HR SMITH GROUP

AIRCRAFT EMERGENCY LOCATION THE EXPRESS ROUTE

Barry Thrower

INTRODUCTION

1. In its Paper to the SAFE Europe 2001 Symposium (Emergency Beacons - the Next Generation) the H R Smith Group discussed the impact of the COSPAS-SARSAT satellite system on the evolution of portable emergency beacons. In addition, the Paper examined some of the expanding applications and new technologies that might find a place in the future SAR arena.

2. These developments, prompted by the COSPAS-SARSAT system, were not however limited exclusively to portable beacons. Indeed, aviation regulatory authorities such as ICAO and the JAA now mandate the use of satellite compliant emergency transmitters on commercial fixed-wing aircraft and helicopters, and a 406MHz capability is now required across the whole panoply of commercial aviation operations. These requirements are, in turn, stimulating further advances in performance and capability for all aircraft emergency transmitters and for SAR technology in general.

3. For example, the tactical limitations of traditional analogue homing systems led the H R Smith Group fundamentally to reappraise this technology and apply new concepts to extract maximum benefit from the 406 MHz waveform's digital characteristics. These developments are poised to transform the way in which SAR missions are conducted; moreover, other data network technologies are beginning to offer even greater capacity and capability for civil and military SAR operations.

AIM

4. The aim of this paper is to outline the latest development trends in emergency aircraft transmitters and homing systems, and to assess the potential of advanced wireless network technology for SAR applications.

EMERGENCY TRANSMITTERS FOR SATELLITE SAR

5. To understand the impact of recent SAR developments, it is useful to revisit some of the practical benefits that COSPAS-SARSAT now provides. Firstly, survivors of an aircraft accident, whatever their location, have a global means of immediately alerting the rescue authorities via one of three Geo-stationary Earth Orbiting Satellites (GEOS) which together provide whole earth cover (+/-70 degrees latitude). The inclusion of message data in the 406 MHz signal means also that the identity of the user can instantly be determined and this, in turn, provides an early and realistic means of assessing the beacon's location based on knowledge of filed flight plans. Furthermore, Low Earth Orbiting Satellites (LEOS) are subsequently able to obtain a geographic 'Doppler' fix of the emergency location when they next over-fly the activated distress transmitter. Therefore, COSPAS-SARSAT effectively eliminates the 'search' element of the SAR operation, and a co-ordinated global network of Mission and Rescue Control Centres are able to ensure the rapid and focussed deployment of SAR services for the 'rescue' phase. Compared with traditional SAR methods, COSPAS-SARSAT and 406MHz beacons therefore brought essential, life-saving improvements in the speed and conduct of rescue operations.

THE NEED FOR GPS CO-ORDINASTES

6. One significant limitation of the COSPAS-SARSAT system is the time taken to achieve a Doppler fix of an activated beacon's location. This so-called satellite 'waiting time' can, in the worst case, exceed one hour, and is also of variable accuracy – factors, which are critical to a survivor in a hostile environment. Not surprisingly, therefore, satellite signal message protocols made early provision for the insertion of positional data into the 406 MHz message, initially so that marine distress systems might transmit position co-ordinates derived typically from on-board navigation equipment such as GPS (Global Positioning System). The challenge, however, was to incorporate a GPS capability within airborne Emergency Locator Transmitters and Personal Locator Beacons, thereby offering the survivors of an aircraft emergency the same probability of early location and rescue as those on a ship in distress. The following paragraphs outline the developments in emergency transmitters for airborne applications.

EMERGENCY TRANSMITTERS FOR AIRCRAFT

7. The introduction of COSPAS-SARSAT and compliant 406 MHz emergency transmitters meant that aviation authorities responsible for safety soon decided that commercial aircraft should be equipped with Emergency Locator Transmitters (ELTs) capable of operating on this frequency. For example, the European Joint Aviation Authority (JAA) issued two directives, one for fixed-wing aircraft (JAR-OPS 1.820) and the other for rotary-wing aircraft (JAR-OPS 3.820). These directives refer to a number of Emergency Locator transmitter (ELT) options ranging from portable, manually activated devices - ELT(Survival) - to automatically activated installations - ELT Automatic-Fixed(AF) and ELT Automatic-Portable (AP). Also, for helicopters engaged hazardous operations over water the JAA have mandated the carriage of ELTs Automatic Deployable (AD). A modular design approach was central to our being able to offer cost-effective easily installed systems to meet the full range of ELT directives and requirements, and to provide in-built supportability.

8. **Survival ELTs.** The Techtest Series 500-12 Personal Locator Beacon (PLB) which featured in the 2001 SAFE Europe Paper met the JAA and ICAO requirements for an ELT (Survival) in full. Moreover, the latest derivative of this advanced and compact beacon (Series 500-27) incorporates an integral GPS antenna and receiver which allows it to determine and transmit its position co-ordinates without reference to any external navigation system. This compact and fully compliant beacon offers unrivalled performance and accuracy, and it also provides two-way voice communications on 121.5/243 MHz.

9. **Automatic ELTs.** An automatically activated ELT (AF/AP) is normally internally mounted in the upper fuselage towards the rear of an aircraft, typically just fore of the tail plane. The radio frequency output from the transmitter module is fed to an external, vertically mounted antenna via a coaxial cable. The Techtest transmitter module, including integral battery unit, and the G-switch activation module, are housed in high impact resistant thermoplastic casings. Automatic activation is achieved through a system of solid state, bi-directional integrating accelerometers (G-switches) designed to respond to a specific deceleration profile. The combination of three accelerometers gives directional sensitivity in all directions ie longitudinal (fore and aft), lateral (port and starboard) and vertical (up and down), although the

latter sensor is normally reserved only for helicopter applications. On activation, either automatically by the G-switch module or manually from the remote control panel, the ELT transmits on the standard distress signals of 121.5 MHz, 243 MHz and on the COSPAS-SARSAT frequency of 406 MHz. The 406 MHz signal is encoded digitally with the ELT's country of registration, a unique identification code (which usually identifies the parent aircraft), and the type of user – ie maritime or aviation. Importantly, because this coded data is stored in the G-Switch module, the ELT transmitter module may be changed between aircraft without the need for reprogramming. Moreover, in its portable form, the ELT may be easily removed from its mounting tray and operated away from the aircraft using a supplementary whip antenna. Importantly, the ELT is capable of accepting and storing GPS co-ordinates from on-board navigation equipment and transmitting the 'last known' position as part of 406 MHz message. The current ELT system requires no interfaces with any other aircraft system except connection to a 28V DC power supply.

Deployable ELTs – Crash Position Indicators.

10. The conduct of helicopter operations over water in hostile areas poses very specific risks both to the aircraft and to its crew and passengers. Not least, is the speed with which a safety-critical situation can develop in these circumstances, and the rapidity with which a ditched helicopter can subsequently become submerged. Not only does such an environment create special survival problems for passengers and crew, it also potentially hampers the task of locating the crash site and effecting a speedy rescue. Whilst JAA regulations governing the use of emergency locating equipment in fixed-wing aircraft favour fixed, automatic installations, the unique hazards associated with helicopter operations at sea demanded a different strategy. JAR-OPS 3.820 therefore addressed the requirements specifically of helicopters operating in such 'hostile' environments (defined as over water at latitudes North of 45ºN and South of 45ºS) and mandated that aircraft in these circumstances should be equipped with Automatically Deployable Emergency Locator Transmitters - ELT (AD). In addition to transmitting on 121.5 MHz and the COSPAS-SARSAT frequency of 406 MHz, the ELT (AD) has also to be capable of deploying from an airborne platform, and surviving the subsequent free-fall descent and impact to operate efficiently for the prescribed period either on land or while afloat.

11. Deployed and activated automatically in response to triggers either from multi-axis integrating accelerometers, water immersion sensors, or by frangible crash switches, the CPI is reliably operated by the full range of physical conditions associated with a crashed or ditched helicopter. Furthermore, the CPI may be manually deployed or switched to transmit in situ by the flight crew, thereby giving added flexibility of operation. The CPI was designed from the outset to accommodate last known position co-ordinates, derived typically from the aircraft's GPS, and to transmit this information as part the COSPAS-SARSAT 406 MHz message, thereby negating the need for a satellite position fix. Thus, once activated, the CPI beacon immediately alerts the rescue authorities and identifies the crash site; moreover, it continues to transmit this information for at least 24 hours, unaffected by any subsequent beacon positional drift. By also transmitting on the 121.5 MHz international distress frequency, the CPI ensures that rescue craft equipped with traditional homing systems are able to receive and home onto its signal for the final rescue phase.

12. The important function of interfacing with on-board GPS equipment and inserting position co-ordinates into the 406 MHz COSPAS-SARSAT message is performed by the System Interface Unit (SIU) which also stores the aircraft's unique identification code. Importantly, by retaining this identification data in the SIU, the CPI beacon assembly can be easily changed between aircraft without the need for reprogramming. Also, should the need arise to reprogram identification data, this task can be carried out on-aircraft with no need for specialist tools or equipment. The SIU also controls the CPI beacon's deployment and activation sequence, and provides emergency power to ensure continuity of operation in the event of an aircraft power failure. The CPI Beacon is attached to the aircraft via the Beacon Release Unit which provides the relevant mechanical and electrical interfaces. Deployment of the beacon is achieved by an electrically initiated, pyrotechnic actuator which releases a compressed coiled spring that projects the beacon safely away from the airframe and rotor blades. The CPI transmitter is housed in an impact resistant, foam-filled, high-visibility casing incorporating an integral, omni-directional antenna.

TRADITIONAL ANALOGUE HOMING TECHNIQUES

13. Once the COSPAS-SARSAT authorities have been alerted by the distress transmissions from an activated emergency transmitter, it is necessary quickly to translate this information gathering phase into action by tasking an appropriate SAR force to effect the rescue. In turn, this requires that the SAR craft - say a helicopter – is able to detect the transmitting beacon and home confidently onto the signal source. Typically, traditional analogue homing systems use matched pairs of antennas and compare the properties of the received signal at each (ie relative amplitude or phase) to determine direction and, hence, provide steering advice to the pilot. The success of this process is governed by a number of factors, including the coverage and efficiency of the beacon's antenna, the sensitivity of the SAR aircraft's homing system, and the effect of the Earth's curvature on line-of-sight communications - typically, at 50 nm an aircraft would have to fly at an altitude of 1000 ft ASL in order to 'see' the beacon. Also, it can be difficult to discriminate between multiple transmitting beacons in close proximity, and in bad weather or at night, the absence of ranging information makes it difficult to determine when the beacon has been reached or over-flown.

14. Although this analogue homing process can be assisted by the availability of positional information from COSPAS-SARSAT, especially if the beacon is transmitting its GPS co-ordinates, the rescue craft must eventually itself locate the beacon source in order to achieve the final homing approach and rescue. Herein lies a fundamental weakness of traditional analogue homing.

DIGITAL HOMING – BEACON LOCATING SYSTEM

15. Given that many emergency transmitters are capable of transmitting their GPS-co-ordinates as part of the 406 MHz message, the natural next step was to develop a homing system capable of receiving and decoding the COSPAS-SARSAT message. Called the Beacon Locating System (BLS), this cockpit-mounted Techtest developmental equipment displays decoded position co-ordinates in alphanumeric form on an integral indicator, together with the beacons ID and time. Up to 10 beacons may be displayed using a simple scroll mechanism, thereby eliminating problems of multiple beacon discrimination. When the search aircraft is equipped with GPS,

the BLS is able to calculate and display relative position data and provide direct navigation advice to the pilot, thereby effectively providing a single-pass rescue capability without the need to maintain line-of-sight communications. In addition, integration of BLS with an on-board or portable electronic map allows information to be displayed in an easily interpreted situational display. In short, BLS closes the digital data loop, and maximizes the use of 406 MHz message data throughout the entire SAR operation. Finally, for the terminal homing phase, the BLS retains a analogue homing capability on 121.5, 243 and 406 MHz, but this is reinforced by accurate GPS co-ordinates based on real time reception of the beacon's data transmissions.

COST-EFFECTIVE COMBAT SAR

16. The capability requirements of combat SAR introduce an additional dimension to the general aim of search and rescue operations – namely, to minimize the probability of unwanted detection and location by enemy forces, while continuing to maximize the prospect of early rescue. These almost conflicting requirements can result in potentially high procurement and ownership costs, and lead to equipping with dedicated, separate SAR and CSAR systems. This not only adds to inventory and cost but also means that aircrew must familiarize themselves with two beacon types – a situation which is itself not desirable for an item of emergency equipment.

17. In addition, there is the need to consider flexibility of operation. In certain theatres, a covert CSAR capability may not be appropriate all the time – it may be more beneficial in some semi-operational scenarios to revert to peacetime SAR methods, thereby expanding the scale and scope of the rescue operation beyond the immediate participating CSAR-equipped forces. Human aid missions, and the fight against terrorism could bring together hitherto unlikely alliances where the ability to co-operate in low risk search and rescue operations using traditional peacetime SAR technology might conceivably enhance the probability of survival and rescue when compared against the use of a smaller, uniquely-equipped CSAR force. Clearly, the ability rapidly to adapt to peacetime or combat scenarios gives the military commander important added flexibility which could potentially save lives.

SAR/CSAR – A DUAL SOLUTION

18. In planning a dual SAR/CSAR capability, the aim was to offer value for money and build on proven digital technology developed for peacetime SAR systems. The beacon would offer a GPS-based tactical combat function which could operate in conjunction with a dual capability airborne Beacon Locating System (BLS). Importantly, however, unlike most dual function beacons, the Techtest CSAR system retains a 406 MHz COSPAS-SARSAT capability and the global future proofing that this offers.

19. In short, we set out to produce a dual-function beacon that combined a *global* peacetime SAR capability with a *tactical* CSAR/survival radio mode. The beacon incorporates an integral 12-channel GPS receiver which is used in both SAR and CSAR scenarios to allow immediate and accurate location in either mode. GPS co-ordinates are transmitted either as part of the COSPAS-SARSAT 406 MHz message or, in the CSAR mode, as a short encrypted data burst on one of 400 pre-programmable frequencies. Normal distress transmissions are inhibited in the CSAR mode, and data bursts are either triggered by external interrogation or initiated manually by the user pressing and releasing the press to transmit switch. The beacon also features a survival radio-

transceiver which provides two-way voice communications.

20. **Dual Function BLS.** An essential part of delivering this dual capability was that of building dual functionality into the Beacon Locating System so that it is able to interrogate the beacon, decode its encrypted response, and display the information to the pilot. The BLS was designed also for flexibility of use and operation, by offering a rapid role-fit capability on the grounds that any military aircraft could be called upon to perform SAR or CSAR operations. Capable of interrogating activated beacons out to a range of 50km, the BLS automatically displays the beacon's ID, position co-ordinates and time, while the probability of unwanted detection is minimized by the use of transmitter power management techniques. In addition, a rapid 'Data Destruction' function allows the crew to erase operationally sensitive data to prevent compromise in the event of capture. The BLS also retains a full peacetime homing capability on traditional distress frequencies and 406 MHz.

21. **Duality of Purpose.** The option for military forces to combine peacetime global SAR functionality, GPS and tactical combat SAR in a single system uniquely offers essential future-proofed satellite coverage for peacetime SAR missions, while also providing flexibility to prosecute CSAR missions in any theatre of operations.

WIRELESS NETWORK TECHNOLOGY

22. Central to current and future SAR developments is the ability to transmit digitally encoded information. In their current form, digital data bursts already provide invaluable information for the rescue force and, by interfacing with other systems such as GPS, they can pinpoint the precise location of the emergency. Clearly, this is just one example of the expanding application of wireless data links generally, and it is no coincidence that this technology is bringing improvements in the capability and effectiveness of a wide variety of communications systems, both commercial and military. Moreover, these advances are also feeding back into the SAR arena, and the following system serves to illustrate just how the latest wireless network technology can embrace multiple applications within a single system, including SAR.

23. The H R Smith Group is working with an American partner company, Sierra Research Inc, on Wide-band Wireless Networks (WWN) – effectively a high capacity data network that can fulfil virtually any application that requires the rapid exchange of digital data. Operating at military radar S-band frequencies, a specific application of WWN is SOSAN - Self-Organizing Situational Awareness Network. Combining direct radar measurement techniques and the exchange of digital data, SOSAN is uniquely able to perform complex positional and trajectory calculations to provide situational awareness for airborne and ground platforms. Also, SOSAN provides a wide bandwidth data link which offers virtually unlimited capacity to exchange tactical information between participants.

24. SOSAN's advanced radio frequency waveform not only provides very high data capacity, but also provides secure communications through the use of spread spectrum, adaptive power management and frequency hopping. Subsequent development of SOSAN will concentrate on a man-portable extension to the system, effectively providing last-mile data connectivity to ground forces. Of course, line-of-sight constraints remain applicable, but with the integration of this technology across a wide range of airborne and ground platforms, and lightweight

man-portable units, it will be possible to exchange important tactical information covertly throughout the command chain. Importantly also, SOSAN's ability to measure direct range and to exchange relative range data allows the system to calculate the positions of multiple users by a process of differential 'multi-lateration', thereby giving the system a GPS-independent, situational awareness capability.

25. **SOSAN & CSAR.** In a CSAR scenario, SOSAN beacons would allow downed aircrew to play a positive and proactive role not only in their own rescue but also in gathering and communicating important tactical information relating perhaps to enemy installations and threats. Indeed, we envisage that, equipped with man-portable SOSAN and laser ranging binoculars with digital azimuth measurement, survivors could play an active role in Close Air Support operations by relaying details of potential sources of enemy fire and thereby enhancing the safety of the rescue mission. SAR aircraft and rescue teams dropped to assist a survivor would also have accurate positional data and secure communications with operational commanders. The application of advance digital wireless networks therefore potentially offers very significant improvements in both CSAR and operational capability.

CONCLUSION

26. The global satellite detection and location system (COSPAS-SARSAT) brought radical improvements in the detection and location of emergency transmitters, and has led to their widespread use in all airborne applications. The introduction of a dedicated 406 MHz, digitally encoded signal capable of transmitting GPS co-ordinates, meant that airborne locating systems could be developed for SAR aircraft capable of decoding these data bursts, thus minimizing dependence on traditional analogue homing technology, and providing a single pass rescue capability. Moreover, the application of GPS technology in portable beacons expanded the scope for accurate positioning and allowed the inclusion combat SAR functionality in the same product, thus providing duality of function within a single system.

27. For the future, the pursuit of advanced digital wireless technology is beginning to offer wide-band, self-organizing networks capable of providing secure and continuous situational awareness between aircraft and ground forces. In such a data-rich environment, downed aircrew will be able to communicate securely with friendly forces both to assist in their rescue and to identify potential hostile threats. In short, survivors will be able to play a proactive role in their rescue and communicate potentially important tactical information.

28. This then is the express route to emergency location and rescue - a path that could transform the way in which SAR operations are eventually conducted.

Barry Thrower
Business Development Manager
H R Smith Group
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