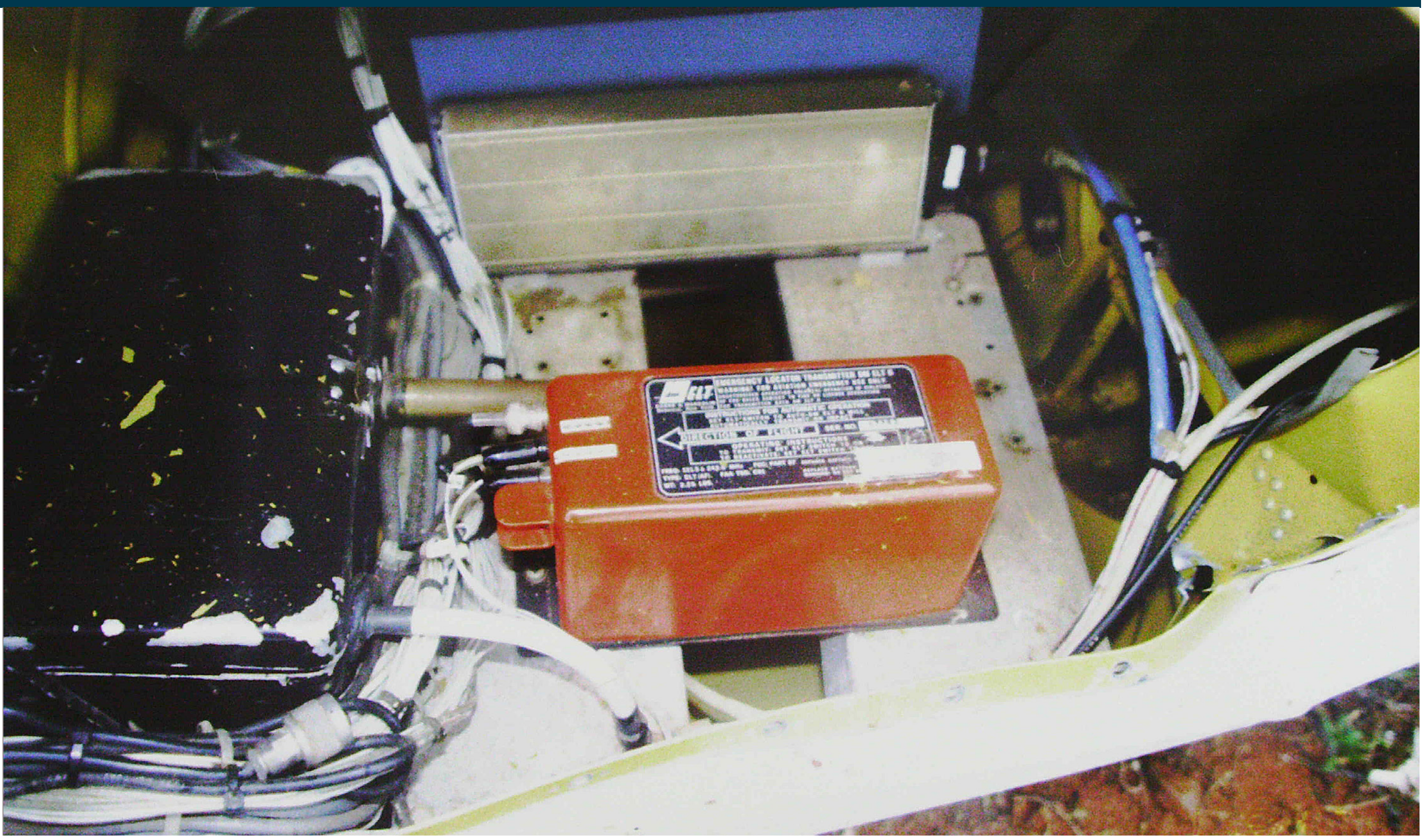
Australian Government

Australian Transport Safety Bureau

A review of the effectiveness of emergency locator transmitters in aviation accidents



Research

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Safety summary

Why the ATSB did this research

Emergency locator transmitters are radio beacons carried on most aircraft so that in the event of an accident in a remote location the aircraft wreckage and its occupants can be located quickly by search and rescue (SAR) operations. Finding the aircraft wreckage quickly not only increases the chance of survival of the occupants, but also reduces the risk to pilots of SAR aircraft who commonly need to operate in marginal weather conditions and over mountainous terrain.

Airframe mounted emergency locator transmitters (ELTs) are designed to automatically activate following an impact typical of a collision. However, the effectiveness of airframe ELTs in aviation accidents has been questioned for some time by accident investigation agencies and by the aviation community. Beyond individual examples of ELTs not activating following an accident, there has been little research done to date to review how reliably ELTs operate as designed after an aircraft accident. In this research investigation, the ATSB identifies safety concerns regarding the operation of ELTs and presents data on the effectiveness of ELTs activating following an accident.

What the ATSB found

Data from the ATSB database show that ELTs function as intended in about 40 to 60 per cent of accidents in which their activation was expected.

Records of the Australian Maritime Safety Authority's SAR incidents shows that search and rescue personnel were alerted to aviation emergencies in a variety ways including radio calls and phone calls, and that ELT activation accounted for the first notification in only about 15 per cent of incidents. However, these ELT activations have been directly responsible for saving an average of four lives per year.

In accidents where ELTs did not work effectively (or at all) it was found that their performance could be affected by:

- not selecting the ELT activation to armed before flight
- incorrect installation
- flat batteries
- lack of water proofing
- lack of fire protection
- disconnection of the co-axial antenna cable from the unit during impact
- damage and/or removal of the antenna during impact
- an aircraft coming to rest inverted after impact.

Safety message

Pilots and operators of general aviation and low capacity aircraft need to be aware that a fixed fuselage mounted ELT cannot be relied upon to function in the types of accidents in which they were intended to be useful. The effectiveness of ELTs in increasing occupant safety and assisting SAR efforts may be enhanced by using a GPS-enabled ELT, using an ELT with a newer 3-axis g-switch, ensuring it is installed correctly, ensuring your beacon is registered with AMSA and pre-emptively activating the beacon if a forced landing or ditching is imminent. Additionally, carrying a personal locator beacon (PLB) in place of or as well as a fixed ELT will most likely only be beneficial to safety if it is carried on the person, rather than being fixed or stowed elsewhere in the aircraft.

Contents

Context

Emergency locator transmitters are radio beacons carried on most aircraft so that in the event of an accident in a remote location, the aircraft wreckage and its occupants can be located quickly by search and rescue (SAR) operations. Finding the aircraft wreckage quickly not only increases the chance of survival of the occupants, but also reduces the risk to pilots of SAR aircraft who commonly need to operate in marginal weather conditions and over mountainous terrain.

Issues regarding the effectiveness of emergency locator transmitters (ELTs) activating as designed following an aircraft accident have been observed by pilots, operators, accident investigators and search and rescue personnel since the inception of ELTs in aircraft in the 1970s. Following an ATSB investigation of a fatal aircraft accident in 2011 where the ELT activation was less than intended due to damage sustained in the accident[1], the Australian Maritime Safety Authority (AMSA) recommended that the inadequacies of ELTs should attract greater scrutiny so that known shortcomings can be addressed. However, evidence of ELT effectiveness has to date remained largely anecdotal and qualitative. This research investigation provides an overview of the use of ELTs, and provides basic quantitative evidence of their effectiveness. Specifically, the aims were to:

- provide an overview of ELTs and their use in Australian aviation
- provide quantitative data showing how effective ELTs are in the types of aircraft accidents in which they are intended to be useful for enhancing survivability and search and rescue efforts
- document any safety concerns learned through accident investigation regarding the use of ELTs.

Types of Emergency Radio Beacons

Emergency locator transmitters (ELTs) are one of three types of emergency radio beacons that are used to provide a location fix on a person, aircraft, ship, or other vehicle. This group also includes emergency position indicating radio beacons (EPIRBs) and personal locator beacons (PLBs). All three devices perform essentially the same task but differ in their design, intended application and method of activation.

Each of these radio beacons operates by sending a signal which is received by a network of satellites managed globally by Cospas-Sarsat[2] who then pass on the distress information to the closest search and rescue (SAR) organisation. In Australia, Australian Search and Rescue (AusSAR) operates a 24-hour rescue coordination centre and is responsible for the national coordination of search and rescue. This service is provided by AMSA.

Historically, these beacons broadcast an analog signal on 121.5/243 MHz. However, as of 1 February 2009 all beacons are required to broadcast a digital signal in the frequency band between 406.0 and 406.1 MHz. Additionally, ELTs are still required to broadcast an analog 121.5 MHz signal; although no longer processed by satellites, the 121.5 MHz signal can still be received by aircraft to assist determining location during SAR. Although not currently a compulsory feature,

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[1] See case study *In-flight breakup in stormy conditions – Cessna 210M Centurion* (ATSB investigation AO-2011-160) below on page 11.

[2] The International Cospas-Sarsat program is an intergovernmental organisation established in 1988 by Canada, France, the former USSR, and the USA. A further 41 states and 2 organisations are now currently formally associated with the program and actively participate in the management and the operation of the Cospas-Sarsat System. COSPAS (КОСПАС) is an acronym for the Russian words 'Cosmicheskaya Sistema Poiska Avariynyh Sudov' (Космическая Система Поиска Аварийных Судов), which translates to 'Space System for the Search of Vessels in Distress'. SARSAT is an acronym for Search And Rescue Satellite-Aided Tracking.

all types of radio beacons may be Global Positioning System (GPS) [3] equipped, significantly improving both the accuracy of tracking signals and the time required to fix its position.

GPS-enabled beacons use geostationary earth orbiting (GEO) satellites which are fixed in their relative position in the sky and cover most of the Australian mainland all the time. As such, AMSA can usually acquire the position of GPS-enabled beacons in a matter of minutes with an accuracy of about 120 meters.[4] In contrast, non-GPS-enabled beacons rely on low earth orbiting (LEO) satellites, which overfly Australia on an irregular basis, to obtain a fix on position. Although GEO satellites will still detect a non-GPS beacon and relay the beacon identifier to AMSA (which can assist SAR if the beacon is registered), the GEO satellites cannot determine the location of the beacon. Thus, the time required to acquire a fix on a non-GPS-enabled beacon is variable, averaging 90 minutes but can be as long as 5 hours depending on conditions and the availability of satellites, and with an accuracy of only about 5 km.

Emergency locator transmitters (ELTs)

Usually fixed in aircraft, ELTs are designed to be activated automatically during a crash, typically by a g-force[5] activated switch or, less commonly, by a water-activated switch. Additionally, ELTs can also be wired into a remote switch on the instrument panel of an aircraft for manual activation by the pilot or a passenger. Once activated, ELTs are required to operate continuously for at least 24 hours. About the size of a 1 litre carton of milk, many ELTs are designed to be portable so that in the event of a crash they can be removed from the aircraft (or wreckage) to a safer location and manually activated if necessary. As such, airframe mounted ELTs are often positioned where they are easily accessible; near cargo doors or access panels for example.

The g-switch in an ELT generally functions in only one plane of orientation (although newer 3-axis g-switches are now available, they are not currently mandated). In fixed-wing aircraft, ELTs are mounted horizontally so that the switch is triggered by fore-aft displacement (along the length of the aircraft), whereas in helicopters, they are mounted at 45° relative to the horizontal plane of the aircraft.

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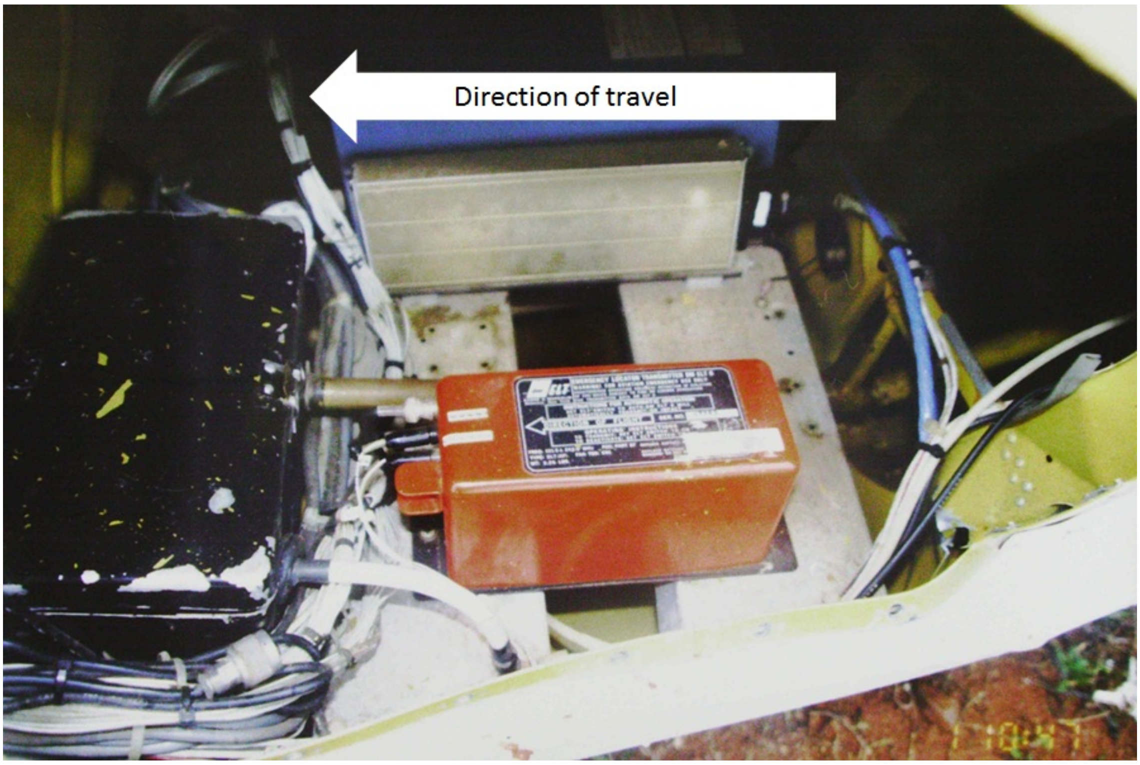
3 GPS (Global Positioning System) is a worldwide navigational facility based on the reception of signals from an array of orbiting satellites.

4 Although both GEO and LEO satellites will pick up and relay the GPS position from a GPS-enabled beacon, unless there happens to be a LEO satellite passing overhead at the time, it is likely that the GPS position will be first received from GEO satellites.

5 The force needed to accelerate a mass. G-force is normally expressed in multiples of gravitational acceleration (normal gravity = 1g).

Figure 1: An example of a fixed ELT mounted in the rear fuselage of a light aircraft



Source: ATSB

Personal locator beacons (PLBs)

These beacons are designed for personal use and are usually smaller in size (roughly pocket sized). Originally intended for personal land use (for example, hiking or remote 4×4 driving), these devices are now finding use in other environments. Changes to the Civil Aviation Regulation 1988 (CAR) 252A mean that since 31 July 1997, a PLB or EPIRB may be used as an alternative to an airframe mounted ELT, provided the requirements to be an eligible portable ELT are met (see Appendix A for details).Thus, it is common for the same PLB to be used by an owner for bushwalking and for recreational boating or in a general aviation aircraft. PLBs are manually activated and are required to operate continuously for 24 hours once activated.

Figure 2: Two examples of typical PLBs

Source: AMSA

Emergency position indicating radio beacons (EPIRBs)

Intended for ships, boats and maritime personnel, EPIRBs are water proof and designed to float. EPIRBs can be either manually activated, water activated, or both, and are required to operate for a minimum of 48 hours continuously once activated.

Figure 3: Two typical examples of EPIRBs

Source: AMSA

Aircraft required to carry an ELT

In Australia, all aircraft are required to carry an approved ELT with the following exceptions: high capacity regular public transport and charter aircraft[6], single seat aircraft, turbojet-powered aircraft, balloons, airships and gliders. Additionally, there are several operational exemptions which include: flights within 50 NM of the aerodrome from which the flight began, agricultural operations, permission given by CASA under CASR 21.197, flights involving the delivery of new aircraft or associated with manufacture of the aircraft, and a flight for the purpose of moving the aircraft to a place to have an ELT fitted or to have one repaired, removed or overhauled.

6 High capacity aircraft are defined as having more than 38 seats of a higher maximum payload of 4,200 kg.

Safety analysis

Review of occurrences reported to the ATSB

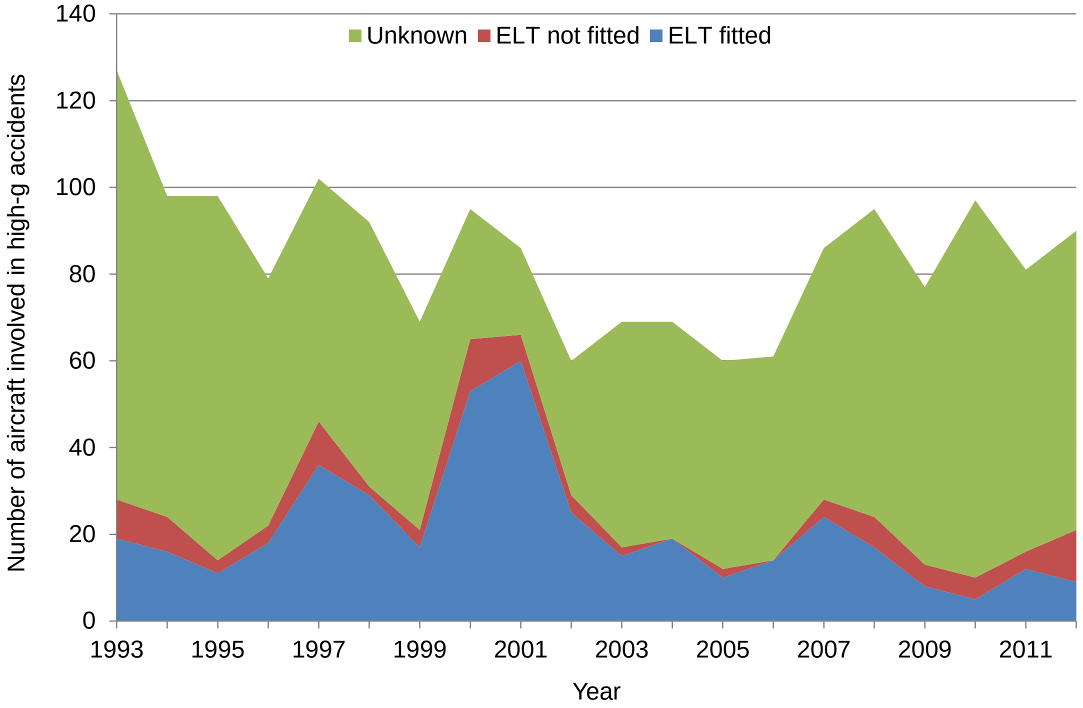
The ATSB database of aviation occurrences was analysed from 1993 to 2012. As ELTs are designed to activate by a g-force, only accident types in which the activation of an ELT was deemed to have been expected have been included in this analysis. Additionally, the ELT exempted aircraft types and operation types have been removed from the analysis as far as possible. The types of accidents which could potentially involve high g-forces are as follows:

- collisions on ground
- collisions with terrain
- controlled flight into terrain
- ditching
- forced landings
- hard landings – helicopters only
- In-flight break-up
- mid-air collisions
- wire strikes.

For the purposes of this report, these will be called 'high g-force' accidents.

An important caveat for the following analysis is that there have been significant changes to the design and construction of ELTs over the past 20 years, including their fire and crash ratings, and the frequency on which they transmit distress signals. Of particular note are regulatory changes that came into effect in Australia in February 2009 resulting in the change in transmission frequency (requiring the purchase of an ELT/PLB capable of transmitting a digital signal), and in general aviation, the ability to use approved PLBs and EPIRBs in place of a fixed ELT since 31 July 1997 (see appendix A for details). Nevertheless, the following figures give an indication of how effective ELTs are in high g-force accidents.

Figure 4: High g-force accidents reported to the ATSB and the fitment of ELTs, 1993 to 2012



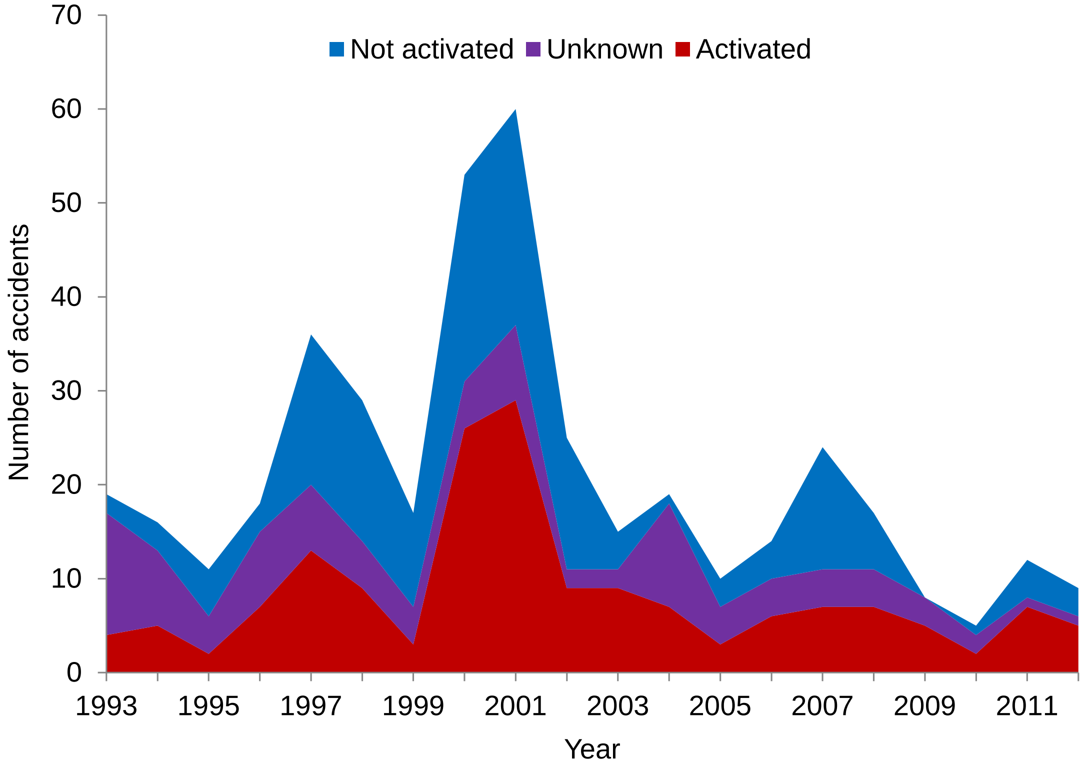
It is clear that data is not well recorded on the fitment of ELTs to aircraft, even in accidents where they are designed to activate. For the 20 year period there were 1,691 high-g accidents for non-ELT exempt aircraft. Of these, in 417 (25%) of the accidents it was known that an ELT was fitted and in 103 (6%) it was known that an ELT was not fitted. The fitment of an ELT was unknown for the remaining 69 per cent.

The proportion of high g-force accidents where it was not known if an ELT was fitted remained reasonably consistent at about 60 accidents per year between 1993 and 2012. The unknown data is a result of this information not being reported for accidents not investigated by the ATSB, or not collected or not able to be collected when the accident was investigated. In addition, as ATSB occurrence recording has only considered whether an ELT was fitted to the aircraft, accidents where a PLB or EPIRB was used may not have been recorded as the aircraft having an ELT fitted. An additional consequence of this categorisation method is that it is not possible to distinguish in the ATSB data whether the beacon used following an accident was an ELT, PLB or EPIRB.

Additionally, at least six per cent of these accidents had no ELT fitted, even though this data applies to aircraft that were required to carry ELTs. However, all or some of these flights may have been exempt if they were not flying more than 50 NM from the aerodrome.

Taking a closer look at the available data, Figure 5 focuses on whether the ELT activated in the high g-force accidents in which it was known that an ELT was fitted.

Figure 5: Fitted ELTs that were activated in high-g force accidents, 1993 to 2012

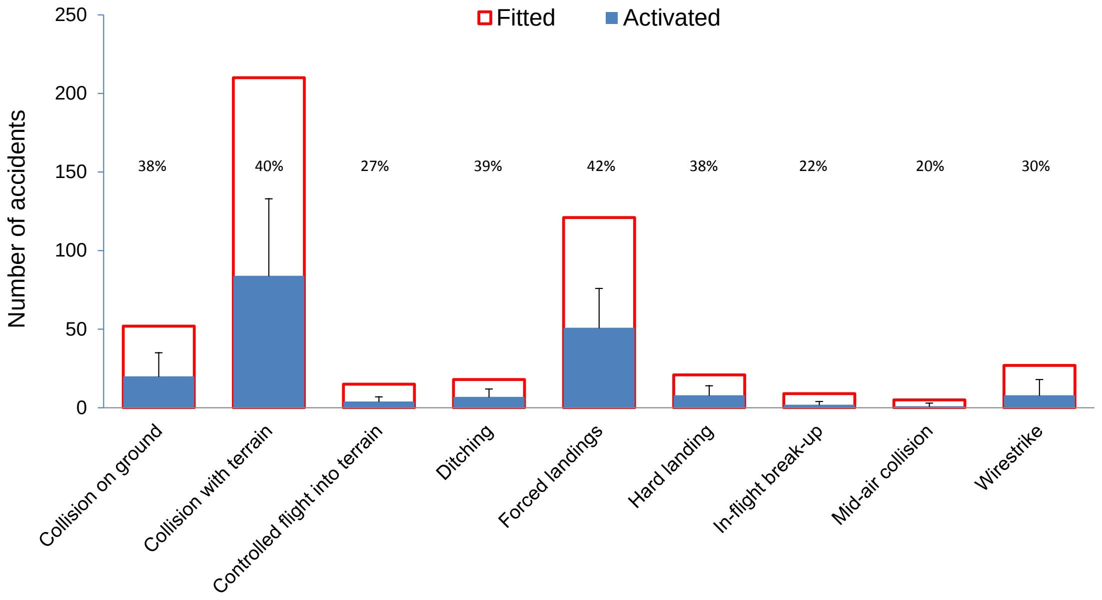


Although the overall number of accidents where it was known the ELT was fitted varies significantly each year over this time period, Figure 5 shows that the ratio of not activated to activated ELTs is relatively consistent, with ELTs being known to have activated in about 40 per cent of accidents. However, it should be noted that activation was unknown in 24 per cent of these accidents, and some of these accidents may have involved an ELT activation which ATSB investigators were unaware of. As such, it is possible that ELT activation may be as high as 64 per cent, but is likely to be somewhere between about 40 and 60 per cent.

Prior to 2009, 37 per cent of fitted ELTs activated and 38 per cent did not activate. However, in the 29 accidents since 2009 (when an ELT/PLB capable of transmitting a digital signal was required), 52 per cent activated and only 24 per cent did not activate.

The data in Figure 5 are an aggregate of all high g-force accident types. To see if there are any differences in the proportion of fitted ELTs failing to activate in any particular accident types, Figure 6 shows the number of fitted ELTs that activated in each type of accident reported to the ATSB in the past 20 years.

Figure 6: Number of fitted ELTs which activated for high g-force accidents by occurrence type, 1993 to 2012



In each individual occurrence type in the high g-force accident set, fitted ELTs were known to have activated in between 20 and 42 per cent of accidents. However, due do the number of unknown data, the maximum activation rate is probably higher (as represented by the error bars in Figure 6). Typically, those types of accidents involving more impact force (controlled flight into terrain, in-flight breakup, mid-air collision, and wire strike) had lower proportions of accidents where the fitted ELT activated due to the destructive nature of such accidents.

Review of AMSA search and rescue incidents

The Australian Maritime Safety Authority (AMSA) maintains a database of all incidents in which they were involved in search and rescue activity. A data set containing information from incidents between June 1999 and December 2012 was provided by AMSA to the ATSB. The ATSB conducted the analysis of this data.

The data show that that for the time period between June 1999 to December 2012, there was a total of 7,441 search and rescue incidents, of which 442 pertain specifically to aircraft crashes or inflight emergencies. A summary of how AusSAR was first notified of these aviation related emergencies is shown in Table 1.

Table 1: Method by which AusSAR was alerted to emergencies related to aircraft crashes or inflight emergencies.

Alert Method	Number	Per cent
Third party concern	106	24.0
VHF voice call	95	21.5
Advised by other agency	74	16.7
Phone (terrestrial)	64	14.5
Aircraft detection of beacon	**35**	**7.9**
Cospas-Sarsat Beacon	**33**	**7.5**
Phone (mobile)	13	2.9
SAR watch[7]	11	2.5
Other	6	1.4
HF voice call	4	0.9
Phone (satellite)	1	0.2
Total	**442**	**100**

These data show that ELT activation is only one of many ways in which AusSAR are informed of an aviation emergency. The most common method is by a third party (24%) contacting AMSA's Rescue Coordination Centre to report seeing or hearing an aircraft possibly in trouble or crashed. This is followed by VHF radio calls from pilots (21.5%). Other agencies, for example Airservices Australia, account for 16.7 per cent of notifications followed by phone calls (14.5%).

Of particular interest here are the incidents in which an ELT (or PLB) has assisted a search and rescue effort and benefitted occupant safety. ELT/PLB activation, which can be detected either by satellite (Cospas-Sarsat) or by another aircraft, represented a total of 68 or 15.3 per cent (combined) of the incidents. The AMSA data reveals that 52 lives were saved in these 68 incidents. In other words, an ELT/PLB has directly contributed to saving the lives of 52 aircraft occupants since June 1999, equating to four lives saved per year on average.

7 Search And Rescue or SAR watch is the system by with Air services Australia follows up on overdue flight plans.

Accident investigation case studies

A review of high g-force accidents reported to the ATSB from 1993 to 2012 showed that emergency locator transmitters (ELTs) have functioned in about 40 to 60 per cent of these accidents. There are various reasons why ELTs may not activate. Inspection of aircraft wreckages during accident investigations have discovered a number of reasons, including the pilot not selecting the ELT activation to armed before flight, incorrect installations and flat batteries, a lack of water proofing or fire protection, the disconnection of the co-axial antenna cable from the unit during impact or damage and/or removal of the antenna during impact, aircraft coming to rest inverted after impact, and of course, the complete destruction of the aircraft to a point where very little remained intact.

Outlined below are a number of accident case studies from ATSB investigations in which one or more of these issues has manifested from an accident.

Power loss, turn back, and loss of control – Piper PA-30 Twin Comanche

ATSB investigation 200102253

On May 23 2001, the owners of a Piper Twin Comanche were conducting a short flight from Archerfield Airport, Queensland to test a newly fitted left propeller governor. Shortly after the aircraft took off, smoke was seen emanating from both sides of the left engine. The pilots shut down the left engine, and initiated a turn back to the airport to land. Witnesses observed the aircraft commence a left circuit at very low level, estimated to be 100 ft above ground level. While initiating a turn during the circuit, the aircraft's angle of bank suddenly increased and it descended rapidly into the ground. Both occupants sustained fatal injuries.

During the initial investigation response by the ATSB, it was noticed that the aircraft was fitted with what appeared to be a reasonably new ELT. Examination of the wreckage found that the ELT was mounted in a fixed cradle on the right side of the fuselage, immediately behind the rear cabin bulkhead. The beacon did not activate as a result of the initial impact. On the day following the accident when the on-site investigation work was complete, the wreckage was transported to a nearby hangar by a tilt bed truck. As the wreckage was lowered from the truck and came into contact with the concrete floor of the hangar, the ELT activated. Closer examination showed that the ELT and cradle had been fitted to the aircraft incorrectly, in that the base of the ELT was facing in the wrong direction.

Figure 7: Wreckage of the Piper Twin Comanche near Archerfield Airport, Qld

Source: ATSB

Observation

While the ELT survived the collision with terrain and was fully functional, incorrect installation resulted in it not activating as intended. This type of ELT was fitted with only a single plane g-switch (3-axis g-switches are now available) that required it to be fitted so that the impact forces are felt through the base of the unit. This requires that this type of ELT be fitted with the base aligned in the direction of travel.

An advantage of ELTs with a g-force activated switch that only operates in one axis is that they are not likely to accidentally activate due to turbulence, however, this may result in the ELT not activating in some types of accidents where there is not a high forward load in the aircraft impact (such as in an in-flight breakup, or in a hard landing). Additionally, the use of a g-switch designed to operate in a particular spatial orientation means correct positioning and installation is critical in ensuring the device can function as intended, as demonstrated in this accident.

In-flight breakup in stormy conditions – Cessna 210M Centurion

ATSB investigation AO-2011-160

On 7 December 2011, the owner-pilot of a Cessna 210M was conducting a private flight under visual flight rules from Roma to Dysart in Queensland. Thunderstorms with associated cloud, rain and severe turbulence were forecast for the area. About 30 minutes into the flight, the outer sections of the wings and parts of the tail separated. The aircraft collided with terrain, fatally injuring the pilot.

When the aircraft did not arrive in Dysart as expected, AMSA’s Rescue Coordination Centre was advised the next morning. AMSA’s Rescue Coordination Centre initiated and managed a search that identified brief 406 MHz ELT signals. The ELT signal was insufficient for AMSA to determine its location but they were able to derive the approximate position of the aircraft wreckage from on-board mobile phone signals. Just after 1600, the aircraft wreckage was sighted about 100 km north-north-west of Roma, near the town of Injune.

Figure 8: Wreckage of the Cessna 210M near Injune, Qld

Source: ATSB

Observation

In situations like in-flight breakups, aircraft debris is likely to be scattered over a wide geographic area, and while an ELT may have activated and survived, it may not indicate the location of the main aircraft wreckage. Although the ELT survived and activated in this accident, during the impact with terrain it detached from its fuselage mounting tray, separating the unit from the aerial cable. Broken antennae and disconnected antenna cables are a commonly observed reason for ELTs not functioning as intended in some high-g force accidents, as either case greatly reduces the transmission range. This is particularly the case in accidents where the aircraft fuselage is seriously disrupted, as in controlled flight into terrain (CFIT) and in-flight break-ups. In this accident, AMSA did not receive position information from the ELT itself, but from on-board mobile phones; a technique which is becoming increasingly frequent.

Controlled flight into terrain – Piper PA-28 Cherokee

ATSB investigation199900044

On 2 January 1999, the pilot of a Piper Cherokee was conducting a visual flight rules flight with a passenger from Walgett to an airstrip near Merriwa, New South Wales. The aircraft failed to arrive at its destination and a search was subsequently initiated. The wreckage of the aircraft was located two days later on the top of a ridge, 3,880 ft above mean sea level, and slightly to the left of the aircraft's intended track between Walgett and Merriwa.

The ATSB investigation into this accident found that the aircraft collided with trees during a right turn, at a rate of descent of about 2,500 ft/min. The impact severed the outboard section of the right wing. The aircraft then collided with other trees before striking the ground. The right fuel tank had ruptured as the aircraft descended through the trees and an intense post-impact fire had consumed the cabin area and the fuselage section immediately behind the cabin. Although the accident was survivable, both the pilot and passenger received extensive burns while escaping from the burning wreckage. The pilot died some time later from his injuries, before the aircraft and surviving passenger were located by SAR personnel. An ELT, mounted in the aft cabin area of the aircraft, was destroyed by the fire. While it was not possible to determine if the ELT had activated during the accident sequence, no signal from the ELT had been received by the satellite monitoring system. The pilot was known to possess a personal ELT; however, this was not located after the accident.

Figure 9: Wreckage of the Piper Cherokee 37 km east of Coolah, NSW (the location of the burnt ELT is outlined in red)

Source: ATSB

Observation

Unfortunately, fixed ELTs are not particularly fire resistant and there have been a number of investigated accidents where there was a post-impact fire in which the ELT burnt before a signal was received. In this accident, one of the occupants survived with serious wounds for approximately 40 hours after impact before succumbing to these injuries. Had the ELT survived the initial impact and subsequent fire long enough to send a signal, it may have shortened the time taken for SAR to locate and arrive at the accident site, and could have improved the survivability of the accident.

Fuel emergency and ditching – IAI Westwind 1124A

ATSB investigation AO-2009-072

On the night of 18 November 2009, an Israel Aircraft Industries Westwind 1124A (Figure 10) ditched into the sea 5 km SW of Norfolk Island Airport. All six occupants survived the ditching and were able to egress the aircraft and were later rescued by boat crews from Norfolk Island.

The omission of the anticipated location of the ditching in the last transmission to the airport Unicom operator resulted in the rescue boats initially proceeding to an incorrect location. Fortunately, observation of the survivors by an airport fire-fighter facilitated the re-direction and timely arrival of the rescue craft at the scene of the ditching.

Figure 10: The Israel Industries Westwind 1124A.

Source: ATSB

The aircraft was fitted with a fixed, fuselage mounted 406 MHz ELT. The ELT was equipped with a g-switch and could be manually activated by a switch in the cockpit. The aircraft was also equipped with four personal locator beacons (PLBs) that could be carried separately and manually activated. Two of these beacons were installed in the life rafts, and one of the remaining beacons was equipped with Global Positioning System (GPS) equipment, which would enable it to transmit its position when it was activated. The aircraft occupants were unable to retrieve any of the PLBs or the life rafts before they exited the aircraft after the ditching. The aircraft-mounted ELT was not GPS-equipped. A geostationary satellite received one transmission from that ELT and the information associated with that transmission was received by AusSAR 8 minutes after the aircraft ditched. AusSAR was able to identify the owner of the ELT, but was not able to assess its location from the one transmission.

Observation

This case highlights three potential safety concerns relating to both ELTs and PLBs; the water resistance of fixed ELTs, the GPS functionality of ELTs, and the passenger/crew awareness and access to PLBs.

Although EPIRBs are required to be waterproof, there is no such requirement for fixed ELTs, which could have contributed to this ELT failing 8 minutes after ditching.

The 8 minutes in which the ELT was functioning was sufficient for only one signal to be received by satellites. This first signal contained the unique hex identifier but not any position information. As a result, the registration of the ditched aircraft was received but not any information regarding its location. Had the ELT been GPS-enabled, it is possible that further information regarding its location could have been transmitted in the first signal; however, this is still not guaranteed as the GPS chip requires some time to acquire its location once activated. Although the aircraft registration can be a good starting point for a SAR investigation, rescuers must wait for confirmation of the beacon's position before sending a search and rescue team, so a non-GPS equipped ELT can potentially increase the SAR response time. For very little additional expense, GPS equipped ELTs significantly increase the accuracy of positional resolution from approximately 5 km (non-GPS) to approximately 120 m for GPS-enabled ELTs.

In addition to the fixed ELT, this aircraft was also carrying four PLBs, one of which was GPS-enabled. Unfortunately, none of these PLBs where activated or made it out of the aircraft.

Partial power loss and attempted forced landing – Cessna 182P Skylane

ATSB investigation AO-2012-083

On 19 June 2012, a Cessna 182P suffered a partial power loss just after take-off from Mayvale Station (near Cunnamulla), Queensland due to the use of contaminated fuel. The aircraft rapidly lost altitude, and during an attempted forced landing, the aircraft clipped a tree and collided with the ground. The aircraft was destroyed, coming to rest inverted, and the pilot was seriously injured.

The fixed fuselage mounted ELT did not activate during the impact. The reason the ELT did not activate was not determined in the ATSB investigation, but may have been due to shielding or disruption of the ELT antenna when the aircraft came to rest inverted. The pilot was also carrying a PLB on the accident flight, but it was not on his person. Due to injuries sustained in the accident, the pilot was unable to retrieve the PLB from the wreckage. Fortunately, the aircraft was still in the vicinity of the station, and the seriously injured pilot was rescued about 3 hours after the accident.

Figure 11: Wreckage of the Cessna 182P in the vicinity of Mayvale Station, Qld

Source: ATSB

Observation

The ATSB has investigated many general aviation aircraft accidents where the pilot attempted a forced landing, and the aircraft came to rest inverted after impacting trees, ruts, or other obstacles. In many of these accidents, the ELT failed to operate. This is typically due to either the antenna (typically located on the upper surface of the fuselage) being disrupted in the impact or by the signal being shielded by the upturned fuselage.

This case also highlights the importance of carrying PLBs on your person (rather than loose in the aircraft or mounted to the instrument panel) so that they are within arm's reach if objects are displaced, if you are unable to reach the instrument panel, or if you are thrown clear of the aircraft in an accident .

Loss of control during go-around – Mooney M20J

ATSB investigation 199802458

On 29 June 1998, a pilot and passenger were travelling in a Mooney M20J from Jandakot to Laverton, Western Australia, via Melita Station to deliver some equipment. On arrival at Melita Station, the pilot overflew the airstrip in a low level circuit. At the completion of the downwind leg, the aircraft banked sharply to the left onto an apparent final approach. A station hand saw the aircraft fly close to the ground for half of the strip length, before adopting a nose-up attitude. The engine noise increased but sounded laboured, before stopping when the aircraft was about 100 ft above ground level. The aircraft then pitched nose-down, and impacted the ground in a near-vertical attitude. The aircraft was destroyed, and both pilot and passenger were fatally injured.

The aircraft was fitted with an ELT and although it appeared to be correctly mounted and connected, the ELT did not activate at the time of the accident. The ELT had a remote instrument panel-mounted activation switch which was selected to ‘arm’ and the switch on the ELT unit itself was selected to ‘auto’. The ATSB investigation could not determine why the ELT had not operated during the accident. When tested during the investigation, it operated normally.

Figure 12: Wreckage of the Mooney M20J at Melita Station, WA

Source: ATSB

Observation

There are many cases like this one where there is simply no explanation as to why an ELT failed to activate during a high g-force impact. In this case, the ELT was found by the ATSB to be intact after the impact; the mounting was intact, the unit itself undamaged, and the co-axial antenna cable still attached. Both the switch on the ELT, as well as the remote switch on the instrument panel where found to be in the correct setting, and a functional test of the ELT unit after being removed from the aircraft confirmed that it operated as expected.

Summary & Key Messages

Emergency locator transmitters (ELTs) that are fitted to aircraft should operate in high g-force accidents to identify where the aircraft wreckage is located, improving occupant survivability by expediting search and rescue efforts. A review of high g-force accidents reported to the ATSB from 1993 to 2012 was conducted, and looked at the fitment and activation of ELTs in accidents such as in-flight break-ups, collisions with terrain, forced and hard landings.

It was found that ELTs only activated normally in about 40 to 60 per cent of the high g-force accidents, supporting previous anecdotal evidence that ELTs were often not activating.

In accidents where ELTs did not work effectively (or at all), it was found that their performance could be affected by:

- not selecting the ELT activation to armed before flight
- incorrect installation
- flat batteries
- lack of water proofing
- lack of fire protection
- disconnection of the co-axial antenna cable from the unit during impact
- damage and/or removal of the antenna during impact
- an aircraft coming to rest inverted after impact.

These accidents show that there are a number of ways in which better use, carriage, fitment, and design of ELTs and other emergency radio beacons could improve their effectiveness in an accident:

- At little additional expense, GPS-equipped ELTs significantly increase the accuracy of positional resolution from approximately 5 km (non-GPS) to approximately 120 m for GPS-enabled ELTs. Incorporation of GPS technology into ELT and PLB units is not presently mandatory.
- Newer ELTs incorporating 3-axis g-switches may improve the likelihood of activation upon impact. Single-axis units are only able to activate correctly if there is a significant impact force in the direction that the ELT is mounted (generally a forward impact for fixed-wing aircraft, and a 45° to vertical impact for helicopters).
- Installing ELTs as far aft in the fuselage as practicable may improve their post-crash survivability, particularly if there is a post-impact fire. However, this may restrict their quick removal in a crash.
- Australian search and rescue (AusSAR) advise that if a pilot is attempting a forced landing, is having serious control difficulties, or becomes disorientated by flying into instrument or dangerous weather conditions, proactively activating an ELT could greatly increase the likelihood of the search and rescue coordination centre knowing the exact position of the aircraft. If the emergency is alleviated, simply turn the unit off and notify AusSAR as soon as possible.
- If using a personal location beacon (PLB), ensure it is on your person. Having it 'close at hand' or in your flight bag will not help you if you cannot reach it after an accident, or if it (or you) is thrown from the aircraft. For other occupants of the aircraft, a PLB is of little use if none of the survivors of a crash is aware of its location, or if they are stowed in a location that is difficult to access in an emergency.
- Briefing all persons on board with both the location and operation of all emergency beacons could help ensure that a device gets activated if an accident does occur.
- Aircraft owner/operators currently face the dilemma of either using a fixed airframe mounted ELT that may not activate during a crash, or using a PLB which the pilot may not be capable

of manually activating after a crash. Although there are currently no requirements to do so, using both could save your life.

- It is important to remember that ELTs are an important safety device, not only for aircraft occupants, but also for SAR personnel. Even if an aircraft is destroyed in an accident and the occupants are deceased, a functioning ELT helps SAR in minimising search times, risk to rescue personnel, and use of SAR resources.

Finally, a review of data provided by AMSA shows that of the 442 search and rescues relating to aircraft emergencies between June 1999 and December 2012, 68 of these incidents benefitted from the detection of an activated ELT or PLB, resulting in 52 lives saved during this period. Although AusSAR was first alerted to the aviation emergency by ELT/PLBs in only 15 per cent of incidents, ELT/PLBs are directly responsible for saving an average of four lives per year.

Sources and submissions

Sources of information

Data for this report were sourced from the ATSB aviation occurrence database and ATSB accident investigations as well as the Australian Maritime Safety Authority search and rescue database. The ATSB are grateful for the assistance of the Australian Maritime Safety Authority and staff at the Rescue Coordination Centre.

A draft of this report was sent to the Australian Maritime Safety Authority and the Civil Aviation Safety Authority for review. Submissions were received from the Australian Maritime Safety Authority. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – Regulatory information

Regulations pertaining to the use of Emergency Locator Beacons (ELTs) in Australian registered aircraft are outlined in Civil Aviation Safety Authority (CASA) *Civil Aviation Regulations 1988* (CAR) 252A and Civil Aviation Order (CAO) 20.11. Standards regarding eligible ELTs can be found in Federal Aviation Administration (United States) (FAA) Technical Standard Order (TSO) C91a for operation on 121.5 MHZ and FAA TSO-C126 for operation in the 406 MHZ – 406.1 MHZ frequency band. The minimum operational performance standards are given in Radio Technical Commission for Aeronautics (RTCA Inc.) Document No. DO-204 *Minimum Operational Performance Standards (MOPS) 406 MHz Emergency Locator Transmitters (ELTs)*.

To be an approved portable ELT, an ELT must meet the requirements outlined in AS/NZS 4280.1:2003 for EPIRBs and AS/NZS 4280.2:2003 for PLBs. Additionally each of these must also satisfy TSO-C91a and TSO-C126 for operations on 121.5 MHz and in the frequency band 406 MHZ – 406.1 MHZ, respectively. Any beacon fitted with $LiSO_2$ batteries must have batteries that comply with FAA TSO-C142 or TSO-C142a.

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Glossary

AMSA	Australian Maritime Safety Authority
AS/NZS	Australian Standard/New Zealand Standard
CAO	Civil Aviation Order (CASA)
CAR	*Civil Aviation Regulations 1988*
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CFIT	Controlled Flight into Terrain
ELT	Emergency Locator Transmitter
EPIRB	Emergency Position Indicating Radio Beacon
FAA	Federal Aviation Administration (United States)
ICAO	International Civil Aviation Organization
$LiSO_2$	Lithium-sulphur dioxide
MHz	Megahertz
NM	Nautical Mile
PLB	Personal Locator Beacon
SAR	Search and Rescue
TSO	Technical Standard Order (FAA)

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Research

ATSB Transport Safety Report
Aviation Research Investigation
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