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COMISSÃO LATINO-AMERICANA DE AVIAÇÃO CIVIL

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CLAC/GEPEJTA/30-NI/01
CORRIGENDUM
23/01/13

TRIGÉSIMA REUNIÓN DEL GRUPO DE EXPERTOS EN ASUNTOS POLÍTICOS, ECONÓMICOS Y JURÍDICOS DEL TRANSPORTE AÉREO (GEPEJTA/30)

(Lima, Perú, 29 al 31 de enero de 2013)

Cuestión 6 del Orden del Día: **Otros asuntos**

Cuestión 6.3 del Orden del Día: **Guía de Orientación de la CEAC para la ubicación de aeronaves bajo el agua y recuperación de restos y caja de registro de datos de vuelo (*Guidance on the Underwater Location and Recovery of Aircraft Wreckage and Flight Recorders*)**

(Nota informativa presentada por la Secretaría)

Antecedentes

1. En el marco de la cooperación mutua, esta Secretaría recibió de la Conferencia Europea de Aviación Civil (CEAC) una copia del documento "Guía de Orientación de la CEAC para la ubicación de aeronaves bajo el agua y recuperación de restos y caja de registro de datos de vuelo (*Guidance on the Underwater Location and Recovery of Aircraft Wreckage and Flight Recorders*)" elaborado por el Grupo de Expertos de Investigación de Accidentes e Incidentes de Aviación de dicha Organización.

Desarrollo

2. El Grupo se enfocó principalmente en la ubicación y recuperación de restos de aeronaves en aguas relativamente profundas. Esta Guía ofrece una visión general de los temas propios de ubicación bajo el agua, las operaciones de recuperación y la experiencia, así como, de los procedimientos y equipo necesario para montar una respuesta eficaz a este tipo de accidentes. La Guía está diseñada para ser utilizada por todos aquellos a los que les resulte útil, en Europa y fuera de esta Región, particularmente por las autoridades de investigación de accidentes aéreos que podrían, en cualquier momento, encontrarse frente a la tarea de investigar la pérdida de una aeronave en estas circunstancias muy difíciles.

3. En sentido de lo expuesto, esta Secretaría acompaña a la presente Nota la Guía de la referencia, la misma que también puede encontrar en la página web de la CEAC (https://www.ecac-ceac.org//publications_events_news/ecac_documents/ecac_guidance). Cabe mencionar que el documento está disponible sólo en idioma inglés (**Adjunto**).

Medidas propuestas al Grupo de Expertos

4. Se invita al GEPEJTA a tomar nota de la información presentada.

CLAC/GEPEJTA/30-NI/01
CORRIGENDUM
ADJUNTO

Guidance on the Underwater Location and Recovery of Aircraft Wreckage and Flight Recorders

Aircraft Accident and Incident Investigation Expert Group
European Civil Aviation Conference

November 2012

ECAC · CEAC

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Foreword

By the Chairman of the Aircraft Accident and Incident Investigation Expert Group of the European Civil Aviation Conference

Jurgen Whyte
Head of the Irish Air Accident Investigation Unit

In June 2009 the Aircraft Accident and Incident Investigation Expert Group of the European Civil Aviation Conference (ECAC), with generous support from the Croatian aviation authorities, organised in Dubrovnik a workshop on the challenges associated with investigating accidents in which the aircraft is under water. The preparations for this workshop had begun a few months earlier, and the tragic loss in the mid-Atlantic of Air France 447, only ten days prior to the workshop, was no more than a deeply unhappy coincidence.

Inevitably however, that accident lent the work of the Expert Group particular purpose and poignancy. The Dubrovnik workshop having focused mainly upon the location and recovery of aircraft wreckage and recorders in relatively shallow waters, it was followed in October 2010 by a second, hosted in Larnaca with equal generosity by the Cypriot aviation authorities, focused upon accidents in deeper waters. Full reports of the workshops, each of which was led by my distinguished predecessor as chairman of the Expert Group Paul-Louis Arslanian, were prepared and made available via the ECAC Web site.

This guidance distils out the learning shared at and won from the two workshops, which brought together experts from national safety investigation authorities and safety regulators (both European and other), and from providers of the specialised equipment and services needed for accident investigation in the underwater environment. All gave their time and expertise unsparingly and without charge, including in supporting the "live" location and recovery exercises at sea that were an important part of each workshop.

The ECAC Expert Group is immensely grateful to all who organised, participated in and supported the Dubrovnik and Larnaca workshops, and who contributed subsequently to the development of this guidance. Special thanks are owed to the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, *which has taken especial care to ensure that the guidance reflects the learning hard-won from its investigation of the loss of Air France 447, always without compromising the integrity and confidentiality of that extraordinarily challenging mission.*

The guidance provides an overview of the issues peculiar to underwater location and recovery operations, and of the expertise, procedures and equipment needed to mount an effective response to such an accident. It is intended for use by all who might find it helpful, in Europe and beyond, and in particular of course by air accident investigation authorities who might at any moment find themselves faced with the task of investigating the loss of an aircraft in these very challenging circumstances.

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1 Introduction

1.1 Any State that has a coastline or internal body of water, or aircraft on its national register flying over international waters, may face the responsibility of having to conduct an investigation into the loss of an aircraft in its territorial waters or on the high seas. Fatal accidents with an underwater dimension occur regularly.

1.2 When an aircraft comes down in water, whether at sea or in a lake or river, the first need - access to the accident site - is problematic in itself. The problems become greater as the water becomes deeper.

1.3 Underwater location and recovery has extremely challenging characteristics, and requires a well-planned and timely response, coordinated amongst many parties.[1] Inadequate preparation or poor management of the initial investigative response has the potential to degenerate into a crisis, and can threaten crucial evidence. That risk increases where the accident site is problematic.

1.4 This guidance was developed following the organisation in 2009/10 of two workshops by ECAC's Expert Group on Aircraft Accident and Incident Investigation. It seeks to provide an overview of issues peculiar to underwater location and recovery operations, and of the expertise, procedures and equipment needed for an effective response. A draft of this guidance was presented and discussed during the 2011 underwater recovery workshop held in Singapore for the Asia Pacific region.

1.5 The guidance considers the preparations needed by States which may have to undertake an underwater location and recovery operation and then the on-site challenges of operations at sea: the working environment, decisions on what to recover, issues specific to location and recovery, and the management of human remains. The guidance also considers ancillary issues, including the costs of underwater operations, and sets out key points for those who may need to undertake operations in this difficult environment.

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1 *Similar challenges arise when an aircraft comes down in other remote locations, such as desert, jungle, mountainous or arctic regions.*

2 Preparation for Underwater Location and Recovery Operations

2.1 Partnerships and Contacts

2.1.1 Safety investigation authorities will not generally be able to conduct an investigation having an underwater dimension without outside assistance. Relationships therefore need to be established in advance with potential partners and sources of assistance.

2.1.2 Within the State of the safety investigation authority, these partners should include Ministries with responsibilities for matters relating to the sea, the naval service and the diplomatic service. It is especially important to have a procedure to secure rapid access to bathymetric and bathythermographic data, at least for national waters.

2.1.3 Partnership relationships should also be established with colleagues in other national safety investigation authorities, as well as in relevant foreign military and diplomatic services.

2.1.4 Although advice should be taken from bodies such as the police, the navy and the coastguard, overall control of the operation should always be retained by the safety investigation authority. Assistance may usefully be sought from other national investigation authorities which have recent experience of mounting similar operations.

2.1.5 In the context of these contacts abroad, there is merit in establishing commonality in the technical specifications of equipment and software used by regional States, so that such resources may be shared and used with ease when needed.

2.1.6 It is also important to have information about where relevant equipment may be sourced. While it might be possible to borrow some equipment from partners, it may be necessary to enter into hire contracts for sea-going vessels, underwater craft and other specialised or expensive equipment. Contact details for suitable contractors, and an understanding of the kinds of equipment and expertise (for example, in diving) each can offer, should be part of the standing preparations for a possible underwater operation.

2.1.7 Check-lists for underwater operations are important for planning purposes. But no two accidents are the same and detailed planning will inevitably be event-specific.

2.1.8 Effective equipment and personnel may be expensive but they can reduce overall costs. “Employing an expert is expensive, but not as expensive as employing a non-expert”.

2.2 Hiring Equipment and Vessels

2.2.1 The key factor in the selection of the vessel and its onboard equipment is the nature of the location of the accident site: sea state conditions, probable depth and the seabed environment. Other important factors will be the proximity of the nearest useful port, and the availability of suitable vessels. Safety investigation authorities unused to underwater operations often underestimate the time it can take to get the necessary maritime assets into position to start work.

2.2.2 In considering the suitability of the vessels available, account should be taken of their capability to perform the required task in the time available, including their fitting out with specialised equipment such as acoustic devices for detecting 37.5 kHz signals and, when necessary, with a hull-mounted multi-beam sonar for bathymetry of the seabed. Other considerations will be the vessel's present location and availability, transit time to the accident site, and the entire charter cost, including provision of equipment, and mobilisation/demobilisation.

2.2.3 Relatively small craft, for use in operations on lakes, rivers and close inshore, are unlikely to be difficult to secure. For operations at sea, it is necessary to know where to find the appropriate kind of larger vessel.

2.2.4 If no suitable State vessels are available an approach to the chartering market may be necessary, and consideration given to issuing a call for tenders or a "Statement of Requirements". Such a document should specify the size of the lost aircraft (this will dictate the lifting equipment and deck space needed), the depth of the site, any human remains issues and the expected duration of the operation. Ancillary issues may be the need for a heli-deck and any auditing or certification requirements. The deadline for responses should be indicated.

2.2.5 Many of the vessels suitable for aircraft salvage are employed in support of the offshore oil and gas sector, notably in the North Sea, the Arabian Gulf, the Gulf of Mexico and off West Africa. Few are designed to support operations in more than 2,000 metres of water and in those cases it may be necessary to charter the vessel and to hire separately the additional equipment. It will be important in those circumstances to establish the compatibility of the vessel and its systems with the equipment being brought aboard, for example in storage, lifting equipment, power supplies, and deck loadings and securings.

2.2.6 Experience shows that the mobilisation of large vessels with deep-water recovery capability

can take time. There may be advantage in taking a two-stage approach, first employing a smaller vessel able to reach the location quickly and begin the task of locating the Underwater Locator Beacons (ULBs), pending the arrival of a recovery vessel. The decision to dispatch the recovery vessel should only be made once the wreckage has been located, and the delay between its location and the departure of the vessel should be kept to a minimum. If the wreckage has not been located during the period in which the ULBs can be assumed to be transmitting, it will be necessary to proceed to another phase of location, using sonar equipment, which will normally correspond to different vessel requirements.

2.2.7 As "principal contractor" it is important to be aware of shared responsibilities which may have been assumed, for example for damage which might be done to sub-sea pipelines or other infrastructure during the operation. It is also important to establish that the vessel has the required certification from the Flag State and Classification Society, for example in relation to its safety equipment and maintenance, crew training and certification, pollution insurance, and health and safety management systems.

2.2.8 The BIMCO[2] charter agreement, "Time Charter Party for Offshore Service Vessels" (Supplytime 2005) is a standard contractual model with which ship owners are familiar. The settlement of disputes relating to the contract is subject to the arbitration procedure provided for and defined in Clause 34, Part II of Annex B to the agreement.

2.2.9 Once the vessel has been selected and contracted, it is important that a good working relationship is established and maintained between the investigation team and the captain of the vessel.

2.3 Other Special Equipment

2.3.1 The depth at which the aircraft wreckage and flight recorders are believed to be located will be the primary determinant of the recovery options.

2.3.2 Air diving is feasible at depths up to 40 metres, and saturation diving up to 500 metres. However, for deep water and sustained operations, the use of a Remotely Operated Vehicle (ROV) is generally the best option. These are connected to the parent vessel by an "umbilical" carrying power and navigational and imagery capabilities. They come in many forms and sizes, and may be equipped with one or more "manipulators" for working at the accident site. Use of an ROV permits the whole investigation team to view and exploit in real time the images transmitted from the ROV to the parent vessel. It also facilitates the mapping of the accident site.

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2 *Baltic and International Maritime Council, an international shipping association representing ship-owners controlling around 65 percent of the world's tonnage.*

2.3.3 A range of ROVs can be deployed in operations at up to 6,000 metres, and certain very specialised (and scarce) ROVs can be used below that depth. The supplier of an ROV can be expected to specify the dynamic positioning capability (eg 'DP I' or 'DP II') required of the vessel from which it will be operated. Such a capability is valuable when conducting sea searches, as knowledge of the exact position of the vessel, for example in relation to a search grid, is important and it may provide a stable working platform for operations in up to Force 7 sea state conditions.

2.3.4 Another type of unmanned vessel available for underwater operations is the Autonomous Underwater Vehicle (AUV), which is a 'search' (rather than 'grapple-and-recover') tool. AUVs are not tethered to a parent vessel but are battery-powered and programmed to follow a defined search programme, at the conclusion of which they surface and upload their findings to the control centre. This may be aboard a vessel or in a road vehicle parked at the lake or river side. The preparation and launching of an AUV will typically take only a few hours and its control team may number only three or four. The more sophisticated AUVs have hovering and automated obstacle avoidance capabilities. A number of sensors may be carried by the AUV, including side-scan sonar and cameras.

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3 Challenges and Priorities On-Site

3.1 Working at Sea

3.1.1 Some challenges in operations at sea derive from the length of time which the investigation team may need to be out of physical contact with the shore. For any long voyage, there is a need to give careful thought in advance (even under time pressure) to all of the types of equipment which may be required and to the specialist personnel needed aboard.

3.1.2 Some of the equipment carried to the accident site (such as transponders and hand-held hydrophones) will prove unserviceable, so it is wise to build redundancy into what is carried and have some onboard capability for repair. For operations in water, more robust equipment is generally needed than at first seems likely.

3.1.3 At the accident site, simple manoeuvres (transiting across the search grid, despatching and recovering small craft and divers) takes considerably longer than those accustomed to working in aviation expect. The investigation team needs to be prepared for this.

3.1.4 Working vessels present particular health and safety issues for those not familiar with them. The investigation team should complete a risk assessment of the working environment in consultation with the vessel's health and safety officer, including the possibility of sea-sickness, with consideration of safe and appropriate medication.

The planning process should include the configuration of accommodation and work spaces.

3.1.5 The noise and movement of the vessel, the confined and less than perfectly clean spaces probably available to the investigation team, the presence of seawater and damp, all make for a working environment which is hostile to individuals and to sensitive electronic equipment such as cameras and computers.

3.1.6 A particular problem in operations at sea is the moment when a large piece of debris is lifted out of the sea and Archimedes' principle is negated. This can lead to a sudden and dangerous increase in load, with potential to damage the wreckage and lose evidence. There may be a need to counter

this risk by providing additional tethering to the wreckage (to take any additional loads at key points) and the use of netting is particularly useful. The use of an active 'heave-compensated' crane can help in alleviating load variations on the lift line. The condition of the wreckage should be recorded before any recovery attempt is made, and likewise any damage sustained during the lift.

3.2 Location

3.2.1 An Underwater Location Beacon (ULB) fitted to an aircraft flight recorder is triggered by immersion in water. It will emit an ultrasonic pulse of 10 milliseconds, at 37.5 kHz and at one-second intervals. The present ICAO requirement is for ULBs ("pingers") to transmit for at least 30 days. They have a nominal audible range of 2 to 5 km, depending on parameters such as depth, water temperature and sea conditions.[3]

3.2.2 There is value in a search operation in deploying the most effective resources as early as possible, to minimise the risk of a protracted search and an even more expensive investigation. It is preferable to undertake a 'passive' acoustic sweep first (while the pingers can be expected to be still transmitting), with an 'active' side-scan sonar search next, taken under less time pressure.

3.2.3 There is benefit in beginning as soon as possible, using a small vessel to find the pinger(s), on the basis of a preliminary review of the 'loss' data such as radar and the Aircraft Communications Addressing and Reporting System (ACARS). The search area may be refined later, as more data become available. The sonar search will begin only after the end of the pinger's transmission period.

3.2.4 The 37.5 kHz frequency is outside the audible spectrum for the human ear. Acoustic hydrophones 'translate' the signal into the audible spectrum, a process which does not exactly reproduce the original emission, which can be 'polluted' by the water environment and thus misprocessed.

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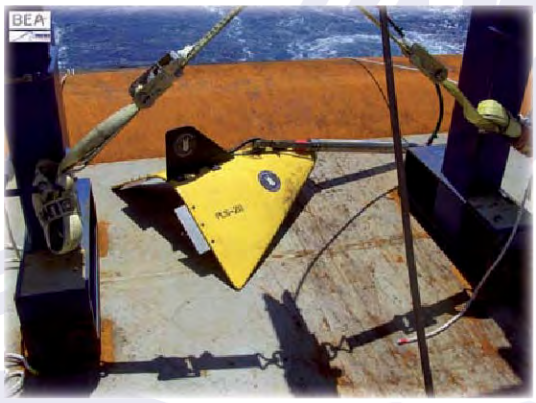
3 *An ICAO State Letter of 4 April 2012 advised that Amendment 36 to ICAO Annex 6 had been adopted by the ICAO Council on 2 March 2012. This amendment includes (i) the extension of the operating period, to a minimum of 90 days, of the underwater locating beacons fitted to flight recorders, and (ii) the introduction of beacons operating for a minimum of 30 days at a frequency of 8.8kHz, attached to the aircraft, with an increased propagation distance. Amendment 36 will become applicable on 15 November 2012. Both the extended duration ULB and the new low frequency ULB are mandated to be fitted at the earliest practicable date, and no later than 1 January 2018.*

3.2.5 ULB signals can be picked up using acoustic hydrophones deployed singly, as a hand-held unit, or in an array (for example, in a flexible tube housing, towed behind and below a vessel). Digitalisation of the ULB signal by onboard software enables the 'listening' for the ULB to be done by a computer, rather than a human.

3.2.6 Such an array may be deployed to good effect even in difficult sea conditions. However in shallow waters the amount of background noise may lead to the signal 'spike', experienced when the 'ping' is detected, not being prominent, and perhaps missed. With such faint signals, difficulties may also be experienced when sounds emitted by the biological environment (eg whales) confuse the acoustic devices. Cetacean sound emissions typically take the form of swift 'chirps' over a wide spectrum of frequencies, which could at times be perceived as a short regular pinger signal, after being sampled and processed by acoustic devices

3.2.7 Towing a hydrophone array at a speed of 4 knots on a search grid of parallel tracks one nautical mile apart will enable forty square miles of sea to be searched in a period of around 10 hours. Use of the vessel's autopilot (if fitted) while following the search grid is valuable in countering the effects of strong crosswinds and crosscurrents. Strong currents may also cause wreckage and recorders to drift from their original location.



3.2.8 Other systems for picking up and locating ULB signals may involve the repeated 'dipping' of a detector below the 'seasonal thermocline' (which separates the noisy mixed surface layer of water from the calm, relatively quiet, deeper water below), at different locations, to generate a triangulated homing point, or the deployment of acoustic listening buoys equipped with GPS and UHF radio.

3.2.9 Military submarine assets, if not set up and crewed by persons trained to search for 37.5 kHz signals, have not been found to be useful. If however the aircraft being sought is equipped with lower frequency ULBs, such as ones operating at 8.8 kHz, the situation would be different, as these can be picked up by many military assets - often the first on site - whether surface vessel or submarine. The nominal audible range of a ULB transmitting at 8.8 kHz could be in excess of 10 kilometres.

3.2.10 For searches in very shallow waters with poor visibility, for example in a river or lake, grapple dragging by surface vessels and the use of metal detectors mounted on inflatable craft are options.

3.3 What to Recover?

3.3.1 The priority targets for the investigation team during the recovery phase should be flight recorders, aircraft debris/parts (including avionics components which may contain non-volatile memory), any human remains[4] and personal effects. Wreckage observation and mapping are also important. When available, a photographic survey of the accident site enables its original state to be recorded before it is altered by diver or ROV interventions.

3.3.2 It is necessary to select carefully, with opinions from all investigation parties considered, the aircraft debris and parts to be recovered, and to prioritise them, with a view to the overall investigation. The initial analysis of the FDR and CVR may assist in this selection process.

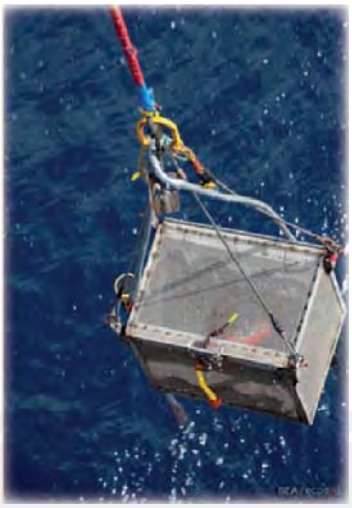
3.3.3 There is a case for recovering only those parts of the aircraft judged to be relevant to the investigation, especially if the aircraft wreckage is very large or fragmented. Divers or ROV operators might be given a 'shopping list' of those parts of the aircraft most desirable to recover, based on preliminary information gathered from recorders, sea bed images and aircraft data (such as manufacturers' drawings, parts catalogues, wiring diagrams and manuals).

3.3.4 It is sometimes more straightforward to recover as much as possible, avoiding the difficulty of finding again particular items which may have been disturbed by underwater currents. The full wreckage may then be examined for its key elements in a more suitable environment. Storing wreckage on land can however pose a challenge, as hangar space is often scarce and in some jurisdictions long-term storage space may not be available.

3.4 Recovery

3.4.1 The recovery of aircraft wreckage is generally accomplished by the parts being rigged to a hoist and lifted by crane out of the water and onto the recovery vessel. Alternatively, the lift might in some cases be achieved by the attachment to the wreckage, by divers, of small 'parachutes', then inflated with compressed air by divers; care is needed to avoid inflatable items being punctured by sharp metallic edges on the wreckage. In at least one recovery operation, sealed buoyant metal tubular fabrications, inserted beneath the aircraft's wings, were used with success.

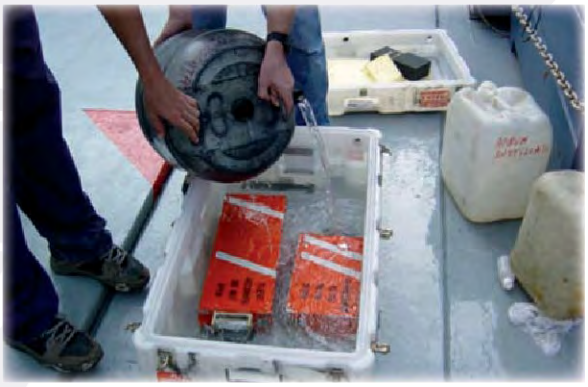
4 *This is especially the case for bodies floating on the surface of the water. Section 3.5 below discusses the recovery of human remains still underwater with or in the aircraft wreckage.*



3.4.2 For ROV operations it may be useful for a steel basket to be lowered to the sea bed, into which debris may be placed by the ROV. Such a basket may also be used for the recovery of human remains, in what should be a separate operation.

3.4.3 When using an ROV, particularly where the wreckage is spread over a large area of the sea bed, it is important to identify clearly those locations which the ROV has visited. This may be achieved by dropping markers, carried down in the basket referred to in 3.4.2.

3.4.4 Where aircraft wreckage has rested for some time underwater, sediments may accumulate within it, increasing its weight and rendering its recovery more difficult. It may be necessary to remove at least some of this sediment before lifting, for example using suction tools. This possible complication is an argument for recovery action to be taken without unnecessary delay, and not to be paused, once begun.



3.4.5 The internal components of flight recorders recovered from underwater are vulnerable to corrosion, and should be kept in fresh water for transit and until they are opened. All wreckage recovered should be rinsed to remove salt water and further anti-corrosion application of specialised products can help in preserving evidence. Access to recovered wreckage should be limited.

3.4.6 It is important to re-stow all equipment in an orderly fashion after use, including the washing off of salt water, so that it is ready and fit for use on the next occasion.

3.4.7 Chapter 5 of the ICAO "Manual of Aircraft Accident and Incident Investigation" (Doc 9756 Part 1) contains guidance on actions at the site of the accident, including dealing with wreckage in water, its preservation, decisions on what to recover, psychological stress and specialist examinations. Chapter 7.4 of ICAO Doc 9962, "Manual on Accident and Incident Investigation Policies and Procedures", is also useful.

3.5 Human Remains

3.5.1 In recovering an aircraft underwater there is frequently a need to deal with human remains. This poses special technical and psychological challenges beyond those associated with an accident site on land. This highlights the need to be prepared.

3.5.2 Unless autopsy is judged important for the safety investigation, there may be no perceived need for bodies to be recovered from an underwater site. Their recovery must nonetheless be considered, to meet the expectations of relatives and for safety reasons. There may be important legal reasons (such as passenger identification) for the recovery of bodies.

3.5.3 Historically, oceans have been considered an appropriate grave for those who perish at sea. A different view is now generally taken in respect to aircraft accident fatalities, but where bodies have been lost for a prolonged period not all relatives may agree about their recovery. These are delicate issues and need sensitive handling.

3.5.4 In fatal accidents on land, emergency service personnel will typically lead the recovery of bodies. At sea, it is likely that surface recovery of human remains will be conducted by search and rescue services, often military or Coast Guard. However, for human remains at deep water sites, deployment of an ROV may be the only means of gaining access and the ROV operator may be wholly inexperienced in encountering images of human remains. He or she will in that event need careful briefing and management.

3.5.5 The recovery of bodies is an operation that should not be improvised - material preparation, ample space, and good conditions are crucial. It is important to have available the necessary specialised equipment (such as refrigerated containers, and body bags) and any special expertise.

3.5.6 Medico-psychological support may be needed, to manage the psychological risks related to the recovery of human remains. This can be done through briefings during transit to site, 'defusing' moments on board and debriefing during the return transit.

3.5.7 It is important to control access to data, including photographs, relating to human remains. It may be desirable to establish a system to filter photographs of human remains from the general investigation data and store them separately.

3.5.8 In general, personal effects should be managed onboard by police. Safety investigators should not bear the responsibility of dealing with these effects or of dealing directly with the recovery of human remains and the identification of victims.

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4 Other Issues

4.1 Wreckage Location, and Responsibilities

4.1.1 In some cases of aircraft lost at sea, there have been difficulties in establishing definitively and in a timely manner exactly where the aircraft came down. Possible indicators will include the last radar report and floating wreckage, which may be in national or international waters.

4.1.2 To avoid a dispute which could compromise the investigation, it is advisable for the national investigation authorities concerned (State of (possible) Occurrence and State of Registry) to reach prompt agreement on their respective responsibilities.

4.2 Costs

4.2.1 The costs of investigations increase quickly if the wreckage or flight recorders need to be recovered underwater, and they may exceed the normal budget of the safety investigation authority. It is important that politicians and other decision-makers are apprised of the international obligations which States have in relation to aviation accident investigation.

4.2.2 The costs of hiring specialist vessels and equipment, may be stated as 'mobilisation costs + (daily rate x duration) + demobilisation costs, plus - as a good "rule of thumb" - an additional 20% as a budget for all consumables. It is important to obtain good information in advance about the accident site, and about the capabilities of the vessel intended to be hired, before chartering, and to understand the nature of task before selecting the other tools. The contract ("charter party") with the vessel provider should be checked for fairness and balance and the charterer should be aware of his full financial responsibilities for the ship and its crew. Liability issues should also be considered.

4.2.3 The investigating authority should be prepared for the possibility that the operation will not be completed quickly. If the site is far out at sea, or the vessel starting from a distant port, even reaching the accident site may take considerable time.

4.2.4 Decision-makers and politicians should be made aware of the cost and timeline realities, and the investigation authority should have a procedure for accessing emergency funds.

4.2.5 In many cases the commercial insurance carried on an aircraft may be used by the investigation to defray at least a part of the search and recovery costs. To achieve a successful outcome it is highly recommended that the safety investigation authority approach the aircraft's insurers at an early stage, probably through the insurers' Loss Adjuster.

4.2.6 In other cases, the costs of search and recovery operations have been shared with other parties involved with the aircraft, such as the operator, the manufacturer or the charterer. The level of involvement of these other parties should be determined by the safety investigation authority.

4.2.7 Alternatively, at least one safety investigation authority has purchased commercial insurance cover against undertaking an operation of this kind.

Control of any investigation funded under such insurance should remain with the safety investigation authority and not be taken over by the insurer. Such an insurance policy might provide for a portion of the total costs to be borne by the claimant (to incentivise the claimant to incur only reasonable costs) and there might also be a deductible sum. The use of a brokerage company could be considered.

4.3 Data Handling

4.3.1 Investigators can be faced with handling large amounts of data, in various formats and locations. Confidentiality issues should be considered, especially for data related to human remains.

4.3.2 Strict procedures need to be developed, and a means of secure transmission implemented, between the various entities involved in the search. In most cases, a database containing as a minimum pictures, coordinates and descriptions of debris will be needed.

4.3.3 Oceanographic data and sonar imagery pose additional challenges for storage, and video footage of all ROV dives may need to be duplicated in different formats. Having available high-capacity external hard drives (in Terabytes) will allow for the back up of relevant data.

4.3.4 It is recommended that high speed VSAT[5] connections be set up between vessels, using a secured File Transfer Protocol site to exchange data. To reinforce confidentiality, those involved in search and recovery operations are generally invited to sign a non-disclosure agreement.

4.4 Training

4.4.1 Where possible, the investigation authority's more experienced personnel should be used for underwater operations, given the special challenges they pose. They should have been trained to handle and monitor such operations, including familiarity with maritime agencies and national navies, participation in workshops and exercises, and involvement in underwater recovery operations. Investigators should receive training in survival procedures at sea (including helicopter underwater escape) and health and safety issues.

4.5 Ecological Aspects

4.5.1 The loss of an aircraft in water may be followed by the leakage into the water of fuel, oil and other noxious fluids. It may be possible to contain and recover these, in order to avoid ecological harm. In shallow waters it may be feasible to surround the wreckage with special protective curtains or booms during an operation to recover the liquids, and these curtains or booms may then be towed to land. Specialist assistance should be considered.

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5 *Very Small Aperture Terminal (VSAT) is a two-way satellite data communication system between a stabilised maritime VSAT antenna set up on a vessel and a satellite in geosynchronous orbit.*

4.6 Closing an Investigation

4.6.1 An investigation involving underwater recovery should document the operations so that other investigation authorities may benefit from the lessons learned. A short report could accompany the safety investigation final report.

4.6.2 A decision to halt an underwater recovery operation should be the prerogative of the safety investigation authority, made after careful assessment of the possible safety benefits of continuing the operation, set against the expenditure of additional resources.

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5 Conclusion

5.1 The need to conduct an investigation into the loss of an aircraft in water is a real possibility for any State that has a coastline or internal body of water, or has aircraft on its register which fly over international waters. Given the number of parties that may become involved, the need to select the right equipment and expertise, the potential for spiralling costs, and the challenges posed by operations at sea, any such investigation will require a very well planned and timely response.

5.2 This guidance material provides advice on planning and preparing for such an investigation. It emphasises the importance of establishing in advance useful partnerships and contacts, the value of checklists, the need to identify and source the necessary funding and expertise, and more generally for the investigation authority to have a good understanding of the tools and assets required for successful search and recovery operations.

5.3 The cost of these operations can be considerable and it is important that decision makers and politicians who control emergency funds are given realistic cost and time estimates, and that consideration has been given to some kind of insurance policy.

5.4 The challenges involved in conducting operations at sea should not be underestimated. There is often a thin line between success and failure and anything that can be done beforehand, in preparation and planning, will increase the chance of success.

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November 2012

Photographs, and Credits

Cover Page

Cockpit Voice Recorder from Air France 447, as discovered on sea-bed. Photograph courtesy of French *Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile* (BEA)/ECPA-D.

Paragraph

2.2.1 Cable ship *Ile de Sein* chartered by French BEA as part of its investigation into the loss of Air France 447. Photograph courtesy of French BEA/ ECPA-D/Alcatel-Lucent/ Louis-Dreyfus Armateurs.

2.2.5/6 Remotely Operated Vehicle (ROV) aboard *Ile de Sein*. Photograph courtesy of French BEA/Phoenix International.

2.2.7 Examples of recovery support vessels. Photograph courtesy of UK Ministry of Defence.

2.3.1 Flight recorder. Photograph courtesy of Italian *Guardia Costiera*.

2.3.3 Sea Lion ROV. Photograph courtesy of UK Air Accident Investigation Branch (AAIB).

2.3.4 Autonomous Underwater Vehicle used by French BEA in locating Air France 447. Photograph courtesy of French BEA/Woods Hole Oceanographic Institution.

3.1.4/5 Examples of operating conditions at sea. Photographs courtesy of UK AAIB.

3.1.6 At-sea exercise during October 2010 ECAC/ACC workshop. Photograph courtesy of EDT Offshore and Phoenix International.

3.2.2 Diagram of Towed Side Scan Sonar operation, courtesy of French BEA/Ifremer.

3.2.5 Hand-held Underwater Acoustic Locator Receiver, as used during at-sea exercise at June 2009 ECAC/ACC workshop. Photograph courtesy of UK AAIB.

3.2.6 Towed hydrophone array, as used during at-sea exercise at June 2009 ECAC/ACC workshop. Photograph courtesy of UK AAIB.

3.2.7 Towed Pinger Locator. Photograph courtesy of French BEA.

3.3.3 Recovery of electronics bay of Air France 447. Photograph courtesy of French BEA.

3.4.1 Parachute flotation devices, as used during at-sea exercise at June 2009 ECAC/ ACC workshop. Photograph courtesy of Croatian Aircraft Accident and Incident Investigation Agency.

Prefabricated metal buoyancy tank. Photograph courtesy of Polish Air Accident Investigation Board.

3.4.2/3 Typical steel basket for use in conjunction with ROV, for recovering items from under water. Photograph courtesy of French BEA/ ECPA-D.

3.4.5 Recorders in fresh water to prevent saltwater corrosion. Photograph courtesy of Italian *Agenzia Nazionale per la Sicurezza del Volo*.

4.5.1 Use of protective curtains to prevent water pollution. Photograph courtesy of Polish Air Accident Investigation Board.

5.4 Memory unit of Flight Data Recorder from Air France 447, as discovered on sea-bed. Photograph courtesy of French BEA.

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