extensive monitoring and analysis of interference in Phase I was done as outlined in the Phase I and II reports and documented in documents EWG-1/2014/2/2 (Canada) and TG-1/2013/Inf.15 (Canada).

It was noted in the analysis that interference was experienced throughout the entire 406 MHz band, with some areas of the Earth having significantly more interference than others. This interference can degrade the detection probability of a beacon burst resulting in some bursts being missed from some satellites. This phenomenon was observed in the MEOLUT data and varied by time and region. However, because of the overlap provided by multiple MEOSAR satellites and multiple MEOLUTs the overall performance of the MEOSAR system meets the expected levels of detection and location probability.

However, in some cases, interferences can overlap with beacon bursts received at a satellite, causing an erroneous alert to be created with an incorrect ID or data content. This can result in an uncorroborated alert. The number and impact of these uncorroborated alerts on MEOSAR system performance should be further investigated, as indicated in section 5.2.

Finally, from Phase II conclusions, due to the unavailability of the Canadian MEOLUT at Shirley's Bay for the majority of the MEOSAR D&E Phase III, there were fewer opportunities for technical test participants to reconcile anomalies and unexpected results with spectrum plots in order to confirm and correlate with interference. However, one instance of interference during test T-3 revealed the impact of MEOSAR D&E technical testing running coincidental with CTEC B.8 testing on the Sarsat LEOSAR SARR-1 instruments.

Conclusions

MEOSAR Ground Segment Operators may wish to consider implementing interference monitoring both to ensure protection of the 406 MHz band and to assist investigations into processing anomalies. Also, CTEC B.8 testing on the Sarsat LEOSAR SARR-1 instruments should be de-conflicted with system testing and MEOSAR QMS implementation and Canada should plan to reduce and eventually phase out B.8 testing.

5.1.3 Test T-3 (MEOLUT Valid/Complete Message Acquisition)

5.1.3.1 General Conclusions

Test T-3 objective was to investigate three main parameters which characterise the production of valid and complete messages by a stand-alone MEOLUT using one or several satellite channels:

a) Valid/Complete Message Detection Probability
This parameter characterises the capability of a MEOLUT to detect valid/complete messages in a given period of time after beacon activation (i.e., after one, two, seven and thirteen burst transmissions) and for beacon output powers of 37 dBm and 33 dBm.

b) Valid/Complete/Confirmed Message Transfer Time
This parameter characterises the time elapsed between the first burst transmitted for each unique beacon ID and the production of valid/complete/confirmed messages by a MEOLUT for beacon output powers of 37 dBm and 33 dBm.

c) Valid/Complete Message Detection Probability within X minutes
This parameter characterises the capability of a MEOLUT to detect valid/complete messages within X minutes after beacon activation and for beacon output powers of 37 dBm and 33 dBm. The MEOLUT throughput is defined as the ratio of the number of valid (or

complete) messages produced by the MEOLUT over the number of bursts emitted during a given period of time.

Referring to MEOSAR minimum performance requirements (Annex E of document C/S R.012), 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 shall be equal or greater than 0.99.

It is noted from the participants results that the probability of detection of at least one valid/complete message at the MEOLUT was nearly 100% after two transmitted bursts (or within two minutes after beacon activation) and was 100% within 10 minutes from beacon activation for both 37 dBm and 33 dBm values of beacon emission power.

Thus, it can be concluded that the requirement above was met with an adequate margin. The transfer time that characterized the obtained performance stayed at 2-3 minutes after beacon activation which is significantly lower than 10 minutes required.

5.1.4 Test T-4 (Independent Location Capability)

5.1.4.1 General Conclusions

Test T-4 objective was to investigate three main parameters which characterise the production of independent location data by Stand-alone MEOLUTs:

a) Independent Location Probability
Characterise the probability that a MEOLUT provides an independent 2D location with a location error less than X km (X = 1, 5 or 10 km), for a given number of transmitted bursts (1 to 7 bursts) and for a beacon transmitting at 33 dBm and 37 dBm.

b) Independent Location Accuracy
Characterise the average value and the standard deviation of the location error of 2D locations provided by a MEOLUT, for a given number of bursts (1 to 7 bursts) and for a beacon transmitting at 33 dBm and 37 dBm.

c) Time to First Independent Location
Characterise the time elapsed between the first burst transmitted for each unique beacon ID and the first 2D independent location provided by a MEOLUT with an error less than X km (X = 1, 5 or 10 km), for a beacon transmitting up to 7 bursts at 33 dBm and 37 dBm.

It was noted from the results that the independent location capability performance in terms of probability to locate a beacon within 10 minutes was closer to expected and stayed at P=1 for all MEOLUTs, thus meeting the C/S R.012 requirement (equal or greater of 0.98).

The independent location capability performance in terms of location accuracy was close to the MEOSAR minimum performance requirements (Annex E of document C/S R.012) but was not met by all MEOLUTs. The degraded performance was mainly caused by scarce space segment (especially in L-band domain) which, in its turn, significantly throttled the satellite selection and, hence, impacted the location accuracy even for static first-generation beacons.

The interpretation of the results also revealed a number of additional factors that, in some cases, could seriously degrade beacon location accuracy:

a) Neglect of beacon elevation - disregarding the beacon position elevation in the localization procedure could result in systematic errors in some cases exceeding the elevation value and noise errors

b) Systematic errors (bias) - bias errors in time and frequency measurements add bias errors to location errors - this could be neglected in most single-burst solutions, but not in the multi-burst solutions where bias errors might be comparable with noise errors and, therefore, have to be accounted for in calculating of Expected Horizontal Error (EHE) values.

It was also reaffirmed that TOA/FOA measurements and their quality are prerequisite for achieving the expected location accuracy even in the conditions of augmented satellite segment. Similar order of accuracy for moving (nearly-static and fast-moving) beacons would require even greater number of measurements and the use specific location algorithms (such as those using beacon velocity estimation, etc.) so the quality of such measurements is paramount to the independent location capability.

Overall, the results reconfirmed that the MEOSAR system is able to provide locations that are accurate enough for effective operational use with first generation beacons.

5.1.5 Test T-5 (Independent 2D Location Capability for Operational Beacons)

5.1.5.1 General Conclusions

The objective of test T-5 was to characterise the 2D independent location performance of the MEOSAR system after each transmitted single-burst, two consecutive transmitted bursts, three consecutive bursts, and so on up to seven consecutive bursts for each operational first generation beacon used in the test, by determining the following parameters:

a) MEOLUT System Throughput and Optional Single-Channel Throughput;

b) n-Burst Independent Location Probability;

c) n-Burst Independent Location Probability with Errors Less Than X km, and

d) n-Burst Independent Location Accuracy.

The MEOLUT system throughput was greater than 90% for all MEOLUTs participating in the test. However, the single-channel throughput and C/N_0 of operational beacons were lower than those observed with beacon simulator, likely due to more realistic conditions that characterise the transmission, resulting in the EIRP value in the direction of the satellite and the C/N_0 obtained at the MEOLUT.

Independent location capability in terms of probability to detect a beacon transmission with a probability of 0.98 within 10 minutes from activation was not achieved for all beacons involved in the test due to partial space segment and/or insufficient number of antennas.

The independent location capability performance in terms of location accuracy (5 km in 95% within 10 minutes from beacon activation) was not achieved by all MEOLUTs and was inferior to T-4 results for static beacons (staying at 10 to 15 km level), likely due to inherent inferior performance of operational beacons as compared to a beacon simulator (e.g., the antenna gain pattern or the rise and fall times of modulating waveform of operational beacons are kept predominantly at the upper boundary of the 150±100 µs allowance range that simplifies the beacon design but impacts the TOA measurement accuracy).

It was noted again that independent location accuracy performance was better for static beacons vice moving and exceeded the requirement with good margin by at least one MEOLUT. Locating slow-moving beacons to the accuracy expected from the MEOSAR was a tall order for all MEOLUTs and could not be completed with limited number of measurements available (due to insufficient number of satellites and number of antennas at the most of the MEOLUTs).

To achieve the independent location performance that MEOSAR inherently possesses (as confirmed by some MEOLUTs) it is recommended to continue increasing the number of TOA/FOA measurements sources (by augmenting the space segment and adding antenna channels to MEOLUT and/or building up network connections between various MEOLUTs), developing more sophisticated tracking schedules at MEOLUTs aimed at expanding the coverage area and work on localization algorithms that take into account the movement of the beacon.

Overall, the T-5 test results confirmed that expected MEOSAR independent location performance is achievable, and the requirements should stay put to encourage Participants to complete their ground segment assets as per recommendations given.

5.1.6 Test T-6 (MEOSAR System Capacity)

5.1.6.1 General conclusions

The objectives of this test were to determine the MEOSAR system capacity which is defined as the maximum number of beacons operating simultaneously that can be successfully processed without degradation of performance.

The system performance parameters used to assess the system capacity were:

a) the probability of detection of a valid/complete message, over a given period of time after beacon activation (after 1, 2, 4 or 7 bursts); and

b) the error for both a single-burst location and for a composite location calculated from the full 7 bursts of each beacon ID.

The results on System capacity using the MEOLUT throughput performance indicated that performance was better that in Phase II (likely due to L-band satellites link budget) and that:

- if compared against the C/S R.012 requirement for detection probability within 10 minutes the threshold of 99% was not crossed even for a traffic load representing 200 operational beacons within 350 seconds. The System Capacity in a detection probability domain was, therefore, more than 200 beacons; and

- if a throughput criteria was assumed the MEOLUT throughput of 70% was not reached for 200 simultaneous beacons.

The results on System capacity using the MEOLUT location performance showed that this parameter continuously decreases with respect to the number of simultaneous beacons, with the EOC single-burst location probability at 75% reached with 75 simultaneous beacons.

5.1.7 Test T-7 (Networked MEOLUT Advantage)

The tests T-4/T-7 and T-5/T-7 were not conducted during the MEOSAR D&E Phase III, however a number of administrations have implemented MEOLUTs operating in a network configuration during MEOSAR EOC Phase and experimental network location processors producing solutions from data collected by several MEOLUTs. A number of benefits of MEOLUT networking over a stand-alone MEOLUT have been observed, as outlined in document CSC-62/OPN/Inf.10 (Can).

In view of the demonstrated performance improvement while implementing MEOLUT networking, it is recommended that participants implement a networking capability to augment their commissioned stand-alone MEOLUT wherever practical, both to address outstanding issues such as slow-moving beacons, processing anomalies and perhaps EHE, or just to contribute to global coverage for MEOSAR FOC declaration.

MEOLUT networking test have been conducted during the MEOSAR D&E Phase II and reported in document C/S R.023.

5.1.8 Test T-8 (Combined MEO/GEO Operation Performance (Optional))

As this optional test had not conducted because of lack of resources, participants are invited to further investigate the possible benefits of combined MEO/GEO operation.

5.1.9 Test O-1 Potential Time Advantage

5.1.9.1 France

MEOSAR D&E Phase III testing allowed the comparison of timing of message receipt between the LEOSAR/GEOSAR and the MEOSAR systems with the limitations of:

- the MEOSAR space segment (not fully deployed),
- the MEOSAR ground segment very partially deployed with most of the MCC connected to the FMCC having only the LEOSAR/GEOSAR capability (only three LGM MCCs with their MEOLUTs and the rest of the data provided by LG MCCs),
- the duration of the measurement campaign.

However, in comparison to the MEOSAR D&E Phase II test campaign, the current results provide higher confidence in the MEOSAR system time advantage compared to the LEOSAR/GEOSAR system.

5.1.9.2 USA

The counts by data type are the best indicator for a clear time advantage for the MEOSAR system over the LEOSAR/GEOSAR system. The values for the gap in minutes demonstrate a similar advantage, also showing that for detect only data the actual median gap is relatively small, but for independent locations the time advantage is significant.

As has been seen before in USA results for both Phases I and II of the MEOSAR D&E, the time data has a wide range (as indicated by the standard deviation) and hence the median, rather than the average, is provided as a clearer measure of relative performance.

As demonstrated in previous phases of the D&E, the MEOSAR system provides a clear time advantage over the LEOSAR/GEOSAR system for the independent locations, and while performance relative to previous phases remains similar for detect only data, Phase III results do demonstrate some time advantage here as well that was not previously as clear.

5.1.9.3 General Conclusions

The MEOSAR system provides a significant time advantage over the LEOSAR/GEOSAR system for the independent locations, and a definite (but less significant) time advantage for “detect only” solutions (i.e., solutions without independent location). A greater time advantage is expected in the future, when more ground and space segment components are operational.

5.1.10 Test O-2 Unique Detections by MEOSAR System as Compared to Existing System

5.1.10.1 France

MEOSAR D&E Phase III testing allowed with test O-2 the comparison of detection of beacon activation by the LEOSAR/GEOSAR and the MEOSAR systems with the limitations of:

- the MEOSAR space segment (not fully deployed),
- the MEOSAR ground segment very partially deployed with most of the MCC connected to the FMCC having only the LEOSAR/GEOSAR capability (only 3 LGM MCC with their MEOLUT and the rest of the data provided by LG MCC).

The current results provide good confidence in the MEOSAR system beacon detection capability, although it points out the need to limit the generation of suspect alerts by the MEOSAR system. This test also highlights the importance of maintaining the LEOSAR/GEOSAR system operational since for one out of eight of the beacon events this was the only system to detect and/or locate the beacon.

5.1.10.2 USA

As with results in previous phases of the MEOSAR D&E, most notably Phase II, the MEOSAR system produces a large number of suspect alerts (uncorroborated single packet MEOSAR alerts). Even with improvements at USA MEOLUTs in this regard, the percentage of 8.4% of all data is still high (although close to the projected value of 5.8% for the improvement).

With respect to other detect only data (not suspect), MEOSAR and GEOSAR/LEOSAR have similar performance with roughly one third of the data recorded uniquely by each system when omitting suspect alerts. Including suspect alerts (per the follow-on analysis) does drive the portion of detect only data up to about 50% of the total. Returning to data without suspect alerts, nearly half of these alert sites had durations of only one minute, and so a missed detection by either system is not surprising.

However, many beacons were active much longer and further investigation into the lack of independent locations as well as the missed detections by either system would be beneficial.

The continuous availability and numerous visibility opportunities presented by MEOSAR appear to account for most of the MEOSAR only sites, which represent about 8% to 9% of all the data. A similar but lower portion, about 6% to 7%, of LEOSAR/GEOSAR only sites were found, but these actually turn out to be almost all LEOSAR only sites. The two most likely explanations for this behavior are blockages or beacons transmitting at low power (i.e., with a low signal to noise ratio), and the more likely cause is low beacon power. While MEOSAR is fairly resilient to blockages, like GEOSAR, it is sensitive to low beacon power transmissions.

5.1.10.3 General Conclusions

MEOSAR suspect (i.e., uncorroborated) alerts are excluded from this analysis, noting that most MEOSAR suspect alerts identified during the test period were due to a US MEOLUT issue in the processing of networked TOA/FOA packet data that was corrected after the test period ended.

The results from France and the USA both show a higher percentage of unique detections by the MEOSAR system (about 28% from France and 8 - 9% from the USA) than the LEOSAR/GEOSAR system (about 12% from France and 6 - 7% from USA). The significantly higher percentage of unique MEOSAR detections by France (28%) vs. the USA (8 - 9%) is largely attributed to an issue with missing GEOSAR detections that affected the FMCC during a portion of the test period. The unique detections by the LEOSAR/GEOSAR system are largely attributed to the fact that the MEOSAR system is more subject to data loss than the LEOSAR system (because of the higher altitude of MEOSAR satellites) when there is a low power beacon transmission.

5.1.11 Test O-3 Volume of MEOSAR Distress Alert Traffic in the Cospas-Sarsat Ground Segment Network

5.1.11.1 USA

In general, the counts for LEOSAR/GEOSAR alert formats (SITs 122 to 127) are lower on the LGM system, but still relatively close. The counts for the MEOSAR alert formats (SITs 142 to 147) are comparatively very low, but this is due to the limited number of operational LGM MCCs (other nodal MCCs or those in the Western DDR), and most of the output to these MCCs shows up in the last column under the SIT 915 formats (which contain MEOSAR alert data encapsulated in the SIT 185 format).

Although somewhat higher, the overall volumes and bandwidths are similar to USA results from previous phases of D&E testing. Relative to previous phases, the increased numbers for the LG result are due predominately to the current LGM driven data distribution procedure of sending after position confirmation. An additional increase in the LGM system is caused by the larger message sizes for the SIT 915 formats, which in turn represent the majority of the load caused by MEOSAR alert data.

The key result here lies in the size of the increased load due to MEOSAR data. In previous phases, this factor has been determined to be about 2.5. In this testing the apparent increase is similar, with a value around 2.8 (a little more for volume, a little less for bandwidth), and when most MCCs have LGM capability (and the SIT 915 traffic is eliminated), that will likely return to a factor of about 2.5. And regardless, the bandwidth remains at an extremely low demand for modern communication systems.

5.1.11.2 General Conclusions

The volume of MEOSAR alerts exchanged (between MCCs) was about 2.8 times the volume of LEOSAR/GEOSAR alerts, meaning that the LEOSAR/GEOSAR/MEOSAR system generates about 3.8 times as many alerts as the LEOSAR/GEOSAR system. The capacity of the MCC communication network is more than sufficient to handle to the volume of LEOSAR/GEOSAR/MEOSAR alerts, with an estimated current use of less than 1% of the available communications network bandwidth.

5.1.12 Test O-4 406 MHz Alert Data Distribution Procedures

5.1.12.1 USA

The breakdowns in First Alerts and Confirmation Alerts in Figure 4-17 and Figure 4-18 provide relatively similar results. As the USA observed in the O-4 Phase II analysis, MEOSAR data does increase the number of unlocated alerts, first alerts in particular, which would be higher with suspect alerts (albeit now reduced) included. The other noticeable difference shows up in the higher percentage of Confirmation Alerts achieved specifically for the case of a new independent position confirming a previous independent position. This behavior is attributed to the increased data flow and hence the number of opportunities provided by the MEOSAR system.

The increased data flow from MEOSAR shows up much more significantly in Figure 4-19 and Figure 4-20, most notably in the much higher percentage for pre-confirmation independent/independent position conflicts. A significant factor in the higher percentage is the poorer location accuracy for slow moving beacons for the MEOSAR system vs. the LEOSAR system, an issue that is actively being addressed by C/S participants. The increase in the number of independent alerts, as well as position conflicts, during continued transmission is attributed to the increase in opportunities (note that USA MEOLUTs send new solutions to the MCC on nearly every burst). The breakdown for redundant data is closer, but the same behavior can be observed.

In addition to the breakdown by categories, several overall statistics can be observed. While the number of sites differs due to the lack of both MEOSAR and foreign data in the LG system, the percentage of sites that achieve confirmed positions is similar, 36.7% (3114 / 8476) for the LG system and 44.9% (5573/12423) for the LGM system, with the increase attributed largely to the presence of MEOSAR data. It is also interesting to note the overall percentage of solutions that result in redundant data, representing 89.4% (267962/299636) for the LG system and 93.9% (1019019/1084865) for the LGM system

In summary, the methodology used here to compare data distribution for an LG system versus an LGM system indicates that while similar overall, the key difference lies in the continuous opportunities to receive and process MEOSAR data, manifesting in more confirmed alerts, more data after position confirmation, but also more position conflicts. Finally, noting that a key goal of MCC data distribution procedures is to limit the data that goes to SPOCs and RCCs to that which is truly necessary, this analysis soundly demonstrates the success of the current Cospas-Sarsat design as indicated by the very large percentages of data that falls into the category of redundant data.

5.1.13 Test O-5 SAR/Galileo Return Link Service

The SGDSP, as D&E Test O-5 Coordinator, thanks all MCCs, participants and manufacturers for their active and collaborative participation in this very useful international test campaign.

In spite of many issues encountered, the D&E test O-5 campaign was partly successful and was an opportunity for validating for the first time the end-to-end RLS system in real conditions. The three objectives of the D&E test O-5 were assessed based on statistics made on the basis of 83 beacon transmissions. Moreover, three scenario configurations out of four were tested.

This test campaign mainly validated the pre-operational RLSP and Galileo part of the Return Link test O-5 campaign was delayed compared to its initial schedule (Q3 2014), MCCs are not all ready and several interpretations of the December 2016 specifications have been observed. The Return Link Service and performance specifications are based on the RLS beacon detection/localization by the MEOSAR system, which is supposed to be more rapid than the historical LEOSAR system. During the test campaign, about 10% of the time, RLS alerts were made by LEOSAR and GEOSAR systems.

Several industrial partners took part in the test O-5 campaign in order to test their RLS beacon equipment. It was one of the rare opportunities to make full-scale tests before the decommissioning of pre-operational RLSP used for this campaign. Configuration tuning is still necessary for beacon manufacturers and MCCs before type approval and commercialization of RLS beacons. New tests with the operational RLSP are essential.

5.1.14 Test O-6 Evaluation of Direct and Indirect Benefits of the MEOSAR System

5.1.14.1 Australia

Some general comments can be derived by analysing the incidents collected for test O-6. However, the data collected was not comprehensive in that not all incidents were included for analysis; only incidents that demonstrated the benefits or challenges of MEOSAR were collected. See document JC-30/Inf.30 (Australia), "An Analysis of Data from the Australian MEOSAR MCC", for an analysis of MEOSAR data over a one-month period.

It is clear that MEOSAR data is useful to SAR agencies; there was an advantage in 27 incidents and reduced work in 3 incidents. In some incidents, MEOSAR was the only beacon data used in a successful rescue (e.g., incident 5). In many incidents, the MEOSAR data provides a significant time advantage over LEOSAR (e.g., incident 23).

The Australian and New Zealand regions did not have good GEOSAR coverage until late 2017 when data from the NZGEO2 tracking Louch-5A was used in the Australian and New Zealand JRCCs. The introduction of Louch-5A resulted in more incidents (e.g., incident 39) involving a beacon with an encoded location detected by both GEOSAR and MEOSAR, resulting in no advantage provided by MEOSAR.

MEOSAR and GEOSAR usually have similar detection times; however, if the beacon does not have an encoded location, MEOSAR DOA location data provides a significant benefit to a SAR agency. A GEOSAR detection of an unregistered beacon without an encoded location cannot be processed by a

SAR agency, but a MEOSAR detection of the same beacon with a DOA location is a benefit to SAR agencies (e.g., incident 41).

In some incidents, the MEOSAR data created more work. Typically, this was an incident with an inadvertent activation of a beacon that was detected only by MEOSAR, resulting in a response by the JRCC. If the beacon was registered, the additional work was a phone call (e.g., incident 5). For unregistered beacons or if the emergency contacts could not be reached however, the additional work could involve expense and effort (e.g., incident 14).

Although the Australian and NZ JRCCs have noted the additional work created by MEOSAR, it has been managed at the operational level and has not resulted in staffing or resourcing changes.

The MEOSAR data reduced work in some incidents. During incident 17, the NZ JRCC received a Doppler location in NZ, but the Australian JRCC was able to advise that MEOSAR data resolved the incident to the other Doppler location in Australia. The NZ JRCC did not have to process the Doppler location in NZ any further, saving work.

Some incidents were detected by LEOSAR but not by MEOSAR. Four incidents (6, 15, 33 and 50) were collected.

None of the LEO-only incidents was a real distress situation. Incident 6 was an activation in a warehouse which is consistent with a weaker reflected signal being transmitted and hence, not detected by the GEOSAR and MEOSAR satellites. Incidents 15 and 50 are believed to be in waste facilities where a beacon may activate with a weaker signal due to the antenna not being properly deployed. The reason for the activation of the beacon in incident 33 was not determined.

The issue of incidents not detected by MEOSAR is important for Search and Rescue authorities; for example, document TG-1/2018/Inf.4 (USA) found 7% of incidents in the LGM USMCC service area were not detected by MEOSAR.

In 17 incidents, there were questions about the performance of MEOSAR. In some of these incidents, MEOSAR still provided an advantage. For example, in incident 19, MEOSAR provided the first detection but there was a 44-minute delay between the detection and first DOA location. In other incidents, the MEOSAR performance affected the JRCC. For example, in incident 53, some of the MEOSAR locations were very inaccurate and almost resulted in the tasking of SAR assets unnecessarily.

Unfortunately, it is difficult to provide a comprehensive answer to the incidents that raise questions about the MEOSAR performance. Usually delay in the generation of a DOA location can be attributed to terrain shielding (see incident 7, for example) but could also be related to satellite geometry or due to tracking DASS S-band satellites with lower detection rates (than Galileo satellites).

Various incidents demonstrate the value of independent locations.

In incidents 23 and 44, although the beacon had GPS capability, no GPS location was received until the rescue was almost complete. In both incidents it appears the GPS antenna was blocked during the incident.

In incident 1, the encoded location was generated 42 minutes before the first matching DOA location. Similarly, in incident 7 the encoded location was generated 30 minutes before the only DOA location. In many other incidents, the encoded and DOA location combined to confirm the location within a few minutes (e.g., incidents 5, 8 and 11).

The 54 incidents collected illustrate the benefits and challenges that MEOSAR data presents to SAR services. The data collected should be incorporated into the MEOSAR D&E Phase III test report.

5.1.14.2 France

Advantages

- The average time advantage between the MEOSAR system and the LEOSAR/GEOSAR for the events analyzed is 45 minutes.
- The average error of the MEOSAR system for beacon position in this analysis is 2.6 NM.
- In about 50% of the cases, the MEOSAR independent location was less than 0.1 NM apart from the actual distress position. About 58% of the MEOSAR independent location provided were less than 1 NM away from the actual distress position. Six MEOSAR independent location were more than 20 NM away from the actual distress position.
- In some SAR cases (all service areas data are considered below, Gris-Nez and FMCC data), the MEOSAR data help to significantly reduce search and rescue operation duration, then search costs, and to maximize the chance of saving human lives.

Disadvantages

- French SPOC Gris-Nez MRCC did not notice a specific increase in the number of false alerts because of better detection or single-burst detection, nor an increase in the number of ceased alerts (beacon only turned on for a short time and then turned off, detected by the MEOSAR system, but not LEOSAR/GEOSAR system). However, SPOC Gris-Nez noticed a large increase of data in each SAR case including a MEOSAR constellation, and so MRCC workload increased since MEOSAR EOC.
- In 67 MEOSAR cases, no DOA was available (Gris-Nez MRCC data, February 2017 to July 2018). This statistic could be due mainly to MEOSAR suspect alerts.
- 12,296 files, from February 2017 to July 2018, did not contain MEOSAR data, but only LEOSAR/GEOSAR ones (all service areas data).

When MEOSAR data were provided very late or never provided, it was due, most probably, to weak beacon emission (low battery or masking difficulty, e.g., beacon activation inside a house).

In some real distress cases, the MEOSAR constellation did not allow to receive distress data.

The lack of beacon signal power could indeed become a difficulty in using the MEOSAR constellation, if GEOSAR and especially LEOSAR constellation were not maintained.

Search Costs and Reliability in MEOSAR Data

Some SAR cases raised questions about the performance of MEOSAR.

At a minimum, quality and quantity of MEOSAR data have to be improved, to increase RCCs and SPOCs confidence in and reliance on the value of 406 MHz Beacons and provide a decrease in search costs.

Improvement of MEOSAR regarding moving beacons is indeed necessary, as the location dispersion is very important in these cases.

Another issue regarding the high quantity of data is the management of a lot of simultaneous emissions, for example during a natural disaster.

At a minimum, regarding the quantity and quality of MEOSAR data produced, the suspect alerts issue should be considered.

MEOSAR system is very efficient in detecting 406 MHz distress beacons and also noticeably faster than the LEOSAR/GEOSAR system. Moreover, it performs at a high level of precision for independent location.

5.1.14.3 Test O-6 – General Conclusion

Reference documents:

- JC-32/8/5 (France), "Test O-6 Results – Evaluation of Direct and Indirect Benefits of MEOSAR System – D&E Phase III",
- JC-33/8/2 (France), "Amendment to Annex 26A of the JC-32 Report - MEOSAR D&E Phase III Operational Tests",
- JC-32/8/2 (Australia), "MEOSAR D&E Phase III Results for Test O-6",
- JC-33/8/3 (Australia), "Revised MEOSAR D&E Phase III Results for Test O-6".

Benefits of MEOSAR Data

MEOSAR data was useful to SAR agencies. In some incidents, MEOSAR was the only beacon data used in a successful rescue. In many incidents, the MEOSAR data provided a significant time advantage over LEOSAR, both in the initial detection of a beacon and the initial location determination.

MEOSAR and GEOSAR often have similar detection times; however if the beacon does not have an encoded location, MEOSAR DOA location data provides a significant benefit to a SAR agency. A GEOSAR detection of an unregistered beacon without an encoded location cannot be processed by a SAR agency, but a MEOSAR detection of the same beacon with a DOA location is a benefit to SAR agencies.

Additional Work Due to MEOSAR Data

In some incidents, the MEOSAR data created more work. Typically, this was an incident with an inadvertent activation of a beacon that was detected only by MEOSAR, resulting in a response by the JRCC. If the beacon was registered, the additional work was minimal. For unregistered beacons or if the emergency contacts could not be reached however, the additional work could involve expense and effort.

Additional work was also noted due to the increase in beacon alerts produced by MEOSAR for an incident.

Reduced Work Due to MEOSAR Data

The MEOSAR data reduced work in some incidents. In some incidents, MEOSAR data was able to confirm the location, removing the ambiguity of unconfirmed LEOSAR Doppler locations.

Incidents Not Detected by MEOSAR

Some incidents were detected by LEOSAR but not by MEOSAR; one study found 7% of beacons were only detected by LEOSAR (see document TG-1/2018/Inf.4).

In many cases, the LEOSAR-only detections were due to inadvertent activations with a weak beacon emission (for example, where the beacon antenna was not properly deployed, or the beacon activated in a building or inside a hull).

However, some real distress incidents were only detected by MEOSAR. It is expected that the evolution of global coverage of MEOSAR satellites and MEOLUTs will reduce the number of LEOSAR-only distress detections.
Given the possibility of LEOSAR-only detections, keeping a functional LEOSAR constellation remains crucial.

MEOSAR Performance

Analysis of incidents indicated that there are remaining questions concerning the performance of MEOSAR.

The accuracy of MEOSAR locations in some incidents did not appear to meet the expected performance of MEOSAR IOC, particularly in incidents with slow-moving beacons.

Delays in the generation of MEOSAR locations was noted in some incidents. Unfortunately, it is difficult to provide a comprehensive answer to these incidents. Usually delay in the generation of a DOA location can be attributed to terrain shielding but could also be related to satellite geometry.

The quantity of data produced by MEOSAR was noted to affect the workload of SAR agencies, particularly in situations (such as a hurricane) where many beacons may be active at the same time.

Uncorroborated alerts increase the workload of SAR agencies and redefining the distribution process of uncorroborated alerts during MEOSAR IOC appears to be a priority.

The Value of Independent MEOSAR Locations

Some incidents demonstrated the value of independent locations.

In some incidents, although the beacon had GNSS capability, no GNSS location was received until the rescue was almost complete. In some of those incidents it appeared the GNSS antenna was blocked during the incident.

5.1.15 Test O-7 MEOSAR Alert Data Distribution – Impact on Independent Location Accuracy

5.1.15.1 France

The results of the O-7 test, even slightly better in networking mode, depend on the proper use and definition of the Quality Factor, which differs from the one manufacturer to another.

Despite the results obtained during the O-7 test do not show complete compliance with the requirements, since the execution of this test, several improvements have been made on MEOLUT software which now allows to rely on EHE as a viable quality indicator for MEOSAR alert data.

Several MEOLUT commissioning reports have demonstrated these improvements in several occasions and for French MEOLUT the software refinements have been achieved during 2019 and 2020.

5.1.15.2 USA

While the improved USA MEOLUT performance was still just outside the specification, the implication was clear that the requirement was achievable, and that the EHE could be used as a viable quality indicator, for both single-burst and multiple-burst solutions. However, it is very important to note that this data only applied to static beacons. It was well established that current location algorithms for processing MEOSAR data yielded poor accuracy when a beacon was slowly moving, and hence at present in these situation EHE values were often smaller than the actual error. However, given improved moving beacon algorithms now being developed, along with potential associated adjustments in the EHE computation, the expectation is EHE will hold as a viable quality factor for MEOSAR alert data.

5.1.16 D&E Phase III Conclusions

As described in document C/S R.018, the achievement of the following conditions characterises the successful completion of the Cospas-Sarsat MEOSAR demonstration and evaluation phase:

- a final report that provides official results of the evaluation, including the documentation of MEOSAR system performance using test and operational beacons, and the characterisation of operational performance;
- a sufficient amount of test results using only satellites with L-band downlinks to confirm the expected performance of the operational MEOSAR system;
- specifications and commissioning standards for MEOSAR space and ground segment equipment (for MCCs documents C/S A.003, C/S A.005 and C/S A.006, and for MEOLUTs documents C/S T.019 and C/S T.020); and
- completion of documentation for the exchange of operational MEOSAR alert data (C/S A.001, DDP), system operation (C/S A.002, SID).

Except for the testing of combined MEO/GEO operation (test T-8), all tests in the MEOSAR D&E Plan should have been accomplished by one or more of the D&E participants.

The participants in the MEOSAR D&E Phase III Report agree that this demonstration and evaluation campaign has been a success, meets the above criteria, and that this Report is ready for Council review as a basis for its decision on using MEOSAR data operationally in the MEOSAR IOC Phase.

This report provides the final official results of the evaluation, including the documentation of MEOSAR system performance using test and operational beacons, and the characterisation of operational performance.

An initial assumption was that at least 14 L-band satellites would be needed to begin MEOSAR D&E Phase III and the D&E Plan tests T-3, T-4, T-5 and O-2, performed with 18 Galileo and 2 Glonass L-band satellites demonstrated sufficient performance to achieve the IOC performance. An adequate number of L-band satellites were available to provide a sufficient amount of test results using only satellites with L-band downlinks to confirm the expected performance of the operational MEOSAR system.

The specifications and commissioning standards for MEOSAR space and ground segment equipment are published:

- C/S A.003, Cospas-Sarsat System Monitoring and Reporting (Issue 3, Revision 2),
- C/S A.005, Cospas-Sarsat Mission Control Centre (MCC) Performance Specification and Design Guidelines (Issue 5, Revision 2),
- C/S A.006, Cospas-Sarsat Mission Control Centre Commissioning Standard (Issue 5, Revision 3),
- C/S T.019, Cospas-Sarsat MEOLUT Performance Specification and Design Guidelines (Issue 2, Revision 4),
- C/S T.020, Cospas-Sarsat MEOLUT Commissioning Standard (Issue 2, Revision 3).

The documentation for the exchange of operational MEOSAR alert data is published:

- C/S A.001, Cospas-Sarsat Data Distribution Plan (DDP) (Issue 8, Revision 3),
- C/S A.002, Cospas-Sarsat Mission Control Centres Standard Interface Description (SID) (Issue 7, Revision 3).

5.2 Recommendations

The impact of moving beacons remains something that needs to be addressed during MEOSAR IOC operations, but continued studies and results of MEOLUT commissioning at MEOSAR IOC performance level, combined with the implementation of QMS, should accomplish this before MEOSAR FOC declaration.

Although O-2 test during Phase III of the MEOSAR D&E indicated that the instances of uncorroborated alerts were reduced from Phase II testing, they still exist. Ongoing work in MEOLUT commissioning for MEOSAR IOC Phase should provide gains and implementation of the MEOSAR QMS should provide indications of performance compliance. Additionally, as more MCCs are commissioned to LGM, the MCCs will be able to manage the distribution of these uncorroborated alerts.

Anecdotal results in O-6 and empirical results in O-7 regarding EHE indicate that more work will be required during the MEOLUT commissioning for MEOSAR IOC operation and MEOSAR QMS. However, the same testing demonstrates that there is value added by the MEOSAR system and the MEOSAR D&E did not actually include a rigorous testing of the EHE nor a comparison of MEOSAR EHE against the same performance indicator in the LEOSAR system.

Noting that data format defined in Annex E of document C/S T.020 resulted from the experience gained during MEOSAR D&E testing, it is recommended that that the data format provided in the tables of Annex E of document C/S T.020 be used in any future MEOLUT testing.

As per section 10.5 of document C/S R.012, during the demonstration and evaluation phase the number of satellites required to operate in MEOSAR IOC shall be determined. An initial assumption was that at least 14 L-band satellites would be needed to begin MEOSAR IOC. As the MEOSAR IOC entrance criteria are not linked directly to MEOSAR coverage, a clear determination cannot be done. The tests T-3, T-4, T-5 and O-2 were performed with 18 Galileo and 2 Glonass L-band satellites and demonstrated sufficient performance to achieve the MEOSAR IOC performance. An adequate number of L-band satellites were available to provide a sufficient amount of test results using only satellites with L-band downlinks to confirm the expected performance of the operational MEOSAR system. Various studies evaluating MEOSAR IOC coverage are on-going within the framework of experts working group on MEOSAR global coverage that will estimate the extent of the coverage achievable by the planned MEOSAR IOC declaration date.

During the next phases of MEOSAR operations, the Council should consider focusing ongoing efforts at JC, EWGs and TG meetings on MEOSAR to continue to use MEOLUT commissioning at MEOSAR IOC performance level and MEOSAR QMS results to address ongoing issues with moving beacons, uncorroborated alerts, EHE and global coverage assessments.

The participants of the MEOSAR D&E Phase III agreed that the Phase III has been a success and accomplished all the objectives for D&E completion set forth in document C/S R.018, and believe that the final Phase III Report is ready for Council review and approval as a basis for its decision on using MEOSAR data operationally in the MEOSAR IOC Phase.

- END OF SECTION 5 -

ANNEX A

LIST OF ACRONYMS FOR OPERATIONAL TESTSTest O-1

TMANU	Time of first MEOSAR Alert Notification Unlocated
TMANE	Time of first MEOSAR Alert Notification Encoded
TMANL	Time of first MEOSAR Alert Notification Location
TMANC	Time of MEOSAR Position Confirmation (Ambiguity Resolution)
TLANU	Time of first LEOSAR Alert Notification Unlocated
TLANE	Time of first LEOSAR Alert Notification Encoded
TLANL	Time of first LEOSAR Alert Notification Location
TLANC	Time of LEOSAR/GEOSAR Alert Position Confirmation (Ambiguity Resolution)
TGANU	Time of first GEOSAR Alert Notification Unlocated (no encoded position)
TGANE	Time of first GEOSAR Alert Notification Encoded
Latitude	Based on encoded position, independent position or ground truth information
Longitude	Based on encoded position, independent position or ground truth information

PTAE	Potential Time Advantage Encoded *(encoded position only)*
PTAL	Potential Time Advantage Location *(computed at ground station)*
PTAA	Potential Time Advantage All Locations *(encoded and/or computed)*
PTAC	Potential Time Advantage Position Confirmation
PTAO	Potential Time Advantage Overall *(first notification all data types)*
PTAU	Potential Time Advantage Unlocated

A.2 Test O-2

LGST	LEO/GEO Start Time
LGET	LEO/GEO End Time
LGDT	LEO/GEO Data Type (U=Unlocated, E=Encoded, D=Doppler, C=Confirmed)
MST	MEO Start Time
MET	MEO End Time
MDT	MEO Data Type (U=Unlocated, E=Encoded, D=DOA, C=Confirmed)
Latitude	Based on encoded position, independent position or ground truth information
Longitude	Based on encoded position, independent position or ground truth information

A.3 Test O-3

MTT	MEO Transmission Time
MST	MEO SIT Type
LGTT	LEO/GEO Transmission Time
LGST	LEO/GEO SIT Type

A.4 O-4

FA UNL	First Alert, no location
FA ENC	First Alert with location, encoded position only
FA DOA	First Alert with location, DOA position only
FA DOA ENC CFM	First Alert with location, DOA/encoded Position Confirmation (dependent event)
FA DOA ENC DIF	First Alert with location, DOA/encoded Position Conflict (dependent event)
NC DOA DOA DIF	position Not Confirmed, DOA/DOA position conflict
NC DOA ENC DIF	position Not Confirmed, DOA/encoded position conflict
NC ENC ENC DIF	position Not Confirmed, encoded/encoded position conflict/update
CA DOA DOA CFM	Confirmation Alert, new DOA to previous DOA
CA ENC DOA CFM	Confirmation Alert[14], new DOA to previous/new encoded
CA DOA ENC CFM	Confirmation Alert, new encoded to previous DOA
CT CFM	Continued Transmission[15] event, DOA and/or Encoded positions, no position conflict
CT DOA DIF	Continued Transmission event, DOA position conflict
CT ENC DIF	Continued Transmission event, encoded position conflict/update
RD DOA ENC	Redundant data (DOA/Encoded dependent beacon event and none of the above)
RD UNL	Redundant data (Unlocated dependent beacon event and none of the above)

A.5 O-6

Type of Analysis (Real-time/Retrospective)	The report could be based on a distress where MEOSAR System played a role in the Search and Rescue Mission in Real-Time (**Real-Time**), or could be based on a LEOSAR/GEOSAR case that has been analysed later trying to assess the benefits/deficits that MEOSAR data would have provided to the Search and Rescue Mission retrospectively (**Retrospective**), as if that MEOSAR data would have been available at that time.
Date and Time	Date and Time in UTC
Location	Name of the Location of the Incident.
Incident Type	Situation of the vehicle/person in distress (sinking vessel, road accident, walker injured…)
Beacon Type	EPIRB/ELT/PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	Geographical environment of the vehicle/person in distress.
Beacon Speed (static/moving/drifting…)	Speed of the beacon.
Local Time	Local Time. This information could be complemented with the lighting conditions (Get dark/Night)
Local Weather Conditions (winds, ice, hot, cold…)	Weather conditions endanger not only the persons in distress but also the Search and Rescue personnel.
Resources moved (Helicopter/Vessel/Aircraft…)	Resources or means used in the rescue.
People Involved	People involved in the incident
People Rescued	People rescued
C/S MEOSAR Alert (Only/First/Other)	The MEOSAR alert received by the RCC from Cospas-Sarsat could be the **Only** alert received or the **First** alert received. Other situations are possible, as for example, the alert was first detected by MEOSAR but first located by LEOSAR, in such cases, a short description could be provided here.
Detection Time (Advantage/No Advantage)	Here the Advantage or No Advantage can be indicated for Detection Time. Between parenthesis the difference in minutes can be expressed.
Location Time (Advantage/No Advantage)	Here the Advantage or No Advantage can be indicated for Location Time. Between parenthesis the difference in minutes can be expressed.
Location Accuracy (Advantage/No Advantage)	Here the Advantage or No Advantage can be indicated for Location Accuracy. Between parenthesis the observed error in Nautical Miles/Kilometres can be expressed.

A.6 O-7

Status	Status of the alert site (beacon activation) when redundant condition occurred **- FA** = First Alert with DOA location; **- CA** = Confirmation Alert (confirmed but no data beyond); **- NC** = Not Confirmed (but beyond first alert with DOA location); **- CT** = Continued Transmission; **- PC** = Position Conflict.; **-** – – – = (Not recorded).
ActLat	the actual latitude as determined from external information
ActLon	the actual longitude as determined from external information
NewSolId	internal reference to the new solution record (if not available, use 0)
NewLat	the latitude for the redundant solution
NewLon	the longitude for the redundant solution
NewQF	the quality factor for the redundant solution
ExistSolId	internal reference to the existing solution record (if not available, use 0)
ExistLat	the latitude for the existing solution (which the redundant one matches)
ExistLon	the longitude for the existing solution
ExistQF	the quality factor for the existing solution

- END OF ANNEX A -

ANNEX B

DETAILED RESULTS OF TEST O-6

Incident 1: 28 June 2017 – New Zealand

LM, Advantage, MEOSAR question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0329 UTC, 28 June
Location	North Island, New Zealand
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	3:39 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded used

An encoded alert was initially detected by MEOSAR and later by a LEO satellite for a registered PLB with a position near Coppermine Track in the Ruahine Range. The Palmerston North Rescue helicopter was tasked to assist and found a tramper who suffered an injury. The paramedic cared for the patient and once stable she was winched and taken to Palmerston North Hospital for further care.

MEOSAR
0326 encoded
0406 conflict
0408 confirmed
0416 update
MEOSAR detections from 0327 to 0515 but DOA locations only produced for 5 of 14 locations sent to LGM AUMCC.

No GEOSAR

LEOSAR
0415 S12 resolved 40 17.1S, 175 44.1E with encoded 40 14.7S, 175 53.5E

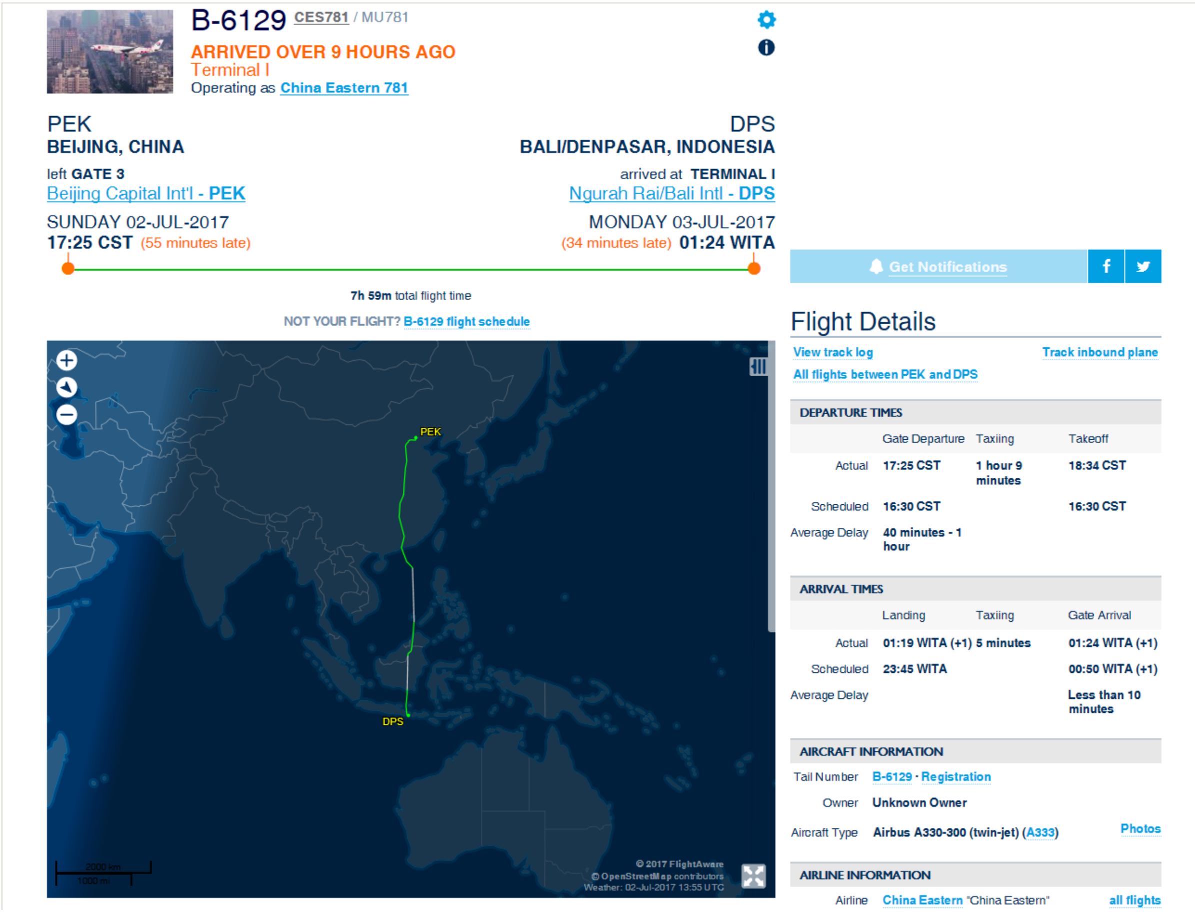
In this incident, MEOSAR provided 49-minute detection time advantage with encoded location but the confirming DOA was not produced until 7 minutes before LEOSAR resolved Doppler.

Incident 2: 2 July 2017 – Chinese ELT

LM, Other.

Type of Analysis (Real-time/Retrospective)	Retrospective
Date and Time	1227 UTC, 2 July
Location	Over China
Incident Type	Accidental activation
Beacon Type	ELT
Beacon Environment (land/sea/cliff/forest/dessert…)	In the air
Beacon Speed (static/moving/drifting…)	Moving
Local Time	
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	Not known
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Same time
Detection Time (Advantage/No Advantage)	None
Location Time (Advantage/No Advantage)	None
Location Accuracy (Advantage/No Advantage)	None

The Hong Kong LEOLUT detected an activated ELT for an hour, which belonged to the China Eastern Airline - registration no. B-6129. This activation was known to be a false alert on a flight from Beijing, China to Bali, Indonesia. The aeroplane flew over the HKMCC service area in its journey. However, all subsequent detections were conflict ones due to the speed of the flight (over 800km/hr). See flight details below:



The Australian MEOLUT had 288 detections of the beacon (where each detection is one antenna/one satellite). There was a detection every minute indicating every burst from the beacon was detected by the Australian MEOLUT, from 12:27 to 13:39. Looking further on the Australian MEOLUT, 66 locations were generated but they all had very poor quality (less than 100 on a scale from 0 to 1000). Usually, quality is above 900. The poor quality locations were very poor, 1000s of kms away from the aircraft.

This incident demonstrates the ability of MEOSAR to detect an ELT in a moving aircraft.

Incident 3: 8 July 2017 – Australia

M, Advantage.

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0153 UTC, 8 July
Location	Curnang State Forest
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	11:53 am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Not known
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

PLB activation in Curnang State Forest, New South Wales. As JRCC spoke with emergency contacts, the beacon owner rang and advised that he had come across a motorcycle accident. Coordination of incident passed to NSW Police. One person taken to hospital.

MEOSAR:
Initial (encoded) 0153
US initial (encoded) 0156
Confirmed 0159 (encoded + DOA)
All DOA locations transmitted to LGM AUMCC within 5kms of encoded.

No LEOSAR/GEOSAR detections.

In this incident, the MEOSAR data was the only Cospas-Sarsat data and the MEOSAR data assisted in the incident.

Incident 4: 9 July 2017 – Australia

M, Additional work.

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0150 UTC, 9 July
Location	Weipa, Queensland
Incident Type	Inadvertent
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	11:50am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

Inadvertent activation - Accidental activation during washdown at home address. Measures taken to shield signal and dry out.

MEOSAR
0150 Initial (unlocated)
0151 Conflict (encoded and DOA). DOA was inland about 21 NMs from encoded. Location accuracy was 8 NM.

Encoded was consistent with address of registered owner.

In this incident, MEOSAR detected an inadvertent activation. As the beacon was registered, minimal work was created for the Australian JRCC.

Incident 5: 9 July 2017 – Australia

M, Advantage.

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0211 UTC, 9 July
Location	Batt Reef, Queensland
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	12:11 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Vessel
People Involved	3
People Rescued	3
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

EPIRB detection received in vicinity of Batt Reef QLD. Nearby vessel was diverted to the area. The vessel located the broken-down pleasure craft with target EPIRB active and launched her fast rescue boat to retrieved the 3 occupants.
3 persons rescued 40 minutes after beacon activation.

MEOSAR
0211 unlocated
0212 DOA location (EHE accuracy 10 NM) (Just over 5 NMs from later encoded location)
0212 Confirmed (DOA and encoded) EHE accuracy 4 NMs (4 NMs from encoded)
0215 Update EHE accuracy 2 NMs that was within 1.5 NMs of encoded.
Beacon detected by MEOSAR from 0210 to 0305.

No LEOSAR/GEOSAR detections.

In this incident, only MEOSAR data was received, resulting in a successful rescue.

Incident 6: 13 July 2017 – Australia

L, No MEO

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	13 July 2017 0757 UTC
Location	Victoria, Australia
Incident Type	Inadvertent Activation
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	17:57
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	No MEOSAR detection
Detection Time (Advantage/No Advantage)	Not applicable
Location Time (Advantage/No Advantage)	Not applicable
Location Accuracy (Advantage/No Advantage)	Not applicable

Registered EPIRB detected. Owner advised beacon is in warehouse.

MEOSAR: No detections

LEOSAR
0757 – unlocated
0911 – Doppler locations
0937 Resolved
Last update 1240

This is an example of an incident where there were LEOSAR detections but no MEOSAR detections. As the beacon is inside a warehouse, the transmitted signal would be weaker, and therefore only detected by the LEOSAR satellites.

Incident 7: 14 July 2017 – New Zealand

M, Advantage, MEOSAR question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	14 July 2017 2356 UTC
Location	Whangamomona Forest, North Island, New Zealand
Incident Type	Hiking
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	11:56am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	2
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

A party of two were hunting deer in the Whangamomona Forest, when one of them slipped and fell down a ravine. He activated his PLB which led to multiple MEOSAR detections. A Rescue Helicopter was tasked from Palmerston North to investigate and on arrival a paramedic was dropped by winch to the patient (Duration 4 hours)

MEOSAR
2356 (14 July) – unlocated
0003 – encoded
0033 – confirmed (DOA + encoded) Expected Accuracy 006 NMS (2.5 kilometres from encoded)
Limited MEOSAR detections – terrain shielding?

Detected from 2356 to 0215. Only one DOA location at 033.

No LEOSAR or GEOSAR detections.

In this incident, MEOSAR provided the only detection in a successful rescue. Although the beacon was detected from 2356 to 0215, only one DOA location was generated. Given location in ravine, terrain shielding may have prevented detection by sufficient MEOSAR satellites to generate more DOA locations.

Incident 8: 22 July 2017 – Australia

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0445 UTC, 22 July
Location	Cape Inscription, WA
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	11:45 am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Aircraft, vessel
People Involved	2
People Rescued	2
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

EPIRB detected at 0445 UTC, registered to a 4.8m aluminium vessel. Believed to have 2 POB. Was known to be operating in vicinity of Turtle Bay.

JRCC advised at 0527 UTC that a charter vessel provided 60 litres of fuel to vessel in the area that had an active beacon and told them to turn their beacon off. At same time beacon ceased and was not detected from that point on. SAR assets stood down.

MEOSAR: detected between 0445 and 0455
0445 – DOA
0445 – confirmed (DOA + encoded)
No LEOSAR or GEOSAR detections.

Looks like beacon was only on for ten minutes. Don’t know why – was assistance given at 0455 but JRCC only informed at 0527?

In this incident, only MEOSAR data was received for a ten-minute period from 0445 to 0455. This created work for the Australian JRCC and assets were tasked. When contacted at 0527 and advised that the vessel had been assisted, the Australian JRCC were able to know that the beacon was no longer active. Without the MEOSAR data, the JRCC would have been unaware of the incident until being informed at 0527 that the vessel had been assisted and the EPIRB turned off.

Incident 9: 22 July 2017 – Australia

LM, Advantage, MEOSAR question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	22 July 2017, 0847 UTC
Location	Blue Mountains, Australia
Incident Type	Hiking
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	6:47pm
Local Weather Conditions (winds, ice, hot, cold…)	Cold
Resources moved (Helicopter/Vessel/Aircraft…)	Not known
People Involved	Not known
People Rescued	Not known
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage (encoded)
Location Accuracy (Advantage/No Advantage)	No advantage

Blue Mountains City Council PLB used for Bush Walking. Coordination passed to NSW Police who later advised that all persons were rescued.

MEOSAR Detected from 0845 to 1210
From 0845 to 1011 – no DOA locations
Australian and NZ MEOLUTs produced DOA at 1011 but then no more DOAs until 1046.
But from 1103 to 1210, lots of detections and almost all with DOAs.
0847 – unlocated
0848 – encoded
1012 – confirmed (DOA + encoded)

LEOSAR
0857 – resolved (encoded and Doppler)

LEOSAR produced a resolved location (encoded and Doppler) before first DOA location.
From analysis, at 0845, the Australian MEOLUT was only tracking 4 satellites 315, 317, 319 and 330. (two antennas on 319) and (two on 330). Only getting detections of beacon from 330. No detections from 315 too far to west. No detections from 317 until 0930. 317 and 319 poor geometry (very close to each other). Detected by 317, 319 and 330 at 0951 but no DOA due to poor location until 1011.

Conclusion – more satellites (i.e., six different and not two similar ones like 317 and 319) would have improved chance of DOA locations.
In this incident, MEOSAR detected the beacon first but LEOSAR was able to provide a resolved location 75 minutes before a MEOSAR confirmed location. Satellite geometry and pass scheduling affected the MEOSAR data in this incident.

Incident 10: 22 July 2017 – Australia

LGM, Advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	22 July 2017, 1120 UTC
Location	Cronulla Beach, NSW
Incident Type	Boating
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Static
Local Time	9:20pm
Local Weather Conditions (winds, ice, hot, cold…)	Rough seas
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	2
People Rescued	2
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	No advantage (1 minute)
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	No advantage

An EPIRB, registered to recreational vessel, was detected offshore from Cronulla Beach, NSW. Inquires with the emergency points of contact confirmed that vessel, with two crew, had departed earlier in the afternoon to go squid fishing. A Bankstown based helicopter, and the Water Police were tasked to respond. The beacon was homed to an upturned craft with one person clinging to hull and the second person in water beside the vessel. Both survivors were recovered by the Police vessel and conveyed to Sutherland Hospital by a waiting ambulance. The survivors were reported to have suffered from mild to severe hypothermia, with one survivor also suffering a head injury. It was subsequently confirmed that the vessel had overturned in rough seas at sunset, and after 3 hours in the water, one survivor had swum back into vessel to recover and activate EPIRB.

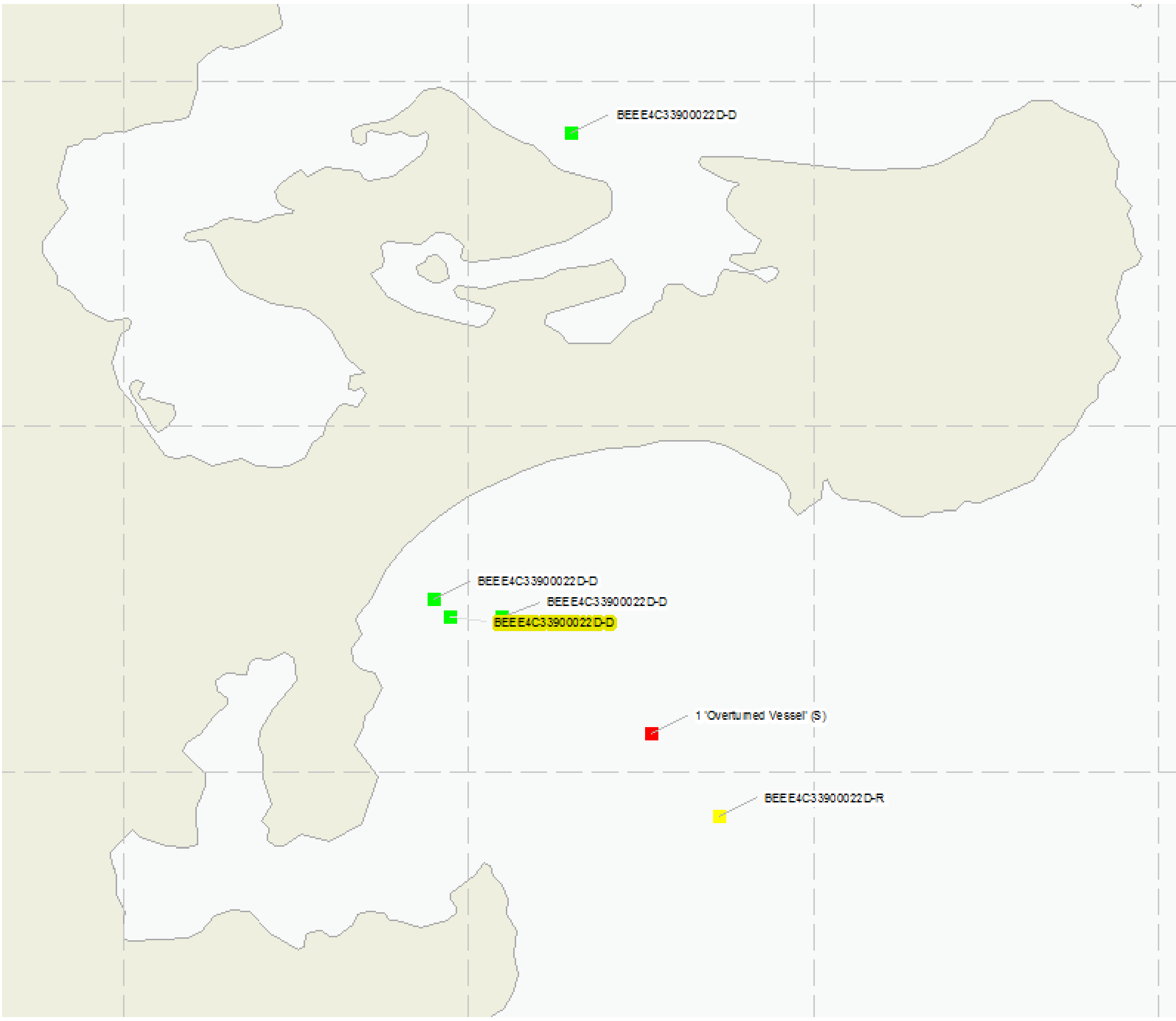
MEOSAR
- 1120 – DOA, reported 4 NM – 3.5 NM from boat
- 1126 – DOA, reported 2 NM - 1 NM from boat
- 1132 – DOA, reported 1 NM – 1.3 NM from boat
- 1137 – DOA, reported 1 NM, - 1.2 NM from boat
- 1141 – confirmed (2 x DOA), reported 4 NM – 1.3 NM from boat

GEOSAR
- 1121 unlocated

LEOSAR
- 1126 initial, Doppler locations (suspect)
- 1208 resolved – 0.6 NM from boat

All systems (LEO, GEO and MEO) provided detections. MEOSAR had a 1-minute detection advantage and 48 minute location advantage (time to resolved location as initial Dopplers were suspect)

LEOSAR – better accuracy location with resolved but initial were suspect Doppler (B-location was 3 NM but this was reported as likely image position).



Red square is location of vessel.
Yellow (R) South-East of vessel is resolved location. Distance to vessel is 0.6 NM (1 km).
Northern Green (D) is first DOA (4 NM reported accuracy)
Other green squares are next three DOA locations.

In this incident, the detection times of LEOSAR, GEOSAR and MEOSAR were similar. However, MEOSAR provided a time advantage for the first location (as the first LEOSAR locations were suspect). The bunching of the MEOSAR locations to the west of the actual location of the vessel caused confusion in the Australian JRCC as the initial search area was two kilometres west of the actual location of the vessel.

Incident 11: 23 July 2017 – Australia

M, Advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0219 UTC, 23 July
Location	Monkey Mountain, NSW
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	12:19am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

MEOSAR alert for an Australian PLB registered for use with bushwalkers from the Brisbane Water Outdoors Club. Encoded MEOSAR detection. NSW Ambulance service already conducting a response and conducted a winch rescue from Monkey Mountain. A bushwalker had fallen 20m after getting too close to a cliff edge. The Brisbane Water club had activated their PLB on the bushwalker's behalf.

MEOSAR – detected from 0218 to 0556, but only 8 of 43 detections transmitted to LGM AUMCC had a DOA location.
0219 DOA
0222 – confirmed (encoded and DOA)
DOA at 0219, reported accuracy 7 NM, was 1.2 NM from encoded
DOA at 0222, reported accuracy 6 NM was 2.2 NM from encoded
DOA at 0331, reported accuracy 4 NM was 1.3 NM from encoded
DOA at 0346, reported accuracy 4 NM was 1.0 NM from encoded
No LEOSAR or GEOSAR detections.

Terrain shielding reason for no LEO/GEO and reduced MEO detections?

In this incident, only MEOSAR data was received. The MEOSAR data was not used in the rescue (as rescue was underway when beacon activated). It appears that terrain shielding may have affected the number of DOA locations produced.

Incident 12: 10 August 2017 – Australia

LM, Reduced Work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	10 August 2017, 1842 UTC
Location	Indonesia
Incident Type	Maritime
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Unknown
Local Time	04:42, 11 August
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Unknown
People Involved	Unknown
People Rescued	Unknown
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	33 minutes
Location Time (Advantage/No Advantage)	24 minutes
Location Accuracy (Advantage/No Advantage)	No advantage

The Australian JRCC received a LEOSAR detection of an Indonesian beacon. The Doppler A position was in Indonesia, the B position was in the north of Australia.

There was a MEOSAR detections of the beacon at 1842, with DOA locations from 1851.

As the MEOSAR data indicated that the LEOSAR B position in the Australian SRR was the mirror (image) position, no SAR action was commenced by the Australian JRCC.

In this incident, the MEOSAR data was used operationally to resolve Doppler data and reduced workload by the Australian JRCC.

Incident 13: 12 August 2017 – Australia

LM, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	12 August 2017, 0311 UTC
Location	Western Australia, Australia
Incident Type	Accidental activation
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static?
Local Time	
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Aircraft
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	11 minutes
Location Time (Advantage/No Advantage)	16 minutes
Location Accuracy (Advantage/No Advantage)	No advantage

JRCC Australia received a detection of an EPIRB on the coast near Warroora Station 80 NM north of Carnarvon. A SAR aircraft was tasked from Perth and tracked the beacon signal to a large beach side campsite. No signs of distress were observed.

MEOSAR
0312: DOA location
0316: DOA location
0324: DOA location
0328: DOA location - conflict

LEOSAR
0323: unlocated
0328: Doppler, suspect, but 4 NM to camp site
0728: resolved

In this incident, the first three MEOSAR DOA locations had large accuracy estimates – 23.75 NM, 17 NM and 17 NM – from the suspected location of the beacon at the camp site. All three DOA locations had good reported accuracy of 4, 2 and 1 NM. All DOA locations were generated from four satellites. The first location was from the Australian MEOLUT and the next two locations from the New Zealand MEOLUT.

Later detections were much closer to the camp site.
The search aircraft reported that the 121.5 homer signal was very weak and difficult to home on.

Incident 14: 13 August 2017 – Australia

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	13 August 2017, 0426
Location	Sydney, Australia
Incident Type	Accidental activation
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	14:26
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	
Location Time (Advantage/No Advantage)	
Location Accuracy (Advantage/No Advantage)	

JRCC Australia detected a registered beacon off Mona Vale, near Sydney registered to a 6.6m recreational vessel. Attempts to contact the owner or emergency contacts were unsuccessful. JRCC Australia tasked helicopter to investigate. After the helicopter became airborne, the owner contacted JRCC Australia and confirmed safety. The beacon had activated during wash down after use.

MEOSAR
0427: DOA location

No LEOSAR or GEOSAR detection.

In this incident, the MEOSAR system provided the only detection of an accidental activation. The MEOSAR system created additional work for the Australian JRCC including tasking of a helicopter. The MEOSAR accuracy was not sufficient for the JRCC to determine if the EPIRB detection occurred over land or sea. If the location data indicated that the detection was on land, the JRCC would have probably tried longer to contact emergency contacts (as the beacon was registered) before tasking a helicopter.

Incident 15: 20 August 2017 – Australia

L, No MEO

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	20 August 2017, 1228 UTC
Location	Yangebup, Australia
Incident Type	Non-distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	8:28 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	Not known
People Rescued	None
C/S MEOSAR Alert (Only/First/Later)	No MEOSAR detection
Detection Time (Advantage/No Advantage)	No Advantage
Location Time (Advantage/No Advantage)	No Advantage
Location Accuracy (Advantage/No Advantage)	No Advantage

Multiple unlocated LEOSAR alerts were received for an unregistered Australian EPIRB between 1221 UTC on 20 August to 2144 UTC on 23 August.

No hearing reports of a 121.5 MHz signal.

One unresolved Doppler location was in close proximity to a waste disposal site.

No SAR resources tasked for this incident.

There were no MEOSAR detections of this beacon. It is assumed that the beacon is in a waste disposal facility and transmitting a weak signal that was detected by the LEOSAR system but not the MEOSAR system.

Incident 16: 23 August 2017 – New Zealand

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	23 August 2017, 0158 UTC
Location	South Island, New Zealand
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:58 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	98 minute advantage
Location Time (Advantage/No Advantage)	98 minute advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

MEOSAR alerts, followed by LEOSAR alerts were received for a New Zealand registered PLB in the foothills northeast of Mt Cook village. The Helicopter Line was initially tasked with a LandSAR crew member to locate and assess the situation. The PLB owner's quad bike, dog and chainsaw were initially located, then the SAR team found the man in the forest with an injury. He had been felling trees on a property and got caught in a tree as it fell down an embankment. The helicopter uplifted a DoC ACR team with stretcher to extract the injured man, and on medical advice from Twizel medical centre flew him direct to Timaru hospital where he was admitted for further treatment.

MEOSAR
0158 unlocated
0158 DOA
0158 confirmed (DOA + encoded)

LEOSAR
0336 resolved (Doppler + encoded)
In this incident, MEOSAR provided a 98-minute advantage in detection time and time of location.

Incident 17: 23 August 2017 – New Zealand

LM, Reduced work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	23 August 2017, 1957 UTC
Location	New Zealand
Incident Type	Non-distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	7:57am, 24 August
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Not relevant
People Involved	Not relevant
People Rescued	Not relevant
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Not relevant
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Not relevant

An initial LEO alert for an unregistered Australian EPIRB was received with one position in Queensland and the other north of New Zealand. AUMCC advised that they had also received a MEOSAR alert for the beacon which located it at the Queensland position.

(Duration .5 hours)

In this incident, the MEOSAR data in Australia resolved the ambiguity of the two Doppler locations. This meant that New Zealand JRCC were not required to commence any SAR activity for this incident.

Incident 18: 9 September 2017 – Australia

LGM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	9 Sept 2017, 1513 UTC
Location	Western Australia
Incident Type	Grounded boat
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On sea
Beacon Speed (static/moving/drifting…)	Static
Local Time	2300
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Vessel, aircraft
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	187 minutes
Location Time (Advantage/No Advantage)	187 minutes
Location Accuracy (Advantage/No Advantage)	Encoded location used

A registered EPIRB was detected 13NM west of Port Hedland. The registered owner was contacted, and she advised that her boat was secure in Broome, nowhere near the beacon location. Fremantle Water Police were contacted and requested to assist. It was later advised that a fisherman had sent a text to his next of kin indicating that he had grounded his tinny in that area and required help. No further communications could be established with the fisherman. The Police accepted coordination for the response, and tasked VMR Vessel to respond. JRCC assisted with the tasking of a SAR aircraft. The VMR vessel arrived on scene first and located the missing man. He had some minor injuries following the boat hitting rocks and capsizing and was transported back to Port Hedland.

MEOSAR:
1513: confirmed (DOA + encoded)
1722: missing person located

GEOSAR
1820: initial (encoded)

LEOSAR
1822: resolved (Doppler + encode)
In this incident, the MEOSAR detection and location enabled the beacon activation to be associated with a phone call, allowing a better response to the incident. The person was rescued before the first

GEOSAR or LEOSAR detection.

Incident 19: 21 September 2017 – Australia

LM, Advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	21 Sept 2017 0530 UTC
Location	Queensland, Australia
Incident Type	Vessel
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	Sea/land
Beacon Speed (static/moving/drifting…)	Static
Local Time	15:30
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, vessel
People Involved	4
People Rescued	4
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	53 minutes
Location Time (Advantage/No Advantage)	26 minutes
Location Accuracy (Advantage/No Advantage)	No advantage

A party of four people suffered mechanical breakdown and were washed onto rocks at the smallest of the Cliff Islands in Princess Charlotte Bay. All managed to make it ashore with one person suffering a minor injury. A SAR aircraft was tasked and dropped supplies and communications to the party. Due to the risk of crocodiles and the need to attend to the injured party. A helicopter was tasked and returned three persons to their campsite on the nearby mainland, and the injured person to Cairns hospital.

0530 MEOSAR unlocated, also US MEOSAR unlocated
0540 hearing reports
0614 MEOSAR DOA location
0623 LEOSAR unlocated
0640 LEOSAR 2 Dopplers
0640 MEOSAR + LEOSAR resolved (LGM AUMCC under test)
0837 LEOSAR resolved (two Doppler)

In this incident, MEOSAR provided a time advantage in the detection time and time of first location. It took 44 minutes for the first MEOSAR DOA location – is this caused by the location which is over 3,000 kilometres from both the Australian and NZ MEOLUTs?

Incident 20: 23 September 2017 – New Zealand

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	23 Sept, 2017 2245 UTC
Location	Opotiki, New Zealand
Incident Type	Mountain bike accident
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	10:45 am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

JRCCNZ received distress alerts via the MEOSAR system for a PLB active to the south east of Opotiki near a hut on a track. Distress contacts advised there was a person running on the track by herself. The Rescue Helicopter from Rotorua was tasked to investigate. When on scene they advised the PLB had been activated on behalf of a mountain biker who had crashed down a twenty-metre bank and suffered injuries. The patient was stabilised and transported to Whakatane Hospital for treatment. (Duration 4 hours)

MEOSAR site 11522
2245: Initial encoded
2251: Confirmed (DOA + encoded)
Detections from 2245 to 0022

No LEOSAR or GEOSAR detections.

In this incident MEOSAR provided the only beacon data for a successful rescue.

Incident 21: 8 October 2017 – Australia

GM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0121 UTC, 8 October
Location	Hervey Bay, Queensland
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	11:21am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, aircraft, vessel
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage – 7 minutes
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

AUMCC detected MEOSAR alerts for a registered Australian EPIRB associated with 6.5m recreational vessel in Hervey Bay. Registration details indicated that the vessel had been sold but JRCC Australia could not contact the new owner. Water Police and the VMR were tasked. Aircraft of Opportunity and a rescue helicopter were also tasked. The Water Police vessel located an up-turned vessel and rescued one person from the water. The survivor stated that he had capsized at about midnight but had only managed to recover his EPIRB from the capsized vessel some 12 hours later. The survivor was taken back to Hervey Bay.

MEOSAR
0121 – DOA
0122 – confirmed (two DOA)

GEOSAR
0128 GEO detection (NZGEO)

LEOSAR – no detections

In this incident, there was a GEOSAR detection but as they beacon did not provide an encoded location and the registration details were out of date, the Australian JRCC could not have progressed this incident further without the MEOSAR data. MEOSAR provided a location that resulted in a successful rescue.

Incident 22: 9 October 2017 – Australia

M, Advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0231 UTC, 9 October
Location	Blue Mountains, NSW
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	12:31pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage (Encoded)
Location Accuracy (Advantage/No Advantage)	Encoded location used

Blue Mountains Police Loan PLB detected near Martins Lookout, Blue Mountains. Solo bushwalker was located by the Police helicopter and winched.

MEOSAR
0231 unlocated
0233 encoded

Detections from 0230 to 0334 but no DOA location (terrain shielding or satellite geometry?).
Rescue about 50m from GPS location.

No LEOSAR or GEOSAR locations. Analysis indicates no LEO passes until 0430 (S12).

In this incident, the MEOSAR detection of the PLB resulted in a successful rescue. No DOA locations were produced suggesting terrain shielding or poor MEOSAR satellite geometry during the incident. The encoded location was used to locate the person in distress.

Incident 23: 11 October 2017 – Australia

LM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0757 UTC, 11 October
Location	Grey, WA
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	2:57 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, vessel, aircraft
People Involved	3
People Rescued	3
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

JRCC Australia received a detection from an Australian EPIRB in a position 1-2NM offshore Grey WA, 90 NM north of Perth. The registered beacon owner had sold the vessel and EPIRB without updating details. Intelligence gathering revealed the identity of the new owner. An airborne aircraft of opportunity was diverted and a rescue helicopter from Perth and Volunteer Marine Rescue Vessel from Jurien Bay were tasked to the distress position. Three persons wearing flotation were sighted clinging to an upturned hull. Two were rescued by helicopter and one by the VMR vessel and all three were transferred ashore to a waiting road ambulance for medical assessment at Jurien Bay.

MEOSAR:
0757 DOA location
0757 confirmed (two DOA)
0940 encoded – why so long for encoded to be transmitted – was antenna blocked, maybe by person holding beacon?

LEOSAR
0922 2 Dopplers
0958 3 persons recovered in water

In this incident, the MEOSAR system provided an 85-minute time advantage in detection and location in a successful rescue. The beacon provided an encoded location at 0940, almost 2 hours after the initial detection and around the time of the rescue. This suggests that GPS antenna on the EPIRB may have been blocked, possibly by a person in the water holding the beacon.

Incident 24: 24 October 2017 – New Zealand

GM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	24 October 2017, 2205 UTC
Location	Tararua Ranges, NZ
Incident Type	Medical situation
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	01:05 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	2
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	86 minutes
Location Time (Advantage/No Advantage)	86 minutes
Location Accuracy (Advantage/No Advantage)	Advantage – fine encoded used

RCCNZ received distress alerts via the MEO system for a New Zealand registered PLB active near the northeast corner of the Tararua Ranges west of Pahiatua. A contact advised that the owner was working on a track in the area usually with one other person. The Rescue Helicopter from Palmerston North was tasked and quickly located the casualty who was suffering a medical condition and transported him to hospital.

(Duration 2 hours)

MEOSAR
2204 – unlocated
2205 – encoded
2205 – confirmed (encoded + DOA)

GEOSAR
2330 – coarse encoded

No LEOSAR detections.

In this incident, the MEOSAR provided an 86 minute time advantage compared to GEOSAR, resulting in a successful rescue.

Incident 25: 29 October 2017 – New Zealand

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	29 October 2015 2328 UTC
Location	Southland, New Zealand
Incident Type	Hiking
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	12:28
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Several
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded used

MEOSAR alerts were received for an unregistered PLB with a position on the Hollyford Track, Southland. Southern Lakes Helicopters were tasked to the location. On arrival they located a guided walking party with one person that had sustained an injury. The patient was winched into the helicopter before being flown to Kew Hospital for treatment.

(Duration 2.75 hours)
MEOSAR
2328 – unlocated
2332 – encoded
2333 – confirmed (encoded + DOA)
Last detection 0119.

No LEOSAR or GEOSAR detections.

In this incident, MEOSAR provided the only beacon alert data for the incident which resulted in a successful rescue.

Incident 26: 11 November 2017 – New Zealand

LM, Advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	11 Nov 2017, 0448 UTC
Location	South Island, New Zealand
Incident Type	Tramping (hiking)
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	Land
Beacon Speed (static/moving/drifting…)	Static
Local Time	17:48
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	9
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	No Advantage
Location Accuracy (Advantage/No Advantage)	No Advantage (encoded used)

MEO followed by LEO alerts were received from a PLB registered to a college in Nelson. The GPS position was at a hut on the Old Ghost Road, northwest of Murchison. The emergency contact advised that the PLB was with a group of eight or nine teachers mountain biking the Old Ghost Road. The Garden City Rescue helicopter was tasked from Nelson. The patient was a teacher who had fallen from her bike, preventing further pedalling. She was flown to Nelson then transported to the medical centre for treatment.

(Duration 1.7 hours)

MEOSAR: site 22024
0448: unlocated
0452: encoded detection
0539: DOA location

LEOSAR:
0501: resolved (encoded and Doppler)

GEOSAR:
No detection

In this incident, MEOSAR provided a 13-minute time advantage for detection of the beacon and providing an encoded location. A MEOSAR DOA location was not generated until 51 minutes after the initial detection.

Incident 27: 13 November 2017 – Australia

LM, Additional work, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	13 Nov 2017, 0045 UTC
Location	Australia
Incident Type	Vessel
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At Sea
Beacon Speed (static/moving/drifting…)	Not known
Local Time	11:45
Local Weather Conditions (winds, ice, hot, cold…)	Not known
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	Not known
People Rescued	Not known
C/S MEOSAR Alert (Only/First/Later)	Not relevant
Detection Time (Advantage/No Advantage)	No Advantage
Location Time (Advantage/No Advantage)	No Advantage
Location Accuracy (Advantage/No Advantage)	No Advantage

The Australian JRCC received six MEOSAR beacon alerts from FMCC for a Panama beacon AE49C34D34D34D1 with an initial location of (27 11.90` S, 117 41.30` E). The SIT 185 message had a footprint error in paragraph 15.

Later alerts were conflict alerts with different locations, most with the footprint error.
The LEOSAR system and the Australian and NZ MEOLUTs provided a location for the beacon of (14.1 N, 109.4E) – in the northern hemisphere.

In this incident, the MEOSAR data from FMCC created confusion and uncertainty in the Australian JRCC. The incident was reported to the FMCC who referred the issue to the MEOLUT manufacturer.

Incident 28: 22 November 2017 – New Zealand

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	22 Nov 2017, 2153 UTC
Location	South Island, New Zealand
Incident Type	Hiking group
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	10:53
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not known
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

MEO only alerts were received for a registered PLB with a location on Banks Peninsula. The emergency contact advised that the beacon owner was out on a day tramp with a group from Christchurch. The rescue helicopter was tasked, located the group and uplifted one person with an injury. Due to the terrain, the person was winched into the helicopter and flown to Christchurch Hospital for treatment.

(Duration 1.0 hour)

MEOSAR
2153 – DOA location
2154 – confirmed (encoded + DOA)
Detected until 2232

No LEOSAR or GEOSAR detections

In this incident, the MEOSAR data was the only data received and resulted in a successful rescue.

Incident 29: 9 December 2017 – Australia

LM, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	9 Dec 2017
Location	Australia
Incident Type	Unknown
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	12:39
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Aircraft
People Involved	Not known
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	
Detection Time (Advantage/No Advantage)	
Location Time (Advantage/No Advantage)	
Location Accuracy (Advantage/No Advantage)	Unknown

Unregistered Australian EPIRB detected on 406.025MHz. First unlocated MEOSAR alert confirmed by encoded position very close to the shoreline at Woodgate Beach Hervey Bay. Water Police contacted and advised large numbers of prawn trawlers in the area. Aircraft of opportunity requested to investigate whilst conducting a patient transfer. Nil signs of distress in area and nil audio reported. Needle deflection only reported. VMR subsequently swept through the position and to the mouth of the Burrum River, and on foot with a homer. Nil signs of distress in area and nil detections on homer. LEOSAR subsequently resolved the beacon to the vicinity of the Childers suburban area, within 2NMs of the Tip.

The beacon was detected by the Australian and NZ MEOLUTs from 0124 to 0147, followed by a break and the beacon started again between 0227 to 0618. Then there was another break, and the beacon was active from 0813 to 2356.

During the first period, the encoded and MEOSAR DOA locations gave a location on the coast, but in the second period, the MEOSAR and LEOSAR gave a location 40 kilometres inland. However, the encoded location in the second period still had the coastal location.

The analysis suggests the following happened during the incident:

Period 1:
The beacon activated near the coast. The encoded and MEOSAR DOA locations indicate this.

Period 2:
The beacon was moved (probably in a boat). While being moved, it was covered and not detected.

Period 3:
The beacon was exposed again and detected by MEOSAR (0227) and a couple of hours later the LEOSAR systems (0444). Both reported similar inland locations (within 2 kilometres), both 40 kilometres from the original coastal location.

The encoded location did not update on the beacon. Either the beacon model does not update or because the GPS antenna was blocked. In this incident, the first encoded location was detected at 0131 but all detections after 0530 did not provide an encoded location. This is due to the Cospas-Sarsat rule that if a GPS location is not updated within four hours, it stops providing a GPS location. It is this behaviour which confirms that the encoded location was originally accurate but was not updated.

In this incident, the timeliness of the MEOSAR data could have assisted in understanding this incident earlier. However, the static encoded location seemed to contradict the moving MEOSAR locations at the time.

Incident 30: 10 December 2017 – New Zealand

GM, no Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	10 Dec 2017, 0006 UTC
Location	Christchurch, New Zealand
Incident Type	Trail bike accident
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:06pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not reported
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Same time
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

Following multiple MEOSAR distress beacon alerts for a NZ registered PLB north of Amberley near Christchurch, a rescue helicopter was tasked to investigate. A man belonging to a group of trail bike riders was airlifted to Christchurch hospital with a shoulder injury.

(Duration 2.75 hours)

MEOSAR, site 28830
0006 - DOA
0007 Confirmed (DOA + encoded)
Beacon detected 0006 to 0108. 126 detections from AU and NZ MEOs, all with DOA locations.

GEOSAR
The beacon was detected by the non-operational GEOLUT tracking Louch-5A.
Detected by NZ GEOLUT 2 tracking Louch-5A.

No LEOSAR.
In this incident, the efficiency of the MEOSAR was demonstrated in combination with an encoded location. The value of the Louch-5A geostationary satellite was demonstrated (the data from this GEOLUT was not yet used by the NZ JRCC at this time).

Incident 31: 11 December 2017 – New Zealand

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	11 Dec 2017, 0346 UTC
Location	Tauranga, New Zealand
Incident Type	Inadvertent activation
Beacon Type	ELT
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	16:46
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

JRCCNZ received MEOSAR alerts from an ELT with a position near Tauranga Airport. Contact with the registered owner revealed the ELT had been sold some time ago, and the new owners name (only) was provided. The new owner was tracked down and confirmed that his aircraft was safe in the hangar, and that the ELT had been briefly activated recently. The previous and new owners were both reminded of the requirement to keep the beacon registration details updated. The incident was closed with no SAR action required.

(Duration .4 hours)

MEOSAR
0346 – initial DOA location

No LEOSAR or GEOSAR detections

In this incident, there was only a MEOSAR detection of an inadvertent activation (probably during testing). There was a small increase in the workload of the New Zealand JRCC operator.

Incident 32: 12 December 2017 – Australia

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	12 Dec 2017, 1017 UTC
Location	Sydney, Australia
Incident Type	Incorrect handling
Beacon Type	ELT
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	21:17
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Not relevant
Location Time (Advantage/No Advantage)	Not relevant
Location Accuracy (Advantage/No Advantage)	Not relevant

JRCC received a detection of an ELT with Virgin Airlines VH-FVY. The beacon was inadvertently activated while in maintenance and is now deactivated.

MEOSAR
1057 initial – DOA

No LEOSAR or GEOSAR detections. The beacon was detected by the non-operational GEOLUT tracking Louch-5A.

In this incident, the MEOSAR detected an ELT that was being tested. The maintainer rang the JRCC after activating the beacon but by then the Australia JRCC had already commenced responding to the activation. No resources had been allocated. The MEOSAR system created extra work for the Australian JRCC.

Incident 33: 12 December 2017 – Australia

L, No MEO

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	12 Dec 2017, 0552 UTC
Location	Mareeba, Australia
Incident Type	Unknown
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	16:52
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	Not known
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	No MEOSAR detection
Detection Time (Advantage/No Advantage)	Not relevant
Location Time (Advantage/No Advantage)	Not relevant
Location Accuracy (Advantage/No Advantage)	Not relevant

Multiple LEOSAR detections of a beacon from 0547 UTC to 2306 UTC on 12 December 2017. Resolved location in urban area of Mareeba, a town in Queensland. Beacon was registered but had been sold and new owner details could not be determined. No SAR resources allocated.

In this incident, MEOSAR did not detect the beacon that was detected multiple times by the LEOSAR system. There were no GEOSAR detections. The reason for the beacon activation was not determined but there is no evidence that it was a real distress situation.

Incident 34: 9 January 2018 – New Zealand

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0056 UTC, 9 Jan 2018
Location	Cardrona, New Zealand
Incident Type	Vehicle accident
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1356
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	ATV
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	No advantage – encoded used

MEOSAR alerts were received for a PLB registered to a farm near Cardrona in the South Island. After calling the distress contacts it was established that the farm manager was working alone in an isolated part of the farm. Two farm workers took an ATV with a satphone to ascertain the situation. The Queenstown Rescue helicopter was also tasked. The two farm workers located the manager who had rolled his ATV but was uninjured. The helicopter was stood down before lifting off and the manager was transported back to his residence. (Duration 2.1 hours)

MEOSAR
0056 – initial – encoded only
0057 – confirmed (encoded and DOA), the DOA location was 2.75 km from the encoded location with a reported accuracy of 5 NM
Detections from 0056 to 0203 UTC

No LEOSAR or GEOSAR detections.
In this incident, the only beacon alert data was provided by MEOSAR for a successful rescue.

Incident 35: 13 January 2018 – Australia

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	1407 UTC, 13 January 2018
Location	Mackay, Queensland
Incident Type	Maritime, vessel overturned
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	Sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	12:07 am, 14 January
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, vessel
People Involved	2
People Rescued	2
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	No advantage (encoded)

A distress beacon registered to a 4-metre runabout was detected 2 miles east of Mackay, QLD. The JRCC contacted the emergency contact who had just received a phone call advising that the vessel had capsized and that the two occupants were sitting on top of the overturned hull. A rescue helicopter and Volunteer Marine Rescue vessel were tasked, and the two people were rescued and brought back to safety.

MEOSAR
1407: unlocated
1407: confirmed (DOA + encoded)
1409: confirmed (DOA + encoded) from US MEOLUT
1414: encoded from European MEOLUT

No LEOSAR or GEOSAR detections

In this incident, MEOSAR was the first beacon detection of the distress incident.
In this incident, MEOSAR provided the only Cospas-Sarsat detection of the beacon. The timeliness of the MEOSAR detection allowed the response to be coordinated between the various authorities.

Incident 36: 21 January 2018 – Australia

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0403 UTC 21 January
Location	Western Australia
Incident Type	Inadvertent Activation
Beacon Type	ELT
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	12:03pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	No advantage
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No location data produced

Inadvertent activation during helicopter wash.

MEOSAR
0405 – unlocated
0405 – unlocated (US)
0408 – unlocated (France)

No LEOSAR or GEOSAR detections.

In this incident, MEOSAR created additional work for the Australian JRCC. It appears that the beacon was on for only one transmission. The single transmission was only detected by the MEOSAR system and resulted in the JRCC responding. Fortunately the beacon was registered, and the matter resolved with a few phone calls.

Incident 37: 21 January 2018 – Australia

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0227 UTC, 21 January 2018
Location	Tasmania, Australia
Incident Type	Rescue
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:27pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not known
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

The Australian JRCC responded to a PLB activation in Tasmania at 0227 UTC on 21 January. A bushwalker was winched out by a rescue helicopter about an hour later at 0338 UTC.

MEOSAR: site 38010
0227 – initial – DOA location
0229 – confirmed (DOA + encoded)
Encoded location from US at 0230.

Beacon detected by MEOSAR from 0226 to 0333.

No LEOSAR or GEOSAR detections.

MEOSAR provided the only beacon data for this successful rescue.

Incident 38: 28 January 2018 – New Zealand

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0133 UTC, 28 January 2018
Location	Kepler track, New Zealand
Incident Type	Non-distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	2:33pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not reported
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage?
Location Time (Advantage/No Advantage)	Advantage?
Location Accuracy (Advantage/No Advantage)	Encoded location used

JRCCNZ received MEOSAR alerts from an Australian coded PLB with a position on the Kepler Track. A local Rescue Helicopter was tasked to the area; however no persons could be found and no beacon signal could be detected. Investigations were made at a nearby hut, but no further info could be obtained. The helicopter was stood down with the likelihood of a false activation, and with no further alerts detected. Investigations continued through the DOC Visitor Centre, which revealed that the registered beacon owner had arrived safely at the hut and confirmed the beacon had been set off in the belief that they were in distress. The beacon holders soon realised they were actually going to be fine, so switched it off. Information was provided outlining the correct use of a beacon, and what to do in a similar situation. (Duration 1.7 hours)

MEOSAR site 40540
0133 – DOA
0133 – confirmed (encoded + DOA)
Detections from 0132 to 0136

No LEOSAR or GEOSAR detections.

In this incident, which was eventually not a distress situation, the early MEOSAR detection caused additional work for the New Zealand JRCC compared with the LEOSAR and GEOSAR systems.

Incident 39: 4 February 2018 – New Zealand

GM, No advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0410 UTC, 4 February 2018
Location	Lees Valley, New Zealand
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:10 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	

MEOSAR alerts were received for NZ registered PLB in the Lees Valley. The Christchurch Garden City Rescue Helicopter was tasked. The activation was associated with an off-road motorbike event. The rider had gone through a fence and was knocked off their motorbike. They were taken to Christchurch Hospital for treatment.

(Duration 1.5 hours)

MEOSAR
0010 – initial (DOA)
0011 – confirmed (DOA + encoded)
Beacon detected until 0044.

GEOSAR
0012 – encoded from NZ GEOLUT2 tracking Louch-5A

No LEOSAR detections.

In this incident, data from MEOSAR and GEOSAR arrived at the same time and was used by the JRCC NZ for a successful rescue.

Incident 40: 4 February 2018 – New Zealand

GM, No advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0214 UTC, 4 February 2018
Location	Stewart Island, New Zealand
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	3:15pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not reported
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage – 122 minutes
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

Multiple MEOSAR alerts received for a NZ coded PLB, resulted in a rescue helicopter from Southern Lakes being tasked to Stewart Island. The helicopter located a tramper on the North West Circuit Track who need medical assistance. The person was taken to Kew hospital for treatment.

(Duration 2.5 hours)

MEOSAR
0214 – initial (DOA)
0215 – confirmed (DOA + encoded)
Beacon detected until 0350.

LEOSAR
0416 – confirmed (Doppler + encoded)

GEOSAR
0214 – detected by NZ GEOLUT 2 tracking Louch-5A
0220 – encoded location from NZ GEOLUT 2

MEOSAR and GEOSAR provided a 122-minute advantage over LEOSAR in a successful rescue.

Incident 41: 8 February 2018 – Australia

GM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0818 UTC, 8 February 2018
Location	Western Australia
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	Sea
Beacon Speed (static/moving/drifting…)	Static
Local Time	4:18pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Vessels, helicopter
People Involved	3
People Rescued	3
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	No advantage

JRCC Australia received an alert from an unregistered EPIRB approximately 5NM offshore of Hillarys Boat Harbour, Western Australia.

Police were contacted and tasked Volunteer Marine Rescue (VMR) and a Police vessel to the location. JRCC issued a broadcast to shipping and tasked rescue helicopter and aircraft to the location. Police later advised that a 000 call had been received from a person in the water. VMR arrived on scene and recovered the 3 persons with nil injuries reported.

Water Police were tasked to respond (as well as VMR, helicopter and aircraft) and were first on scene. Police were carrying a portable homer and homed the 121.5MHz signal to within 100 metres of the vessel in distress but received a MEOSAR position further offshore. Survivors advised that they could see the police vessel, which had not seen them, but then watched it speed away as it headed to the MEOSAR position provided. Police subsequently lost the 121.5MHz signal and later returned to the actual distress position following advice that the VMR had located the vessel in distress.

Police indicated that the EPIRB was tethered to vessel and deployed correctly.

MEOSAR
Beacon detected and located from 0818 to 0915 and 1003 to 1031. Note that 0915 is consistent with the time of rescue (reported at 0922) when the beacon was reported as lost when the persons were recovered by the VMR.

GEOSAR
0820: unlocated detection from NZ GEOLUT 2 tracking Louch 5A.
0826: unlocated detection from UAE GEOLUT tracking MSG-1.

LEOSAR
First detection at 1006 by AULUTE tracking S7.

The AULUTE detection only received three bursts with a TCA (time of closest approach) of 1001. It appears from the timing of the MEOSAR data that the beacon was shielded at 1001 when satellite S7 was closest to the beacon and the beacon only transmitted at 1006. This resulted in poor Doppler locations (about 11 NM from vessel) marked as "suspect" by the LEOSAR processing as the detections were outside the TCA window.

In this incident, the MEOSAR data provided the first detection and location. Although the GEOSAR detection was only minutes later, as the beacon was unregistered, no SAR response would have been possible with the unlocated GEOSAR detection.

The MEOSAR locations were not accurate and the accuracy indication provided to the Australian JRCC was mis-leading. The DOA location provided to the Police at 0900 had an accuracy indication of 1NM but was 3.7 NM from the vessel and resulted in the Police ceasing homing and moving away from the target.

Although the MEOSAR locations were inaccurate, without the MEOSAR locations, no response would have been possible until the phone call, by which time at least one person was in the water. There were no LEOSAR detections until after the rescue (and these were suspect Doppler locations).

Incident 42: 14 February 2018– New Zealand

GM, No advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0258 UTC, 14 February
Location	Wanaka, New Zealand
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	3:58 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	5
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Same time as GEOSAR
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	Encoded used

RCCNZ received MEO and GEO alerts for an Australian registered PLB located on the south side of Rabbit Pass. Contact was made with the JRCC Australia who provided the beacon registration details. The emergency contact was called who provided the party names and their planned route. A rescue helicopter was tasked with a rescue team who located the group of five, along with one of the group, who was injured after falling. The injured person was flown to the Wanaka Medical Centre for treatment while the remainder of the group continued their trip as planned.

(Duration 2.5 hours)

MEOSAR
0254 unlocated
0256 fine encoded
Beacon detected from 0253 to 0420, but no DOA locations produced by either Australian or NZ MEOLUTs.
Suggests that beacon may have been shielded – hence no DOA locations generated.

GEOSAR
0255 NZGEO2 – Louch 5A – unlocated
0256 NZGEO2 – Louch 5A – coarse encoded
0256 NZGEO2 – Louch 5A – fine encoded
NZGEO2 detected bursts from 0253 to 0420 (98 bursts).

LEOSAR
0421 – coarse encoded – TCA 0320
In this incident, MEOSAR and GEOSAR both detected the beacon at approximately the same time and provided an encoded location that resulted in a successful rescue.
No DOA locations were generated, although the beacon was detected for 87 minutes.

Incident 43: 3 March 2018 – New Zealand

GM, No advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	1241 UTC, 3 March 2018
Location	Orongorongo Ranges, NZ
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:14am, 4 March
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	Not reported
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

RCCNZ received MEOSAR (only) alerts from a PLB with a position at a hut in the Orongorongo Ranges. The Lifeflight Trust Wellington helicopter was tasked to the position and retrieved a child with a medical condition. The patient was taken to Wellington Hospital for treatment. (Duration 1.8 hours)

MEOSAR
1241: Confirmed (DOA + encoded)
Detected from 1241 to 1336.

GEOSAR:
NZGEO2 (Louch 5A): 1242 UTC (encoded)

LEOSAR:
No detections.

GEOSAR and MEOSAR provided information that resulted in a successful rescue.

Incident 44: 25 March 2018 – Australia

GM, Advantage, MEOSAR location vs encoded

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0506 UTC, 25 March 2018
Location	Cape Naturaliste, Australia
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Static
Local Time	1.06pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, vessel
People Involved	2
People Rescued	2
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

2018/2059
JRCC Australia received satellite detections of an EPIRB registered to a jet ski in the vicinity of Cape Naturaliste WA. The emergency points of contact advised that the jet ski was expected to be in that area with two persons onboard engaging in tow surfing. A rescue helicopter from Bunbury and a local Volunteer Marine Rescue vessel were tasked to the location where the jet ski and two persons were located afloat but obviously experiencing mechanical failure. The VMR vessel recovered the persons and took the jet ski in tow.

MEOSAR
0506 – DOA
0509 – confirmed (two DOA)
MEOSAR detections from 0506 to 0614, however encoded location only produced at 0614. Was GPS antenna obscured?

LEOSAR – no detections

GEOSAR
0507 unlocated – Louch-5A
0528 unlocated - MSG-1

In this incident, the early MEOSAR location resulted in a successful rescue. Although the beacon had GPS capability, no encoded location was received until shortly before the beacon was turned off. As this incident occurred on water with no shielding, it is presumed that the GPS antenna was obscured, possibly by the person holding the EPIRB during activation.

Incident 45: 5 April 2018 – Australia

M, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0319 UTC, 5 April
Location	Victoria, Australia
Incident Type	Distress
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:19 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Encoded location used

JRCC received an alert from an Australian PLB with an encoded position on the coast near Yuulong (Great Ocean Road). Beacon encoded position is around 400m along the beach from the end of Melanesia track. Co-ordination transferred to Victoria Police. Person stranded on rocks was winched to safety by helicopter and was taken to Port Campbell.

MEOSAR – site 58538
0319 – confirmed – DOA and encoded
Beacon detection from 0318 to 0451.

No LEOSAR or GEOSAR detections.

In this incident, MEOSAR was the only beacon data provided to the JRCC and resulted in a successful rescue.

Incident 46: 6 April 2018 – New Zealand

M, Additional work

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0848 UTC, 6 April 2018
Location	Thames, New Zealand
Incident Type	Inadvertent
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	8:48pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

An MEOSAR initial alert was received for a NZ registered PLB with a position approx. 8.5 miles Southeast of Thames. The incident was soon cancelled with a call to the owner. He advised they were going out into the bush on Saturday and was testing it, he apologised for generating an alert.
(Duration 0.25 hours)

MEOSAR – site 58952
0848 DOA location
One burst detected by NZ and Australian MEOLUTs.

No GEOSAR or LEOSAR detections.

In this incident, before MEOSAR, the inadvertent activation during testing would not have been detected with no resulting SAR response.

Incident 47: 28 April 2018 – New Zealand

LM, No advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	2021 UTC, 28 April 2018
Location	Dairy Flat, New Zealand
Incident Type	Inadvertent
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	8:21am
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Later
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

290821 Local Time (282021 UTC) RCC0431/18

LEOSAR alerts were received from a PLB indicating a position in a forestry block near Dairy Flat. When JRCCNZ contacted the registered owner, he had been mountain biking in the area of the alert location and had taken a fall. The PLB must have fallen out of his bag during the fall. The owner went out to the location in an effort to find the beacon but was unsuccessful. The owner is intending on heading back to the location on Saturday with friends in an attempt to locate the PLB.

(Duration 8 hours)

LEOSAR:
Detected (TCA) 28 April, 2013 UTC by S10.
Other detections: 2053, 2232, 0416, 0557, 0634, 0816, 0838.

MEOSAR:
First MEOSAR detection at 0646 by NZ MEOLUT via Galileo satellite (419).
First MEOSAR by DASS on 29 April, 1746 UTC (satellite 306).
First US MEOLUT detection was 29 April, 0843 UTC, again with Galileo satellite (419).

No DOA locations. No detections by Australian MEOLUT.

In this incident, a PLB activated inadvertently and was not correctly deployed. The beacon was detected multiple times by LEOSAR but was not detected by the MEOSAR system for 18 hours. The first MEOSAR detections were from Galileo satellites. The NZ MEOLUT was only tracking one Galileo satellite during this incident. The incident demonstrates that a weaker signal from an incorrectly deployed beacon may not be detected by the S-band DASS satellites but is detected by LEOSAR and Galileo satellites.

Incident 48: 28 May 2018 – New Zealand

GM, No advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	UTC
Location	
Incident Type	
Beacon Type	PLB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	
People Involved	1
People Rescued	1
C/S MEOSAR Alert (Only/First/Later)	y
Detection Time (Advantage/No Advantage)	
Location Time (Advantage/No Advantage)	
Location Accuracy (Advantage/No Advantage)	

MEO and GEO alerts were received for a NZ coded PLB with an eventual position on the Rob Roy Track in the Mount Aspiring National Park. Aspiring helicopters were tasked along with the ACR team out of Wanaka to investigate. Once the initial tasking was underway RCCNZ was advised by someone at the scene that there was a person with an injury needing assistance. Helicopters Otago was then tasked to rendezvous with the SAR helicopter for the hospital transfer. The beacon owner had come across the accident and set off the beacon to assist the person as they were in an area without cell phone coverage.

(Duration 4 hours)

MEOSAR:
0150 unlocated detection
0207 encoded location
Beacon detected from 0150 to 0328 by MEOSAR but no DOA locations generated. Detections by Australian, New Zealand, US and Argentine MEOLUTs.

GEOSAR
Detected by NZGEO2 (Louch-5A) at 0154 (unlocated) and 0209 (encoded).

LEOSAR
No detections

In this incident, both GEOSAR and MEOSAR detected the beacon and provided an encoded location. There were no DOA locations generated although the beacon was on for 90 minutes.

Incident 49: 30 May 2018 – Australia

GM, Advantage

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0356 UTC, 30 May 2018
Location	Queensland, Australia
Incident Type	Distress
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	At sea
Beacon Speed (static/moving/drifting…)	Drifting
Local Time	1:56 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	Helicopter, Vessel
People Involved	4
People Rescued	4
C/S MEOSAR Alert (Only/First/Later)	First (with GEOSAR)
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

JRCC Australia received detections from a Cospas-Sarsat distress beacon. The EPIRB was detected 22 nautical miles east of the Southport Seaway. A powerboat had sunk, and four persons were in the water. A rescue helicopter dropped a life raft about twenty minutes after the initial detection of the beacon. The persons were later transferred onto a rescue vessel.

MEOSAR
0356 initial unlocated
0356 DOA
0356 confirmed (DOA + DOA)
Beacon detected until 0426.

GEOSAR
0354 Detected by NZGEO2 (Louch-5A)

LEOSAR

No LEOSAR detections of beacon.

In this incident, the DOA location allowed for a very quick response and resulted in a successful rescue.

Incident 50: 3 June 2018 – Australia

L, No MEO

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0610 UTC, 3 June
Location	Stapylton, Queensland
Incident Type	Incorrect disposal
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	4:10pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	No MEOSAR detection
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

Owner advised that the EPIRB had been sold. New owner confirmed that the EPIRB had been incorrectly disposed and the beacon was detected in the vicinity of the Stapylton Landfill and Recycling Centre. Nil distress.

MEOSAR:
No detections

LEOSAR:
0610 Dopplers (TCA 0558)
0853 Confirmed (2 Dopplers)
Last detection TCA 1717 UTC.

GEOSAR:
No detections.

In this incident, there were no MEOSAR or GEOSAR detections, but there were many LEOSAR detections. This suggests that the beacon in the landfill was transmitting a weaker signal which could not be detected by the MEOSAR and GEOSAR satellites further from the Earth.

Incident 51: 6 June 2018 – New Zealand

LM, No advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	1830 UTC, 6 June
Location	Hamilton, New Zealand
Incident Type	Incorrect disposal
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	1:30am, 7 June
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

An initial MEOSAR alert followed by LEO alerts were received for a NZ registered EPIRB with a position in the Hamilton area. The beacon owner was contacted and advised that he had thrown the beacon away in the rubbish a week earlier. No further action was taken when the beacon stopped transmitting.

(Duration .5 hours)

MEOSAR
1830 Unconfirmed
Detected by Australian and NZ MEOLUTs but no DOA location generated.

LEOSAR
1844 Two Dopplers
2008 Confirmed (Doppler + Doppler)

GEOSAR
No detections.

The beacon in this incident was assumed to be in a landfill and would not have been correctly deployed. MEOSAR detected the beacon but did not generate a DOA location. The LEOSAR system generated a confirmed location about 90 minutes from the initial detection.

Incident 52: 12 June 2018 – Australia

LM, No advantage, MEO question

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	1828 UTC,12 June
Location	Queensland, Australia
Incident Type	Inadvertent activation
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Moving
Local Time	3:28 am, 13 June
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	1
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	No advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

A beacon registered as sold in Dec 2017 was detected in the Macartney Range area in Queensland. The beacon location then moved 448 NMs to the coastal area of Proserpine. JRCC contacted Brisbane Police Communications who on-passed details of the new boat owner. The owner confirmed he was driving to the coast, towing his boat on a trailer. The beacon had accidentally activated due to heavy dew in the area.

MEOSAR
1828 unlocated
1829: DOA (-23.099,141.188), about 450 NMs from the eventual confirmed location
1838: DOA (conflict – correct location)
1840: confirmed (two DOA). Correct location (-20.409,148.588)

LEOSAR:
1901: Two Dopplers

In this incident, the first MEOSAR DOA location was about 450 NMs from the actual beacon location, probably due to the beacon being in a moving trailer. Later detections gave a more accurate location.

If the first location was the only location produced, this would have provided invalid data to the Australian JRCC and affected any response.

Incident 53: 10 July 2018 – New Zealand

LM, No advantage, Additional workload, MEO question

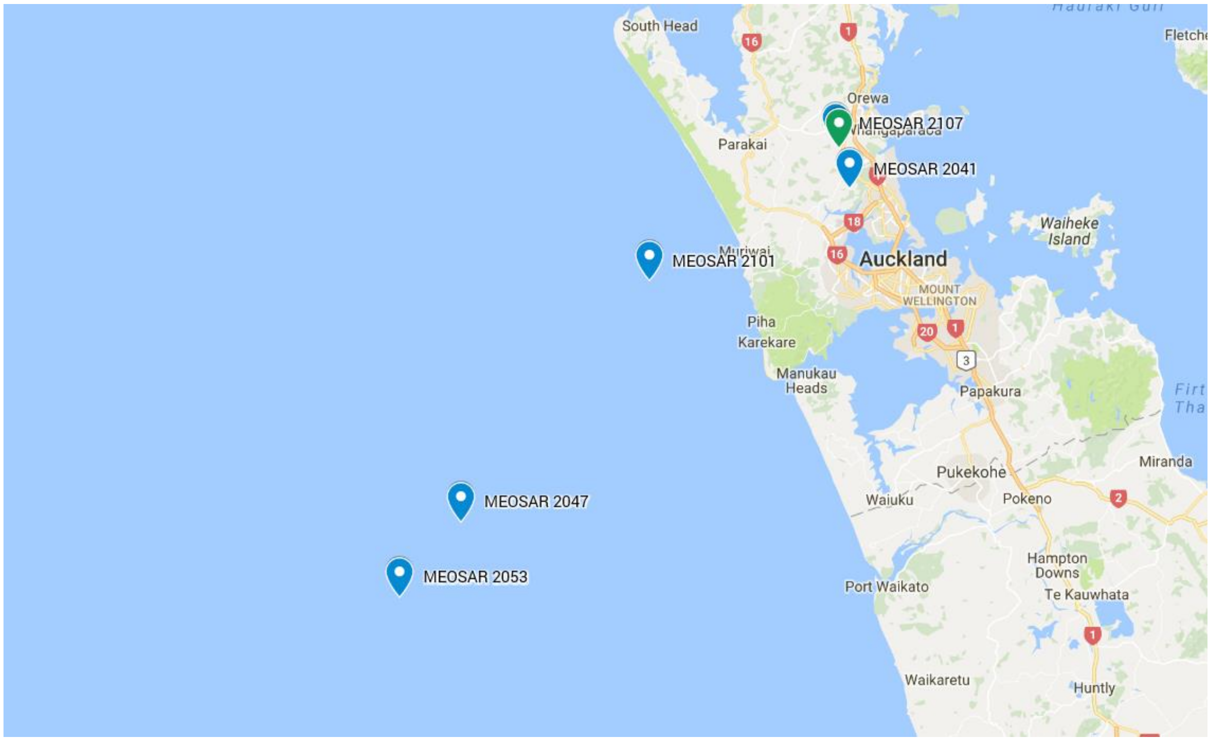
Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	2041 UTC, 10 July
Location	North of Auckland, New Zealand
Incident Type	Incorrect disposal
Beacon Type	EPIRB
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	03:41 am, 11 July
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	First
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	No advantage
Location Accuracy (Advantage/No Advantage)	No advantage

MEOSAR and LEOSAR alerts were received for a US coded EPIRB giving varying positions over a vast area of land and sea. USMCC confirmed the beacon was registered to a 62-foot sailing yacht. Distress relays were commenced by Maritime Radio. Aircraft in the vicinity of Auckland reported hearing the signal. As investigations progressed it became more likely that the beacon was located in close proximity to a landfill North of Auckland. After extensive enquiries it was established that the vessel had been sold in 2013 and shipped to NZ. Eventually a contact of the owner was reached who confirmed the EPIRB had been discarded on Friday. A radio inspector spent some 4 hours attempting to locate the beacon however it would it appear it has ceased transmitting.

(Duration 6 hours)

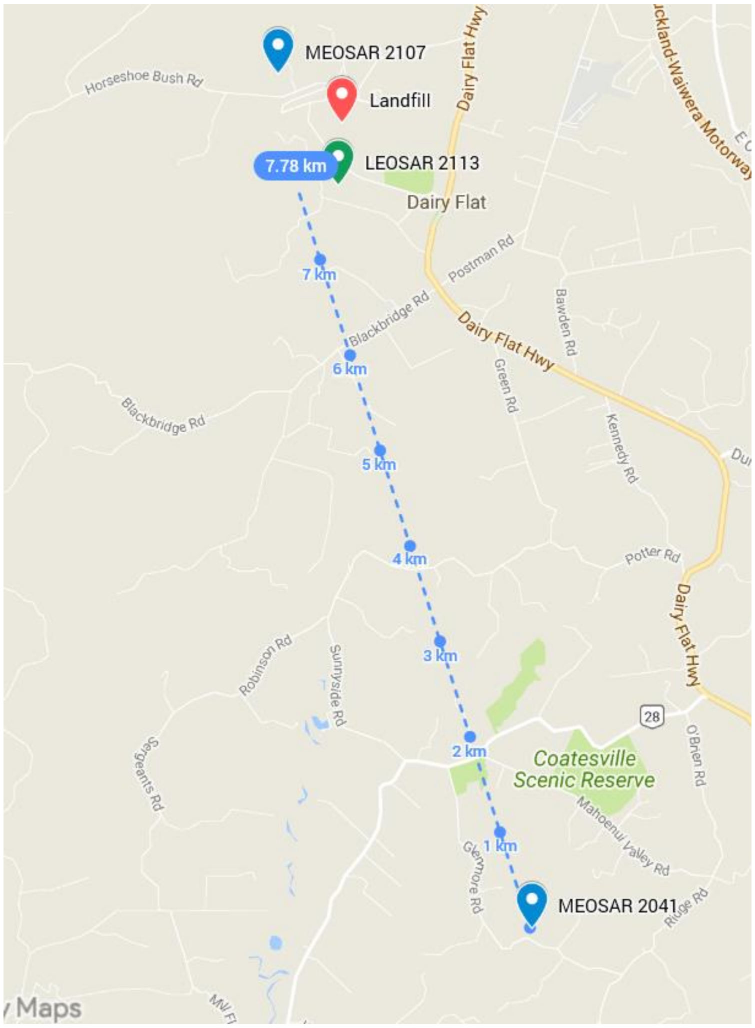
MEOSAR
MEOSAR locations sent to NZ JRCC:
2041: 36 43.9S 174 38.9E accuracy 11 NM
2047: 37 17.0S 173 50.6E accuracy 5 NM - conflict
2053: 37 24.5S 173 42.9E accuracy 5 NM – position update
2101: 36 53.1S 174 14.0E accuracy 4 NM – conflict
2107: 36 39.3S 174 37.2E accuracy 4 NM - confirmed

LEOSAR
2113: 36 39.9S 174 37.6E (Doppler A)



Map of first five MEOSAR locations sent to JRCC NZ (blue icons) and first LEOSAR location (green icon) – one blue icon is behind the green icon. Distance from MEOSAR location at 2041 to LEOSAR location approximately 8 kms. The three MEOSAR locations to sea are approximately 100, 116 and 43 kilometres from the landfill.

The second map shows the locations near the landfill in greater detail. Landfill location is (36 39.56S, 174 37.63E). [-36.659, 174.627]



In this incident, some of the initial MEOSAR locations were very inaccurate (over 100 kilometres from the landfill). This resulted in extra workload in the NZ JRCC. The JRCC were very close to tasking a helicopter to head to the locations out to sea before registration information, the confirmed MEOSAR location and the LEOSAR location indicated that the locations out to sea were inaccurate.

Incident 54: 23 July 2018 – New Zealand

M, Reduced workload

Type of Analysis (Real-time/Retrospective)	Real-time
Date and Time	0357 UTC, 23 July
Location	Christchurch, New Zealand
Incident Type	Inadvertent activation
Beacon Type	ELT
Beacon Environment (land/sea/cliff/forest/dessert…)	On land
Beacon Speed (static/moving/drifting…)	Static
Local Time	3:59 pm
Local Weather Conditions (winds, ice, hot, cold…)	Not reported
Resources moved (Helicopter/Vessel/Aircraft…)	None
People Involved	0
People Rescued	0
C/S MEOSAR Alert (Only/First/Later)	Only
Detection Time (Advantage/No Advantage)	Advantage
Location Time (Advantage/No Advantage)	Advantage
Location Accuracy (Advantage/No Advantage)	Advantage

Christchurch Air Traffic advised that the tower was hearing a strong 121.5 signal. Shortly thereafter MEOSAR alerts were received for an Australian coded ELT. The aircraft was traced to a hangar on the airfield and the beacon was turned off. (Duration .5 hours)

MEOSAR (site 90812)
0357 – detected
0358 – DOA location
0400 – confirmed (2 DOA locations)

No LEOSAR or GEOSAR detections.

In this incident, without the MEOSAR detection data, the hearing of the 121.5 signal could have resulted in extended activity by Air Traffic and the JRCC New Zealand to determine the source of the signal. With the MEOSAR data, the incident was resolved within 30 minutes.

- END OF ANNEX B -

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