Galileo Search and Rescue Service at work over a powered paraglider flight

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Abstract

In flight emergencies over water or over land, the capability to communicate in a very simple way your distress and position is essential if you want to get a chance to be rescued quickly and sometimes avoid a fatal issue.

This is typically the case of adventure travel with a powered paraglider (paramotor) where distances of up to 200 kilometres can be flown in a single flight in 4-5 hours. During such flights, many incidents can occur due to changing weather or material issue on your glider/engine bringing you in an emergency and where fast actions are needed to transmit your position in case things would turn wrong. This is even truer if you travel in a place where communications networks are inexistent. In these cases, the use of a 406MHz satellite distress beacon such as a PLB (Personal Location Beacon) which can be quickly activated by a simple "press button" could save your life. The signal of such distress beacon can be localized by the Galileo Search and Rescue System and transmitted to the relevant national Search and Rescue centres.

Want to clear any doubt on whether this works efficiently or whether Galileo is capable of localizing you fast enough and with sufficient precision as a moving target to enable the rescue? This is what a team of people of the Galileo Programme with the support of the French National Space Agency and the Cospas-Sarsat French Mission Control Centre has tried to demonstrate through the test of the activation of a PLB during a paramotor flight in a controlled environment (Figure 1).

Figure 1: In-flight test of Galileo Search and Rescue

Introduction: The SAR Galileo Service

The Galileo Search and Rescue Service (SAR) has been operational since 2016 and has delivered since then excellent performances in terms detection and localisation of signals transmitted by distress beacons. As a contribution to the Cospas-Sarsat System, the Galileo SAR infrastructure includes 24 in-orbit transponders on-board the Galileo satellites which relay the distress beacons to a set of three Ground Stations connected to each other – called MEOLUTs – located in Maspalomas, Svalbard and Cyprus (Figure 2).

Figure 2: The 4-antennas MEOLUT in Svalbard

The three Galileo EU MEOLUTs, which provide an overall tracking capability of 12 satellites, can detect the distress signal, compute the location of the beacon and send the corresponding information to the Cospas-Sarsat Mission Control Centres.

Galileo SAR Performances – Impact of moving beacons

In order to guarantee the complete independence of the Galileo SAR Service from the availability of GNSS signals, the position of the distress beacon is primarily based on the measurements of the time difference and frequency difference of arrival (TDOA and FDOA) of the distress signal relayed by several satellites in parallel. The associated performances reach typically performances between 1km to 5km, which is suitable for SAR operational purposes. In some cases, a GNSS position can also be computed by the beacon (if a GNSS receiver is embedded and depending on the time to first fix and beacon switch-on time), this position can be encoded in the distress signal message to provide more accurate information (typically in the order of 100m considering the truncation of the message). As a result, the performances of the Galileo SAR Service are defined only based on TDOA and FDOA measurements (without any GNSS encoded location). These performances are reported on a monthly basis and have shown to be excellent (Figure 3) over the last year.

The system performances are monitored continuously with fixed, non-moving reference beacons, and not many data are unfortunately communicated on the very good performances of Galileo SAR Service achievable with moving beacons. Indeed, in the majority of cases a fixed distress beacon assumption is not really representative and the additional Doppler effect resulting from the beacon movement can impact the performances of the localization algorithms of the MEOLUTs. Testing the performances of the Galileo SAR over a powered paragliding flight can therefore turn to be also a useful mean to demonstrate how the system behaves with rather slow moving speeds (between 20km/h and 40km/h), without suffering from the blockage /masking that would result from a ground test. In addition, such a demonstration will be used to confirm the relevance of owning a Personal Location Beacon (PLB) when travelling abroad paramotor flight.

Definition	Committed Target	Worst Case from Jan 2020 to Sep 2020
Valid message detection probability	≥ 99%	99.7%
Localisation probability (1 burst)	≥ 90%	99.1%
Localisation probability (up to 12 bursts)	≥ 98%	99.7%
Localisation success within 5 km (1 burst)	≥ 90%	98.6%
Localisation success within 5 km (up to 12 bursts)	≥ 95%	99.1%

Figure 3: SAR/Galileo Performances over fixed reference beacons

Flight Test set-up

- Personal Location Beacon (PLB), HEX Identifier: 1C6E980002FFBFF;
- Flight software on a smartphone: use of PPGPS application providing a sampling of the flight with one recorded GPS/Galileo position every two seconds, storing all information on a KML (Keyhole Mark-up Language) file;
- Paramotor Miniplane Top80.

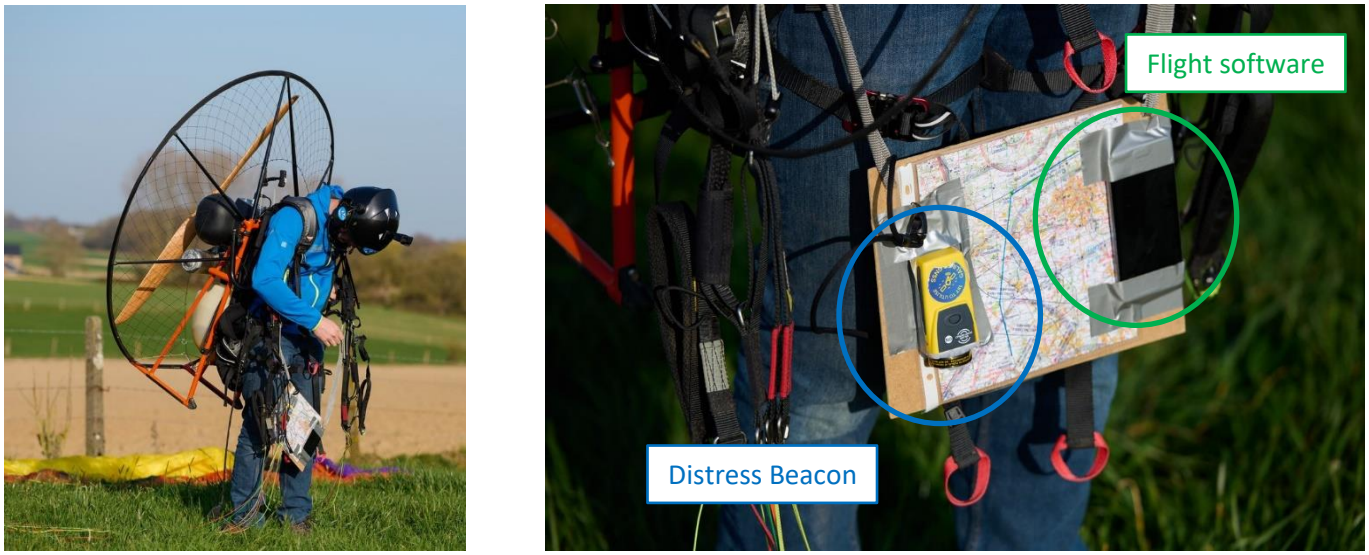

Figure 4: Test set-up with PLB Galileo Enabled and Flight Software

Test Execution and Technical Performances:

The test was executed on 31st of March 2021 in the Control Zone of Beauvechain (Belgium), not active at that time:

- Take-Off Time: 16:16:26sec UTC, Position: 4.7448°E, 50.6917116°N, Longueville, Belgium
- Landing Time: 17:06:45sec UTC, Position: identical to Take-Off

The flight path recorded by the Flight Software PPGPS is shown on Figure 4.

The beacon was switched on at 16:20:15sec, in a position identical to Take-Off. A first location was achieved by the European MEOLUT at 16:23:01sec based on the first burst transmission of 16:21:01, i.e. **in less than 3 minutes** and with a localization error of 5.07km. This first position was obtained through a combination of the 3 European MEOLUTs and a combination of 6 Galileo SAR Transponders (GSAT-0206, 0209, 0215, 0219, 0220 and 0221) and 3 GPS DASS transponders (USA equivalent to SAR/Galileo).

Figure 4: Recorded flight pass over 27km in Beauvechain CTR

During the 50-minutes flight, 58 bursts were transmitted by the distress beacon following its activation. The overall technical performances are the following:

- **Detection Probability**: 100% (All the 58 signal bursts transmitted by the distress beacon have been detected - 80% through more than 6 satellites)
- **Single Burst Location Probability**: 96.6% (56 localisations out of 58 bursts)
- **Single Burst Location Accuracy**: 4.16km @70% and 8.56km @95%, which is line with the Cospas-Sarsat specification for slow-moving beacons at medium speed (10km @70% and 20km @95%)
- **Multi-Burst Location Probability (@10min)**: 2.71km @75% and 3.77km@ 95%

The performances are of course not as good as for fixed beacons monitored on a monthly basis with the Galileo Reference Beacons but are more than compliant with Cospas-Sarsat specifications for moving assets and meet the operational needs of Search and Rescue teams for localising quickly the distress location.

Another important aspect is the capability of the Galileo SAR Service to track the distress position over the overall flight. Figure 5 below depicts all the multi-burst locations that could be computed by the Galileo EU MEOLUT and compares them with the actual flight path, the colour code indicates the error of the location with regard to the exact position on the flight pass at the moment of the computation of the position by the Galileo EU MEOLUT and as it can be seen, all positions errors are well below 4km.

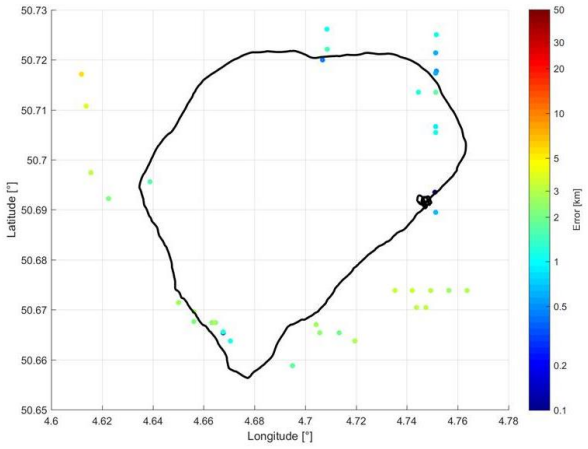

Figure 5: Successive Multi-burst locations vs. actual flight track

CNES has developed in-house an experimental algorithm that implements a Kalman filter and which enables to further optimize the tracking of the flight based on the measurements made by the Galileo EU MEOLUT, taking into account the estimated speed of

the beacon. This algorithm is not deployed in the Galileo EU MEOLUT but has clearly a potential for improving the performances for tracking moving beacons, as shown on Figure 6 where the successive computed position reflect quite well the flight pass.

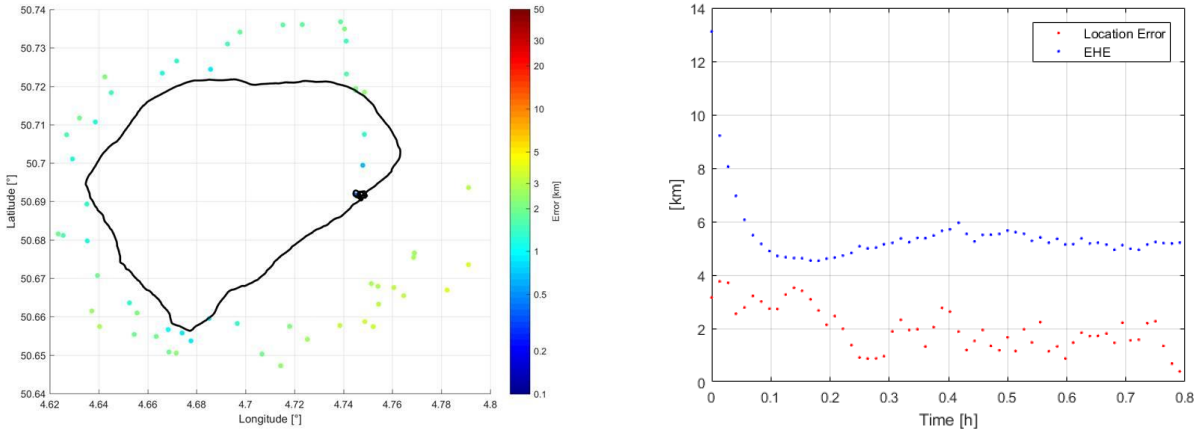

Figure 6: Computation of successive distress positions through CNES Kalman algorithm and Galileo EU MEOLUT Measurements

Operational Aspects

Due to the lack of Test Distress beacon, the test was executed with an operational distress beacon (beacon used in a previous event coordinated by the European Commission for the SharkBait demonstration). In order to avoid triggering the complete Search and Rescue command chain with national SAR authorities, the HEX ID of the distress beacon had been preventively communicated to the FMCC. However, for some reasons, the HEX ID indicated on the beacon (1C6E8CAE5CFFBFF) had been previously reprogrammed to another value (1C6E980002FFBFF) for the European Commission "SharkBait" demonstration, such that an incorrect HEX ID was communicated to the FMCC unknowingly and this alert could not be filtered out as a test transmission.

As a result, the overall command chain for Search and Rescue was triggered following the information disseminated by the Cospas-Sarsat French MCC to relevant RCCs in Belgium. In particular the ARCC of Beauvechain, very close to the place where the alert was located, reacted in a very efficient and professional manner, tried to contact several times the beacon owner to ascertain about the "validity" of the alert and prepared actively the rescue operations. The test nature of the transmission could only be confirmed an hour later by the test executor. This demonstrated once again that the Galileo SAR Service is not just a standalone technical capability but is integrated in a real operational chain aiming at rescuing all citizens over Europe and beyond as soon as possible.

Conclusions

Want to clear any doubt on whether Galileo Search and Rescue works efficiently or whether Galileo is capable of localizing you fast enough and with sufficient precision as a moving target over a paramotor flight to enable the rescue? This test demonstrated the real benefit of owning a Cospas-Sarsat 406MHz distress beacon when going through adventurous destinations. Galileo SAR not only is capable today to locate you extremely fast – in less than 3 minutes – and with a good operational precision – below 4km without any GNSS encoded location – to allow Rescue Operations to intervene but also the Galileo SAR Service has the potential for tracking your distress all along your journey with unprecedented accuracy!