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NORTHERN AIRBORNE TECHNOLOGY LTD.

Evaluation of a 406 MHz Emergency Locator Transmitter (ELT)

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Evaluation of a 406 MHz Emergency Locator Transmitter (ELT)

by
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16. Abstract

This report details the field evaluation of two previously developed prototype Emergency Locator Transmitters (ELTs): a 406 MHz ELT and a 406 MHz ELT with a Global Positioning System (GPS) interface. These two ELTs were field-tested in a Boeing 727 aircraft at various locations across Canada. The antenna used for these tests was installed into the tail cone of a Boeing 727 aircraft. Mounting the antenna in this location prevented the puncturing of the aircraft skin, provided protection for the antenna, and allowed a much clearer view of the sky compared with mounting on the fuselage. The ELT was placed adjacent to the ELT antenna during the tests.

Phase 1 tests were completed in Hamilton and Vancouver using the 406 MHz ELT. Phase 2 tests were completed in Hamilton and Kelowna using the 406 MHz ELT with GPS interface.

Both phases of this project were successful. With the distress location received on the first transmission to the satellite, Search and Rescue (SAR) forces can be deployed immediately, saving an average of two hours, reducing SAR costs, and saving more lives.

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16. Résumé

Ce rapport rend compte de l'évaluation en vraie grandeur de deux prototypes de radiobalises de détresse mises au point lors de projets antérieurs : une radiobalise 406 MHz et une radiobalise 406 MHz avec interface GPS (*Global Positioning System*). Ces deux radiobalises ont été mises à l'essai à bord d'un Boeing 727, à divers endroits au Canada. L'antenne utilisée pour ces essais était installée à l'intérieur du cône de queue d'un Boeing 727. En plaçant l'antenne à cet endroit, on se dispensait de faire des trous dans le revêtement de l'aéronef, on assurait une protection à l'antenne et on obtenait une vue beaucoup plus claire sur le ciel que si on l'avait montée sur le fuselage. Pendant les essais, la radiobalise était placée à proximité de l'antenne.

Les essais de la phase 1, mettant en jeu la radiobalise 406 MHz, ont été réalisés à Hamilton et Vancouver. Ceux de la phase 2, portant sur la radiobalise avec interface GPS, ont eu lieu à Hamilton et Kelowna.

Tous les essais se sont avérés concluants. Lorsque la position de l'aéronef en détresse est transmise avec la première rafale de la radiobalise, les équipes de recherche et sauvetage peuvent être déployées immédiatement, soit deux heures plus tôt, en moyenne, qu'avec la radiobalise sans interface GPS. Ce gain de temps diminue le coût des opérations de sauvetage et augmente les chances de sauver des vies.

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EXECUTIVE SUMMARY

Two previous National Search and Rescue Secretariat initiatives saw the development a 406 MHz Emergency Locator Transmitter (ELT) and a 406 MHz ELT with a Global Position System (GPS) interface. These two ELTs were field-tested in an aircraft at various locations across Canada. The ELT antenna was installed into the tail cone of a Boeing 727 aircraft. Mounting the antenna in this location prevented the puncturing of the aircraft skin, provided protection for the antenna, and allowed a much clearer view of the sky compared with mounting on the fuselage near the rear of the plane. The ELT was placed adjacent to the ELT antenna during the tests.

Tests were completed in Hamilton and Vancouver using the 406 MHz ELT for Phase 1 tests, and in Hamilton and Kelowna using the 406 MHz ELT with GPS interface for Phase 2 tests. In the Phase 1 test in Hamilton, the geostationary satellites received the beacon transmission within 1 minute of beacon activation. The first Doppler location was determined at 62 minutes after activation with an accuracy of 1.6 km. In the Phase 1 test in Vancouver, the geostationary satellites received the beacon transmission within 2 minutes of beacon activation. The first Doppler location was determined at 51 minutes after activation with an accuracy of 1.6 km. In the Phase 2 test in Hamilton, the geostationary satellites received the beacon transmission within 51 seconds of beacon activation and reported a decoded position that was within 31 m of the distress location. In the Phase 2 test in Kelowna, the geostationary satellites received the beacon transmission within 2 minutes of beacon activation and reported a decoded position that was within 40 m of the distress location.

Both phases of this project were successful. The ELT and the ELT with GPS interface both transmitted successfully from an aircraft. Accurate location data were received by the geostationary satellites within two minutes of activating the beacons. The search area was reduced from an average radius of 2 km to a radius of 100 m. This represents a 400:1 reduction in search area. With the distress location included on the first transmission to the satellite, SAR forces

can be deployed immediately, saving an average of two hours, reducing costs, and ultimately saving more lives.

SOMMAIRE

Deux projets antérieurs menés sous l'égide du Secrétariat national Recherche et sauvetage ont permis la mise au point d'une radiobalise de détresse 406 MHz et d'une radiobalise 406 MHz avec interface GPS (*Global Positioning System*). Ces deux radiobalises ont été mises à l'essai en vraie grandeur à bord d'un Boeing 727, à divers endroits au Canada. L'antenne de la radiobalise était installée dans le cône de queue de l'avion. En plaçant l'antenne à cet endroit, on se dispensait de faire des trous dans le revêtement de l'aéronef, on assurait une protection à l'antenne et on obtenait une vue beaucoup plus claire sur le ciel que si on l'avait montée sur le fuselage, dans la partie arrière de l'avion. Pendant les essais, la radiobalise était placée à proximité de l'antenne.

Les essais de la phase 1, mettant en jeu la radiobalise 406 MHz, ont été réalisés à Hamilton et Vancouver, et ceux de la phase 2, portant sur la radiobalise avec interface GPS, à Hamilton et Kelowna. Lors de l'essai de la phase 1 à Hamilton, les satellites géostationnaires ont capté le message de la radiobalise moins d'une minute après l'activation de celle-ci. La première localisation (par mesure de l'effet Doppler) de l'avion a été faite 62 minutes après l'activation, avec une précision de 1,6 km. Lors du même genre d'essai effectué à Vancouver, le message de la radiobalise a été reçu dans les deux minutes suivant l'activation. Il a alors fallu 51 minutes pour effectuer une première localisation Doppler, avec une précision de 1,6 km. Au cours de l'essai de la phase 2 mené à Hamilton, les satellites géostationnaires ont reçu la transmission de la radiobalise dans les 51 secondes de l'activation, et ont décodé la position de l'avion en détresse à 31 m près. Au cours du même type d'essai réalisé à Kelowna, le message de la radiobalise a été reçu dans les deux minutes de l'activation, et la position de l'avion en détresse a été déterminée à 40 m près.

Les deux phases du projet ont été couronnées de succès. Ainsi, les deux radiobalises, avec et sans interface GPS, ont transmis des messages de détresse depuis l'avion. De plus, dans le cas des radiobalises avec interface GPS, les satellites géostationnaires ont capté des données de positionnement précises dans les deux

minutes de l’activation de la radiobalise. Ces données ont permis de mieux circonscrire la zone de recherche, le rayon de celle-ci passant de 2 km, en moyenne, à 100 m,
ce qui représente une superficie 400 fois moindre. Lorsque la position de l’aéronef en détresse est transmise avec la première rafale de la radiobalise, les équipes de recherche et sauvetage peuvent être déployées immédiatement, soit deux heures plus tôt, en moyenne, qu’avec la radiobalise sans interface GPS. Ce gain de temps diminue le coût des opérations de sauvetage et, ultimement, augmente les chances de sauver des vies.

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GLOSSARY

ARINC	Aeronautical Radio, Inc
ELT	Emergency Transmitter Locator
EPIRB	Emergency Position Indicating Radio Beacon
GOES	Geosynchronous Orbiting Environmental Satellite
GPS	Global Positioning System
LEO	Low Earth Orbiting
MCC	Mission Control Centre
SAR	Search and Rescue
TDC	Transportation Development Centre
UTC	Universal Coordinated Time
PR	Probability

1 INTRODUCTION

This document is the final report for the project entitled *Evaluation of a 406 MHz Emergency Locator Transmitter (ELT)*, sponsored by the Transportation Development Centre (TDC).

1.1 Objectives

The objectives, as set out in the contract's Statement of Work, are as follows:

1.1.1 Project Objective

To test and evaluate a 406 MHz ELT in Phase 1 and an ELT with a Global Positioning System (GPS) interface in Phase 2.

1.1.2 R&D Objective

To develop expertise, techniques, and equipment to improve flight safety in the Canadian air transportation system.

1.1.3 R&D Sub-objective

To conduct research and develop techniques and equipment to improve accident survivability.

1.2 Background

Existing TSO C91 ELTs are plagued with problems. False alarm rates are upwards of 97%. Units activate when they should not, and do not activate when they should. The location accuracy of these older beacons is approximately 20 km. Furthermore, because of the high false alarm rate, the Mission Control Centres (MCCs) and Rescue Coordination Centres will not respond immediately to an activated beacon until they are confident that a distress situation is likely. With 406 MHz technology, the transmitted message includes the identity of the user or the aircraft and has a typical location accuracy of 2 km. The location accuracy of the new ELT with GPS interface is improved to approximately 100 m. This is a 400:1 improvement in total search area. The transmitted signal is received by the Cospas-Sarsat satellites and by the Geosynchronous Orbiting Environmental Satellites (GOES). The Cospas-Sarsat satellites are low earth orbiting (LEO) satellites that rely on Doppler shift to determine the beacon's position. It can take an average of 2 hours for a Cospas-Sarsat satellite to be in view of a transmitting beacon. The GOES satellites are in a geostationary orbit and receive signals from the transmitting beacon immediately; however, they cannot determine the beacon's location using Doppler shift. Location information must be included in the message transmitted by the beacon.

This project represents the continuation of several previous initiatives sponsored by the National Search and Rescue Secretariat's New Search and Rescue (SAR) Initiatives Fund, including the design and development of a 406 MHz ELT and a 406 MHz ELT with GPS interface. These units were developed with technologies first implemented in the marine sector and are now being adopted for the aviation sector. The aviation community has been slow to adopt the new 406 MHz beacon technology mainly because of the large installed base and lower cost of the older 121.5 MHz units.

This project evaluates the performance of these ELTs and attempts to introduce the newer technology and highlight its advantages to the aviation community. Some of these advantages include a digital signal with unique identifier and, for the ELT with GPS interface, a near instantaneous distress alert that includes the position coordinates of the distress site.

This initiative supports government priorities to enhance SAR technology and is an integral part of TDC's program to enhance emergency beacon capabilities in Canada.

1.3 Scope

This report discusses the installation concerns and presents the results from ELT Phase 1 testing and ELT with GPS interface Phase 2 testing.

2 WORK UNDERTAKEN AND RESULTS ACHIEVED

2.1 Installation Details

The equipment used for the evaluation project were the Northern Airborne Technology SATFIND-406 ELT Models A-1000 (Figure 1) and A-1500 (Figure 2) connected to a Comant CI319-1 High Speed Triple Frequency antenna (Figure 3). Arrangements were made with Kelowna Flightcraft Ltd. of Kelowna, B.C., to install the equipment on a Purolator BOEING 727 aircraft. The original intent was to install the ELT in the tail of the aircraft, install the cockpit monitor and control unit in the cockpit, and mount the antenna on one side of the fuselage between the rear starboard engine and the vertical member of the tail structure. Unfortunately, completing the installation in this manner would have required a Supplementary Type Certificate (STC). Obtaining an STC would have been an expensive and time-consuming exercise and was beyond the scope of this project. As a result, an alternative mounting technique was required.

Figure 1: NAT SATFIND-406 ELT A-1000

Figure 2: NAT SATFIND-406 ELT A-1500

Figure 3: Comant CI319-1 High Speed Antenna

One approach proposed by Kelowna Flightcraft was to mount the antenna to the rear of the pressure vessel in the tail section of the fuselage. This approach, however, would still require an STC. Also, with the T-tail structure of the tail, significant shadowing of the transmitted signal could result.

Another suggested approach was to mount the antenna on a suitable ground plane, which would then be installed in the tail cone situated at the top of the T-tail between the horizontal stabilizers, as shown in Figures 4 and 5. The advantage of this was that the skin of the aircraft was not pierced. Also, with the antenna mounted inside the tail cone, it would not be subjected to the concentrated airflow patterns that exist in the vicinity of the tail structure and engines. Although a high-speed, triple-frequency antenna was used in this evaluation, a less expensive, low-speed antenna could have been used. Another important advantage of this installation method was that the antenna had a much clearer view of the sky when mounted in the tail cone. This would increase the probability of a successful emergency transmission to the satellites after a crash situation.

Figure 4: Antenna Mounted on Ground Plane Inside Tail Cone

Figure 5: Tail Section of Boeing 727

With the antenna mounted high in the tail cone of the aircraft, the next question was where to mount the actual ELT. The most desirable location was in the rear of the aircraft so that the unit could be accessed easily if required for battery replacement, testing, or manual deactivation. With the ELT mounted in the rear of the aircraft, however, the length of coaxial cable between the ELT and the antenna would have been far too long. The estimated loss would have been greater than 3 dB at 406 MHz, making this arrangement impossible. The nominal output level of the ELT is 5W +/- 2dB. There is not enough battery capacity to boost the output level of the ELT by 3 dB, not to mention the higher cost of the electronics. The other option was to mount the ELT in the tail cone section adjacent to the antenna. This mounting arrangement would limit the signal loss between the ELT and the antenna, but would increase the length of control cable required between the ELT and the remote switch. A disadvantage of this approach was that the ELT would not be easily accessible for battery replacement or in case of unit malfunction. The composite structure of the tail cone provided a negligible amount of attenuation for the 406 MHz and 121.5 MHz signals.

The ELT's unique identification number was A79C20001040403. This unit was test coded and the 121.5 MHz homing signal was disconnected. Canadian Mission Control Centre in Trenton, Ontario, assisted by providing the received satellite data for the evaluation.

For Phase 1 tests, the ELT was activated and tested on Flightcraft 725 in Hamilton, Ontario, on December 11, 2000, and in Vancouver, B.C., on December 21, 2000. For Phase 2 tests, the ELT with the GPS interface was activated and tested on Flightcraft 725 in Hamilton, Ontario, on February 2, 2001, and in Kelowna, B.C., on February 17, 2001. For Phase 2 tests, the ARINC 429 bus was not available so an ARINC 429 simulator was used to download the GPS location data into the ELT. A remote switch, provided by Artex Aircraft Supplies, was used to activate the beacon manually.

2.2 Test Results

2.2.1 Phase 1: Hamilton Test

Test Location: 43°10.0´ N
79°56.0´ W

Table 1: Hamilton Test Result - Phase 1

Time (UTC)	ΔTime (min)	Satellite	LEO		
			Doppler Location	PR	Doppler Accuracy
184500	UNIT ACTIVATED				
184600	1	GOES 10			
184600	1	GOES 8			
194700	62	S8	43°10.2´ N 79°56.7´ W	97%	1000 m
202100	96	S6	43°9.8´ N 79°56.9´ W	96%	1300 m
202700	102	C8	43°10.0´ N 79°56.3´ W	96%	400 m
204900	124	C4	43°9.5´ N 79°55.2´ W	89%	1400 m

2.2.2 Phase 1: Vancouver Test

Test Location: 49°11.7´ N
123°10.9´ W

Table 2: Vancouver Test Result - Phase 1

Time (UTC)	ΔTime (min)	Satellite	LEO		
			Doppler Location	PR	Doppler Accuracy
163600	UNIT ACTIVATED				
163700	1	GOES 10			
163800	2	GOES 8			
172700	51	S4	49°11.3´ N 123° 9.7´ W	99%	1600 m
180000	84	S7	49°11.2´ N 123°10.1´ W	93%	1300 m
183300	117	C8	49°10.9´ N 123°10.0´ W	98%	1800 m
190800	152	S4	49°11.5´ N 123°10.3´ W	96%	800 m
194900	193	S8	49°10.7´ N 123°10.3´ W	84%	2000 m

2.2.3 Phase 2: Hamilton Test

The coordinates of the actual test location were determined from a Garmin GPS receiver. These coordinates were input manually into the ARINC 429 simulator via a laptop computer to simulate the ELT being connected to the aircraft's navigation system.

Hamilton Test Location: 43°09.75′ N
79°56.07′ W

Table 3 shows the results of the Hamilton test.

Table 3: Hamilton Test Result - Phase 2

Time (UTC)	ΔTime (min)	Satellite	LEO				GOES	
			Doppler Location	PR	Reported Position	Doppler Accuracy	Decoded Position	Accuracy
190000	UNIT ACTIVATED							
190051	51 sec	GOES 8					43° 09.73′ N 79° 56.07′ W	31 m
190051	51 sec	GOES 10					43° 09.73′ N 79° 56.07′ W	31 m
190200	2	C6	43° 10.0′ N 79° 55.3′ W	60%	43° 00′ N 79° 45.0′ W	1140 m		
192500	25	C9	43° 10.1′ N 79° 56.2′ W	97%	43° 00′N 79° 45.0′ W	670 m		
195800	58	S6	43° 10.8′ N 79° 57.5′ W	98%	43° 00′ N 79° 45.0′ W	2750 m		
204500	105	S8	43° 10.8′ N 79° 56.4′ W	78%	43° 09.7′ N 79° 56.1′ W	2000 m		
213000	150	S7	43° 12.8′ N 79° 58.9′ W	71%	43° 09.7′N 79° 56.1′ W	6830 m		
213800	158	S6	43° 10.4′N 79° 54.6′ W	92%	43° 00′ N 79° 45.0′ W	2320 m		

2.2.4 Phase 2: Kelowna Test

Again, the coordinates of the actual test location were determined from a Garmin GPS receiver. These coordinates were input manually into the ARINC 429 simulator via a laptop computer to simulate the ELT being connected to the aircraft's navigation system.

Kelowna Test Location: 49°11.7´ N
123°10.9´ W

Table 4 shows the results of the Kelowna test.

Table 4: Kelowna Test Result - Phase 2

Time (UTC)	ΔTime (min)	Satellite	LEO				GOES	
			Doppler Location	PR	Reported Position	Doppler Accuracy	Decoded Position	Accuracy
190420	UNIT ACTIVATED							
190513	47 sec	GOES 10					49° 57.3´ N 119° 22.9´ W	40 m
190608	115 sec	GOES 8					49° 57.3´ N 119° 22.9´ W	40 m
193606	32	S4	49° 57.6´ N 119° 23.3´ W	99%	49° 57.3´ N 119° 22.9´ W	4253 m		
195350	48	S8	49° 58.5´ N 119° 22.6´ W	98%	49° 57.3´ N 119° 22.9´ W	2216 m		
210932	124	S4	49° 57.5´ N 119° 23.1´ W	87%	49° 57.3´ N 119° 22.9´ W	407 m		
212815	143	S8	49° 56.2´ N 119° 23.3´ W	74%	49° 57.3´ N 119° 22.9´ W	527 m		
215042	165	S6	49° 58.4´ N 119° 24.5´ W	90%	49° 45.0´ N 119° 15.0´ W	2764 m		
224103	217	S4	49° 57.5´ N 119° 23.1´ W	97%	49° 57.3´ N 119° 22.9´ W	407 m		

2.3 Discussion

When the ELT was activated in the Phase 1 testing, the GOES satellites detected the transmissions in less than 2 minutes. At this point, the MCC would know that an ELT had been activated and be able to identify the ELT, but it would not know the distress location. The distress location is not known until the footprint of a Cospas-Sarsat satellite passes over the transmitting ELT. In Hamilton, the first Cospas-Sarsat satellite pass was 62 minutes after beacon activation and produced a Doppler location that was within 1.0 km. In Vancouver, the first Cospas-Sarsat satellite pass was 51 minutes after beacon activation and produced a Doppler location that was within 1.6 km. The typical average time for a Cospas-Sarsat satellite to be within view of a beacon is about 2 hours and the typical average Doppler location accuracy is about 2 km.

When the ELT with GPS interface was activated in Phase 2, the GOES satellites detected the transmissions in less than 2 minutes. With the GPS location data included in the transmitted message, the MCC would almost instantaneously receive the identity and the location of the ELT to an accuracy of about 100 m. In some cases, the decoded location data from the LEO satellites defaulted to the first protected field (nearest 1/4 degree) because the Cospas satellites could not decode the long message. Also, when too many errors are received in the second protected field, that field is ignored.

3 CONCLUSIONS

The ELT antenna was installed into the tail cone of a Boeing 727 aircraft. Mounting the antenna in this location prevented the piercing of the pressure vessel and of the aircraft skin. The tail cone also provided inherent protection for the antenna. Furthermore, the antenna had a much clearer view of the sky when mounted in the tail cone compared with mounting on the fuselage near the rear of the plane. If the antenna were mounted on the fuselage, the shadowing effect of the T-tail structure could significantly limit the transmission of the emergency signals to the satellite. The ELT was placed adjacent to the ELT antenna during the tests.

Tests were completed in Hamilton and Vancouver for Phase 1, and Vancouver and Kelowna for Phase 2. In the Phase 1 test in Hamilton, GOES 8 and GOES 10 received the beacon transmission within 1 minute of beacon activation. The first Doppler location was determined at 62 minutes after activation with an accuracy of 1.6 km. Subsequent Doppler locations occurred at 96, 102, and 124 minutes after activation with accuracies of 1.3, 0.4, and 1.4 km respectively. In the Phase 1 test in Vancouver, GOES 8 and GOES 10 received the beacon transmission within 2 minutes of beacon activation. The first Doppler location was determined at 51 minutes after activation with an accuracy of 1.6 km. Subsequent Doppler locations occurred at 84, 117, 152, and 193 minutes after activation with accuracies of 1.3, 1.8, 0.8, and 2.0 km respectively. In the Phase 2 test in Hamilton, GOES 8 and GOES 10 received the beacon transmission within 51 seconds of beacon activation and reported a decoded position that was within 31 m of the position input to the ARINC 429 simulator. This accuracy is somewhat meaningless as the beacon-coding scheme has a precision of only 100 m. The first LEO Doppler location was determined at 2 minutes after activation with a Doppler accuracy of 1.14 km. Subsequent Doppler locations occurred at 25, 58, 105, 150, and 158 minutes after activation with accuracies of 0.67, 2.75, 2.00, 6.83, and 2.32 km respectively.

In the Phase 2 test in Kelowna, GOES 10 received the beacon transmission within 47 seconds of beacon activation. GOES 8 received the first transmission within 2 minutes of beacon activation. The first Doppler location was determined at 32 minutes after activation with an accuracy of 4.2 km. Subsequent Doppler locations occurred at 48, 124, 143, 165, and 217 minutes after activation with accuracies of 2.2, 0.4, 0.5, 2.7, and 0.4 km respectively.

Both phases of this project have been successful. The ELT and the ELT with GPS interface transmitted successfully from an aircraft. Accurate location data was received by the GOES satellites within two minutes of activating the ELT with GPS interface. The search area was reduced from an average radius of 2 km to a radius of 100 m. This represents a 400:1 reduction in search area, which means search and rescue teams can fly virtually directly to a distress site. With the distress location included on the first transmission to the satellite, SAR forces can be deployed immediately, saving an average of two hours, reducing SAR costs, and ultimately saving more lives.

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