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Deep Water Location and Recovery of Military and Civil Aircraft: Technical and Business Risks for the Maritime Responder – Air France Incident

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SYNOPSIS

The UK Ministry of Defence (MoD) is the lead recovery authority for the maritime recovery of all UK military and civil registered aircraft. It has a significantly successful record over decades of deep water location and recovery on a global basis and has close working relationships with other global providers of this capability. The recent loss of the Air France Airbus 330M and the major efforts to locate it (yet to succeed) indicate some of the fundamental problems associated with this kind of operation.

The UK MoD recognised these problems in the late 1960s and has made significant efforts to mitigate the risk of non-recovery of military aircraft that crash in deep water. This paper covers the problems associated with locating crashed aircraft in deep water such as equipment fitted to aircraft (both UK military and civil), the differences and complications arising from the differences; the nature of recovery operations post-location, the platforms and equipment required to undertake a successful recovery and practical aspects of the task; technical, personnel and business risks, and hazards associated with this kind of operation, including the handling of mass fatalities; a brief review of potential legal pitfalls that complicate this kind of operation; considerations for marine organisations engaging in this kind of activity.

As an employee of the UK Ministry of Defence (MoD) I am obliged to state that the views expressed in this article are my own and do not represent the official views of the MoD or the UK government. They are, however, based on a great deal of personal experience associated with aircraft accident intervention and management associated with more than 150 military and civil air accidents. The lessons identified and lines of development are based on actual case histories. This paper complements a verbal presentation given to the *ITS 2010* in Vancouver. Within the limitations of the forum it can only touch lightly on the many issues and facets of this topic and is therefore only intended to act as a lodestone and point towards the key issues. To address these at depth would require a textbook rather than an isolated paper.

CONTEXT

Air France Flight 447, an Airbus 330-200 carrying 228 personnel, disappeared over the South Atlantic during a night flight from Brazil to France on 1st June 2009. Despite the best efforts of a diverse civil and military technical community and despite the aircraft being fitted with the industry standard electronic detection systems, it has yet to be found. It would be inappropriate to comment on a wide range of issues associated with the early phases of the operation, as it is an ongoing investigation, but I consider the key issue of wreckage location has profound implications for public safety that need to be addressed.

Evidence exists that the aircraft impacted the water approximately five minutes after its last automated position report. An international air and search effort located the first floating wreckage five days after the accident. More than 600 pieces of wreckage and 50 bodies were recovered in the initial phases of the operation, all from the surface. A massive underwater search then ensued, including the use of a French nuclear submarine, US and French Naval Units and research submersibles, but without success. Since July 2009 the French Air Accident Investigation Authority (BEA) has been trying to understand what happened to AF447 and determine how best to search for the Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR).

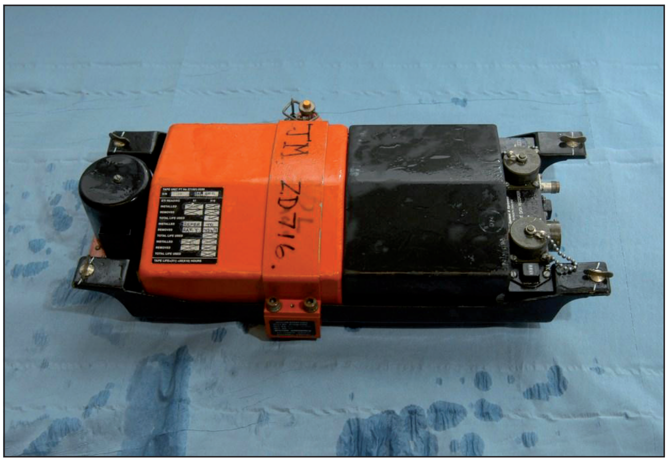

Figure 1: FDR fitted to Tornado aircraft. The Black Box is actually the orange-coloured component.

The challenge is immense, given the potentially massive search area and depths that vary from 700m to 5,000m. The problem is not, however, unique and there are precursors generating similar search requirements such as the ***USS Scorpion*** operation[1]. Unlike ***Scorpion***, all civil aircraft are fitted with underwater locating devices[2] (ULB) which should theoretically make their location and recovery a fairly simple matter. This is obviously not the case here, which raises the question: in a society where the authorities can track individuals on a virtual global basis by their use of mobile phones, how can a large passenger aircraft fall into the ocean and remain undetected?

THE FUNDAMENTAL PROBLEMS ASSOCIATED WITH LOCATING CRASHED AIRCRAFT IN DEEP WATER

Any underwater recovery process is primarily reliant upon acoustic-based detection systems. The technology is improving exponentially and a short examination of the work done by my organisation with ADUS gives clear indications of how much has been achieved in a very short period.

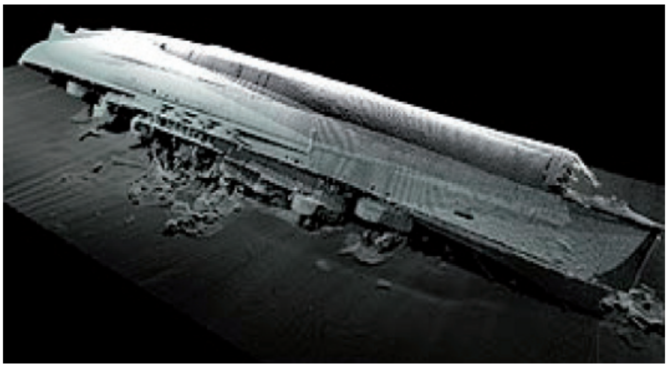

Figure 2: The sonar image of the wreck of **HMS Royal Oak***, as well as helping to gauge whether the ship is an environmental hazard, is an invaluable resource for historians of war. Photograph: UK MoD Salvage Marine/ ADUS*

However, the laws of physics still constrain sound-based systems. Put simply, you can have a high-definition acoustic 'image' at short range (50m-150m) or poor definition at long range (1,000m+). There is a further complication given that humans primarily rely upon the visual spectrum to interact with their surroundings. For most humans there is no conceptual correlation between an individual's visual capability and their acoustic abilities. As animals we are primarily reliant on visual cues to navigate around our environment.

Here is a very simple example: close your eyes and listen to a vehicle with its engine running. Depending upon its range you might be able to point in the right direction. By the nature of the sound, with some experience, you might be able to determine (guess) what kind of engine the vehicle has and from that deduce possibilities as to the nature of the vehicle. If the vehicle switches its engine off, ie ceases transmitting a noise, as far as the 'blind' observer is concerned, it is now undetectable. If, however, we are allowed to look at the vehicle, even at a considerable distance we can identify, classify, locate and describe, even if the background environment is confused and cluttered and the vehicle engine is not running. Evolution recognises that the 'refresh rate' of visual processing dramatically outruns acoustic systems, hence our biological bias.

Historically, this optical limitation on underwater search was tackled by inserting a man deep into the marine environment, but it was rapidly appreciated that the marine environment precludes the unassisted human eye from being effective. The visible spectrum diminishes rapidly with depth[3] and density of water compared to air and the opaque nature of sea water precludes visual effectiveness. Technology has enabled us to take light to the depths and produce low-light cameras, but the fundamental limitations apply and visual range is severely limited. Thus acoustic solutions must be pursued, whatever the limitation. There are two choices: we must either inject a noise hoping to interpret an echo or rely on the object to make a noise and locate it. In the case of the former a good example of the average image is seen in *Figure 3*, which is taken from directly above a German U-Boat wreck at a distance of about 200m.

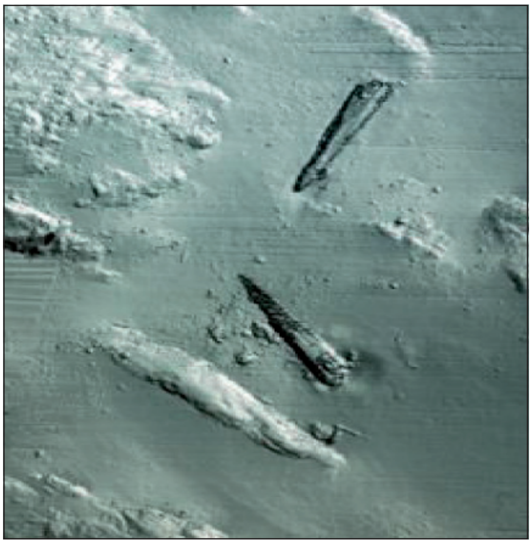

Figure 3: Sonogram of **U684***[4] showing debris field.*

While some technical understanding is required it might be possible for the average observer to determine that the image in *Figure 3* is of a submarine. But if the observer thinks about how a submarine only 200m away from the surface would appear visually, a sense of the difficulties with sonar interpretation becomes apparent. Imagine also a greater degree of fragmentation, a less smooth sea bed and this method of location becomes increasingly problematic as can be seen in *Figure 4.*

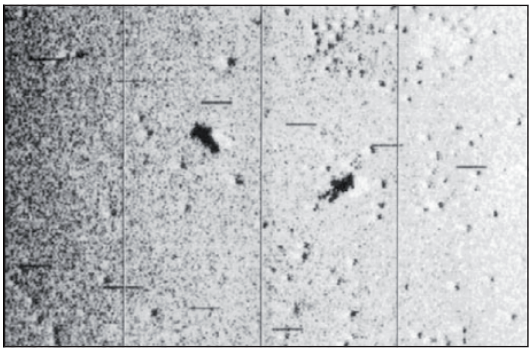

Figure 4: Typical 'side scan' trace showing debris field on the sea bed.

These images are primarily derived from 'side scan' sonar which is towed behind a surface support vessel. Its depth is adjusted to maintain its altitude above the sea bed which needs to be kept constant. Thus an undulating terrain or adverse slope directly affects the quality of the image. Likewise the operating frequency can be adjusted with the limiting range at around 500m, but normally operated around 150m either side of the 'fish'.

Figure 5: Typical side scan 'fish' rigged for deployment over the stern. The image does not show the handling winch, launch array or the control cab also required to operate the system.

Much of the success of these systems is vested in the computer-processing capability and the systems used to navigate or fix the position of the track swept by the fish. There are a large number of variables that directly affect the quality of the recovered image and the speed over the ground is compromised by those same variables, thus the system is speed- and quality-limited. A fundamental limitation is the sensor array which precludes observation of the area directly below the tow fish. There can also be significant variation of the swept area caused by pitch, roll and yaw of the tow fish as can be seen in *Figure 6*. All of these factors require significant overlap in the searchlines that the tow fish is run down, and even then there is no surety that the entire area has been covered or that all the 'shadow' zones have been subjected to the sonar probe.

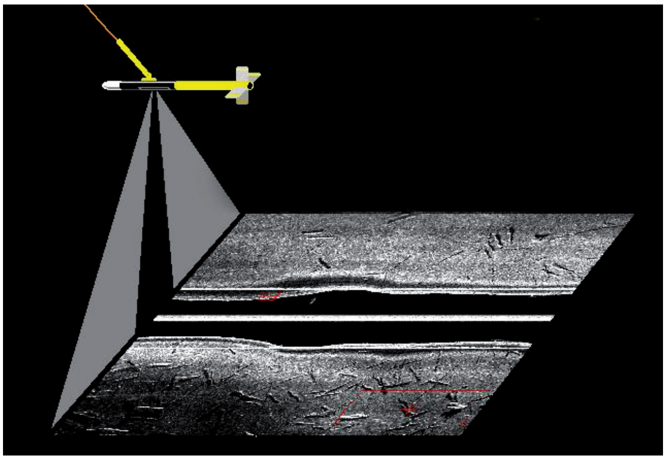

Figure 6: Typical side scan swept path. It is possible to visualise how changes in the terrain or the attitude of the fish can radically alter the image presented at the surface.

Thus a better proposition is to make the object you are searching for generate a sound and the frequency of that sound be tailored to facilitate location, ie use the physics rather than fight it.

MITIGATING THE RISK OF NON-RECOVERY OF MILITARY AIRCRAFT THAT CRASH IN DEEP WATER

The UK MoD recognised these problems in the late '60s but it took two aircraft accidents in particular during the following decade to prompt an effective solution. Both losses involved prototype aircraft during test runs; the first was a Victor bomber, the second a Tornado fighter aircraft. Both were lost in the Irish Sea in locations that were extremely adverse to successful sonar operations.

The delay in location had severe implications, both operationally and financially. The accidents followed from a number of previous events, both civil and military, where aircraft wreckage detection had been rendered ineffective by the limitations of sonar detection systems. The MoD salvage organisation had recognised the problem as early as 1963 when engaged in the location and recovery of a Comet air liner off Elba and had recommended that all UK military aircraft be fitted with a ULB. I cannot find specific development details, but by the end of the '60s civil aircraft were starting to be fitted with ULB operating on 37.5 KHz. This remains the industry standard for ULBs fitted to commercial aircraft, but there is scant detail as to why this particular frequency was chosen. Indeed, if the technical parameters of this ULB as defined by the international aviation standards are considered logically, they make no sense at all in the context of modern technology. The frequency chosen has a maximum range of around 3,000m. (Why does the standard require it to be pressure proof to around 7,000m, ie more than twice its detectable range?) Likewise, the survival parameters for temperature are well below fuel burn temperatures and I can find no evidence of 'destruction tests' to establish impact limitations.

Figure 7: Selection of commercial ULBs post impact. Failure rate in military aircraft is in excess of 30 per cent of cases where it does not survive impact.

There is some evidence to indicate that the beacon was developed around extant technology and the 'standard' was written to match the developed beacon. The capabilities of the beacon, although limited, were proportionate to the ability of the prevailing technology to recover objects from depth. This beacon was then mandated for fitting to all aircraft and the civil variant has not evolved since. The problem of the limitations of the civil ULB was identified as a significant weakness by the UK MoD following a further Tornado loss in 1982; when I joined the organisation in 1985, one of his first tasks was to address this issue. Some key points were quickly established:

- The extant commercial beacon operating at 37.5KHz could be destroyed on impact and a second beacon was required;
- The 37.5KHz frequency had a limited range which now fell far short of the credible recovery depth;
- There were few, if any credible, detection systems for the 37.5KHz system;
- 37.5KHz could not be detected by military air deployed sonar systems;
- The triggering mechanism required only that the battery get 'wet', which could cause problems for military aircraft operating at low level over the sea, especially helicopters in the hover.

EQUIPMENT FITTED TO AIRCRAFT (BOTH UK MILITARY AND CIVIL), THE DIFFERENCES AND COMPLICATIONS ARISING FROM THE DIFFERENCES

Following the loss of the prototype Tornado, the MoD developed its own variation of the civil ULB to fit military aircraft. This was optimised to assure compatibility with military detection systems and survive the more destructive nature of military aircraft accidents which might involve supersonic speeds and detonation of weapons during impact.

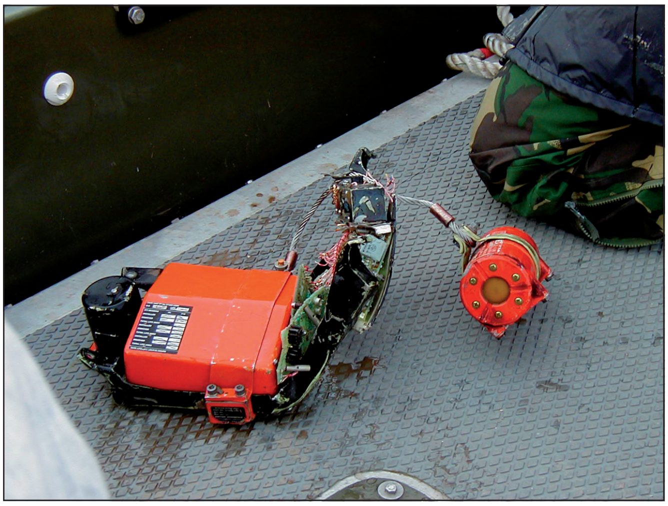

Figure 8: MoD ULB fitted to **Tornado FDR**. *ULB and data storage module survived impact. The FDR recording component did not.*

The military ULB was configured to operate at 9.6KHz and was designed against specific user requirements as opposed to the commercial beacon, which had inherent vice when considered against its purpose. The reduction in frequency achieved quite specific deliverables:

- Increased detection range to around 10,000m covering the maximum known ocean depth;
- The frequency is within human audible range and could be heard over a standard underwater telephone (UWT);
- The UWT compatibility meant that detection could be carried out by any military ship or submarine from the surface at high speed, maximising the search area, without development of specialist detection equipment;
- The frequency could be detected by anti-submarine warfare sensors, including air-dropped beacons and helicopter-mounted 'dipping' sonar;
- It could be located by other NATO systems;
- It was triggered hydrostatically by pressure and therefore could not be triggered accidently.

The military ULB was slighter bigger but of similar endurance in terms of transmission time. The only disadvantage that the new ULB had was that at close range (less than 300m) the low frequency made it difficult to get a directional fix on the noise source as it swamped the location system. This was considered a small price to pay, however, for the other significant benefits. The logical outcome of my efforts was a Defence Standard (DEFSTAN) being issued in 1989, requiring all UK military aircraft carry two ULBs[5]:

- A commercial fit 37.5KHz secured to the CVR or FDR for close range detection with high bearing discrimination;
- A military 9.6KHz beacon secured to the air frame for long range detection by surface units.

This DEFSTAN remains current and reflects the current ULB fit-for-in-service UK military aircraft. There are indications that the French BEA will put forward a recommendation paralleling this approach to the International Air Safety body as a consequence of the AF447 accident.

However, technology does not stand still and even the MoD-designed 9.6KHz beacon is being rendered obsolescent as changes in sonar technology are moving military sensors towards lower frequencies. This beacon is now suffering some of the drawbacks experienced by the commercial ULB; primarily its frequency falls outside the range of interest to military detection systems.

The good news is that, as technology allows for better bearing discrimination at lower frequency, a future ULB operating at some 4KHz should be detectable by military sensors at about 25,000m. This would massively enhance the detection capability, reduce the cost of location and accelerate recovery time.

THE NATURE OF RECOVERY OPERATIONS POST-LOCATION, THE PLATFORMS AND EQUIPMENT REQUIRED TO UNDERTAKE A SUCCESSFUL RECOVERY, AND PRACTICAL ASPECTS OF THE TASK

In some respects the recovery from depth is now the least technically challenging component of a maritime crash-recovery operation. Once located, the issue becomes one of gathering a scattered debris field, cataloguing it and getting it to the surface in a mechanistic, programmable way. Once on the surface it is an issue of safe storage and preservation for analysis. A practical observation is that the vessel configuration for a search phase is unlikely to be well suited for a recovery operation and a two-phase or two-vessel approach is more efficient and may well reduce costs in the long run.

This paper only addresses deep water recovery so this will be assumed to be beyond diver intervention depth, which is generally accepted to be around 350m, although manned 'hard suits' (see *Figure 10*) can operate down to around 650m. These suits have all the complications of being 'manned' submersibles and the operator is limited to using manipulators, thus the advantage over an unmanned system is marginal, given the latter's potential for extended operation without recovery to the surface at depths down to 6,000m.

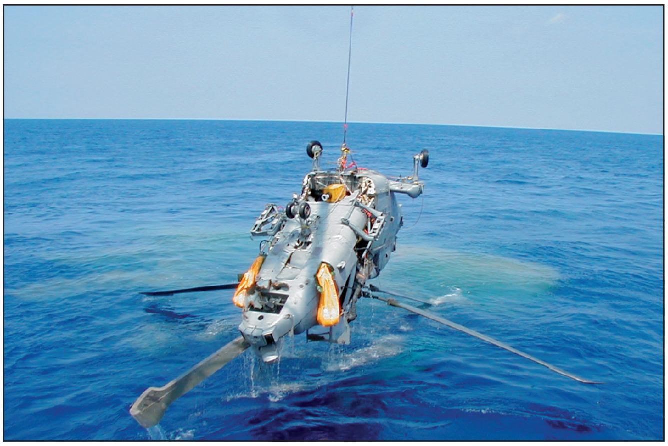

Figure 9: Lynx recovery from 4,200m using ROV recovery methodology.

There are a number of contractors who specialise in aircraft wreckage location and recovery, but it is a small club, and the location technology has evolved little. On the other hand the recovery capability has evolved significantly, driven primarily by the much wider desire to recover cargoes and commodities from the sea bed as a commercial proposition. This has led to the development of rapid recovery spooler systems and sea bed intervention techniques on a global basis. The danger is that some of the purported technically capable or aware operators can promise much, but deliver significantly less.

A major difficulty in operations of this type is the large number of non-technical supernumeries required to facilitate an effective recovery, in addition to the recovery system operators. In the case of a civil aircraft recovery involving fatalities this can easily exceed 30 or more additional staff. When this is combined with the protracted nature of the operation to meet forensic requirements, platform endurance becomes a significant issue. From the other end of the problem, many of the specialists required do not normally operate in the maritime domain and few are compliant with the standards of training and medical standards mandated for shipboard employment. In many cases a problem arises as the lead investigation authorities have little maritime awareness and both parties operate on the basis of invalid assumptions that often only become apparent at the mobilisation phase, after the contract and price has been fixed.

Figure 10: Manned ADS and typical ROV utilised in wreckage recoveries.

TECHNICAL, PERSONNEL AND BUSINESS RISKS AND HAZARDS ASSOCIATED WITH THIS KIND OF OPERATION, INCLUDING THE HANDLING OF MASS FATALITIES

The term 'aircraft' covers a very wide range of platforms that are designed for myriad purposes. I will not differentiate between fixed or rotary wing and will use the generic term 'aircraft' to mean both, as the issues and risks hold true for both platforms. In the context of air accidents the military airframe presents the most significant risk to the operator engaged in recovery, given the nature of the payload they carry. Civil aircraft present a problem of volume as they are generally bigger and, inevitably, there is a much higher body count. NB: There is no such thing as a textbook aircraft wreck site**.**

The fundamental difference between an aircraft wreck on land and one at sea is that, generally, the effect of fire on the airframe is minimal as the fire is extinguished on impact with the water. Therefore, the mode of physical destruction is primarily disassembly through impact, rather than destruction by fire. Consequently, in a maritime wreck, many of the components remain intact and to a degree functional. It is not uncommon to recover, for some years after the event, more than 90 per cent of an aircraft from a maritime crash site, most of it readily identifiable. The size, weight, payload, crew numbers and design parameters are legion, as are the materials used to construct aircraft and their sub-components. Historically aircraft were fabricated from metals, but even at this level the building materials were at times 'exotic' compared to standard industry practice. Magnesium and titanium alloys, as well as special grades of aluminium, were the norm. Although the metals were only comparatively exotic, they carried specific risks associated with fire in that they relied on conformation (shape) and crystalline structure for their strength.

Although these alloys require very high temperatures to start 'burning', once initiated, a chemical reaction will commence similar to a thermite process, when the aircraft metal becomes the oxidising agent and temperatures generated will easily melt through mild steel. Water is an ineffectual fire-fighting medium (the reaction is capable of breaking it down into hydrogen and oxygen) and special extinguishing agents are required; thus recovered wreckage should always be considered a potential fire hazard until proven otherwise. These alloys do, however, rapidly degrade in a salt-water environment, especially if dissimilar metals are present. This, combined with loss of structural conformity, makes lifting any composite piece of wreckage highly dangerous. Even a complete airframe that has been submerged for a few weeks is likely to disassemble without warning during lift.

More exotic materials appeared as components installed within the aircraft became more sophisticated. Electronics covers a wide spectrum of systems, but many incorporate small quantities of quite unusual materials such as thallium, beryllium, cadmium, lithium and a number of heavy metals. These are all comparatively harmless when the systems are intact but accidents, especially impact, have a tendency to disrupt the casings and crush the components. Even so, this risk to personnel can be managed provided that the material is kept wet and secured in an impervious container; plastic is usually sufficient, but the wreckage is sharp and needs to be managed carefully. If the components dry out and the dust becomes airborne, ingestion through a wound or breathing becomes a possibility and this is the usual source of any problem. The quantities concerned are very small in the overall environmental context, but there is scope for localised assimilation or long-term residual presence.

Long-term exposure is particularly damaging and can occur unexpectedly. Components have been removed from wreck sites by souvenir hunters. This acquisitiveness can also extend to items of ordinance, with significant explosive content, being secreted away for subsequent display or used as doorstops or paperweights by otherwise intelligent people.

Figure 11: EH 101 Merlin ditched. The aircraft was on fire at time of impact. Note failure of inflation bags to activate. Each bag represents over 3 tonnes of positive buoyancy and a massive risk to operators during recovery.

The inclusion of exotics in the aircraft components extended to complete sub-systems and crossed a range of disciplines. An example would be the utilisation of glass re-enforced plastic (GRP) and synthetic composite such as Kevlar for pressure vessels and fluid reservoirs. A specific example would be bottle reservoirs containing oxygen in liquid, cooled form. Apart from the obvious cryogenic aspect, with potential for thermal shock or brittle fracture if it leaks on to the deck of the recovery platform, there is the need to consider flammability issues, especially if contaminated with fuel or hydraulic fluid. Even a slow leak will allow oxygen enrichment of an enclosed space which could easily allow a 'flash' fire to develop if an ignition source is present. Similar reservoir bottles can contain pressurised nitrogen or hydraulic fluid.

Many of these items can be neutrally buoyant if partly discharged before aircraft break-up. It is often the case that these components are being held to the sea bed by other wreckage, pipework or electrical wiring. Disturbing the wreckage can release such buoyant items which will surface in an uncontrolled manner.

A specific hazard with helicopters can be the flotation assistance bags (similar in concept to a car air bag) which are filled with nitrogen gas from pressurised reservoirs. These are external to the aircraft and can be triggered manually by the pilot or automatically by water-activated electric cells. They are not foolproof and activation can be delayed through a number of circumstances. If they should deploy during the recovery process or in close proximity to individuals, severe damage or injury can occur. Some older aircraft such as the Wessex have external flotation systems with protective covers weighing around 15K. These covers will be blown off at very high velocity if the system triggers. The buoyancy bags have the capability to roll the wreckage over and, if they deploy subsurface, generate uncontrollable buoyancy with catastrophic effect on any divers working on the wreckage.

1. Rotor blades: prepregs/carbon/glass honeycombs. Machined Nomex® cores. Redux® adhesives. 2. Rotor hub: carbon epoxy prepregs. 3. Glazing bars: epoxy carbon/glass prepregs. 4. Flooring: Fibrelam® panels. 5. Seats and interior fittings: glass prepregs/fabricated panel material. 6. Engine/body fairings and access panels: epoxy/BMI glass/carbon/aramid prepregs. 7. Fuselage: carbon and glass prepregs. Honeycomb. 8. Main and cargo doors: epoxy carbon/glass prepreg, honeycomb and Redux® adhesive. 9. Boom and tail section: epoxy carbon/glass prepreg, honeycomb and Redux® adhesive. 10. Horizontal stabilisers: epoxy glass/carbon/aramid prepregs. 11. Fuselage panels: epoxy carbon/glass prepreg, Nomex® honeycomb and Redux® adhesives.

Figure 12: This drawing is generic, to allow the maximum number of potential composite applications to be identified. The drawing is not intended to represent a specific helicopter[6].

Having addressed some of the subsystems, it is worth considering the migration of exotics into the airframe itself. Currently the main strength members remain metal, but increasingly elements of it are being constructed of non-metallic composites, a pattern that has carried forward into commercial passenger aircraft. A fine example of this is the EH101, the naval variant being called the Merlin. The fuselage is mainly of aluminum-lithium construction. The aerodynamic rotor blades are constructed from carbon/glass with Nomex honeycomb and rohacell foam. The outer shell is made up of a range of man made composites secured around the metallic strength member[7].

There are specific risks associated with the products of combustion of these materials and burnt remnants should be handled with care. Edges of shattered fragments often throw off ‘fibres’ of the composite but these are usually more akin to hypodermic needles. Although they will break or snap easily, their penetrating power if ‘stabbed’ into the skin is phenomenal. If this is combined with their radio opaqueness multiple stab injuries, contaminated with broken segments of x-ray transparent fibres are a significant risk.

Conversely, experience has demonstrated that if some of these materials are submerged for several days, under pressure, in salt water they will undergo a very material change, reduce to the consistency of wet fibreboard and can be crumbled into a paste of fine fibres. If this dries out and becomes wind blown it can be a significant irritant to the eyes and respiratory tract, thus any of the material washed ashore and assimilated into beach material could have a pernicious but subtle effect.

Many of these effects are only just being realised as experience at crash sites is being assimilated and understood. For some 15 years people in the aircraft crash response business have been concerned about the possible health hazards caused by composite materials – particularly carbon fibre composites – at aircraft crash sites. The issue was first raised when, in 1990, an RAF Harrier GR5 aircraft crashed and personnel suffered health hazard problems and casualties at the crash site. The structure of this particular aircraft was approximately 30 per cent carbon fibre composites, which represented about 0.6 tonnes – far less than the amount of carbon used on future aircraft such as the Joint Strike Fighter. Many of the health problems experienced in the 1990 crash were due to the release of respirable carbon fibres during the crash. Research at Farnborough in the 1990s indicated that, if carbon fibre composite material is shattered in the absence of fire, there will also be little or no release of respirable fibres. If you burn carbon fibre composite material without subjecting it to high-energy impact there will be little or no release of respirable fibres.

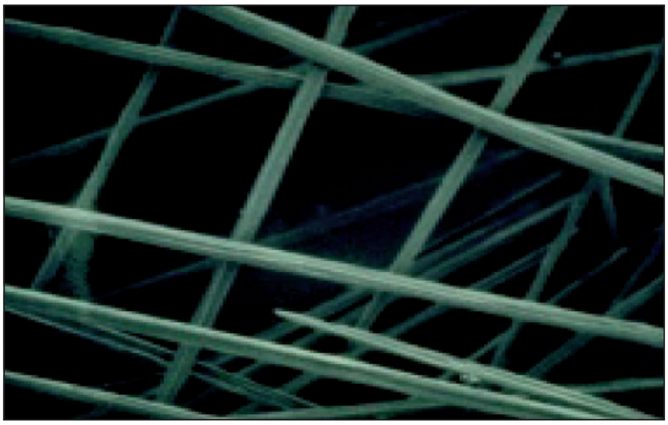

Figure 13: Magnified view of carbon fibre needles used in composite materials.

However, if you subject carbon fibre composite material to high-energy impact while simultaneously burning it with a high temperature flame – typically 1,000C (typical aircraft crash or explosion conditions) – significant quantities of respirable fibres may be released. The fibres, depending on the type of carbon fibre, are normally 2-3 microns in diameter and perhaps 15 microns in length. They are non-toxic but have a strong affinity to contaminants and, as they easily penetrate human skin and tissue, they carry the often highly toxic substances of the crash site into the unprotected skin of anyone working with the recovered materials. The results on the first RAF Harrier crash sites in 1990 were traumatic dermatitis on exposed skin coupled with a few cases of discomfort in breathing.

Aircraft ejector seats represent a very particular hazard. As safety equipment it has a number of independent initiating methods thus, however the seat is activated, there will be unused explosive actuators present. The worst case scenario is if the seat is wrenched from the aircraft by impact where the crew had no chance to activate the system (often the body will still be strapped in, which leads to a more concerted attempt at recovery). It is effectively an unexploded rocket with the potential to accelerate several hundred kilograms of steel to near supersonic speeds in a fraction of a second with devastating consequences.

The only other airframe components which sit on the border between equipment and ordnance are the explosive ‘bolts’ that secure load panniers or pylons to the air frame. These are electrically activated and are used to dump payload of any kind should an aircraft get into difficulty. If recovered ‘unfired’ there is potential for them to be triggered, with consequent fire and shrapnel damage. Any of these electrically triggered systems have a radiation hazard (RADHAZ) component in that they could be triggered by induced current from high power transmitters via ships radar or radio masts. Great care should be taken when operating any electrical equipment in the vicinity of aircraft wreckage.

A BRIEF REVIEW OF POTENTIAL LEGAL PITFALLS THAT COMPLICATE THIS KIND OF OPERATION

The legal issues surrounding a military accident site are significantly different from those associated with a civil crash site. The Protection of Military Remains Act 1986 (1986 c. 35) is an Act of Parliament in the United Kingdom which provides protection for the wreckage of military aircraft and designated military wrecks. The Act provides for two types of protection: *protected places* and *controlled sites*. The primary reason for designation as a protected place is to protect as a war grave the last resting place of UK servicemen (or other nationals).

It is worth pointing out that such wrecks containing human remains, although designated ‘graves’, do not come under the control of the War Graves Commission (WGC). In the context of maritime wrecks the WGC is generally only responsible for any land-based or mounted memorials or the graves of the bodies recovered on land.

The wrecks of UK military aircraft are automatically *protected places* irrespective of whether there was loss of life or whether the wrecking occurred during peacetime or in combat**.** The law concerning protected places applies anywhere in the world, but in practice, outside the UK, the sanctions can only be enforced against UK citizens, UK-flagged ships, or vessels landing in the UK, unless backed by local legislation.

Although the Protection of Wrecks Act 1973 and the Protection of Military Remains Act 1986 are the main pieces of legislation that have been used to restrict activities on some wreck sites, it is important to note that other wrecks may also have restrictions placed on them, for example by harbour authorities or by Directives issued by the Secretary of State’s Representative for Salvage and Intervention (SOSREP).

The Protection of Wrecks Act is in two sections. Section 1 provides protection for designated wrecks which are deemed to be important by virtue of their historical, archaeological or artistic value. Any activities within this exclusion zone can only be carried out under a licence granted by the Secretary of State, who receives advice from the Advisory Committee on Historic Wreck Sites (ACHWS). Section 2 of the Protection of Wrecks Act provides protection for wrecks that are designated as dangerous by virtue of their contents. Diving on these wrecks is strictly prohibited. This section of the Act is administered by the Maritime and Coastguard Agency through the Receiver of Wreck.

It is important to recognise that military aircraft wrecks have a significant number of issues associated with them that may not be relevant to the wrecks of commercial aircraft, eg the presence of unexploded weapons. These factors can make any wreck intervention a very complex proposition and it is well to consider these risks as they often overwhelm the environmental considerations in the early stages of an intervention.

Controlled sites must be specifically designated by location. The Act makes it illegal to conduct any operations (including any diving) within the controlled site that might disturb the remains unless licensed to do so by the Ministry of Defence. As the Ministry of Defence has its own diving teams that are capable of carrying out any diving operations considered strictly necessary, it is highly unlikely that a request for such a licence would be granted. Controlled sites are marked on Admiralty charts and their physical location is marked by means of a buoy (sea mark).

In the case of civil aircraft, the legal issues become much more complex as they are inevitably corporately owned and do not have the same protections afforded to government property. There are few national organisations with an effective response plan for a large civil aircraft crashing in the maritime domain, especially if it is not in shallow water. Inevitably the response is to try and initiate and follow through the plan for a land-based event, which has been regularly rehearsed. Following the SAR effort, which is generally pretty well co-ordinated, there follows a vacuum as the police take the lead and try to apply land- centric ‘scene of crime’ protocols to the sea bed at a remote location. Shortly thereafter the majority of players quietly fade out as it is realised that all the usual planning assumptions are now void.

It remains the case that, under the CAA regulations, national authorities are bound to investigate the loss of a civil passenger aircraft if there have been fatalities. A major player in the event of a fatality involving a UK citizen is the coroner. This person has massive legal authority and influence and is virtually the *de-facto* owner of any deceased UK citizens' bodies until he (or she) decides otherwise. They are regionally based and very aware of both their responsibility and authority. Failure to comply with their mandates, however nicely they have been expressed, can result in operational paralysis. Like the police, however, most of these investigatory bodies have little offshore experience. In the case of the UK this was recognised many years ago and as a consequence the UK AAIB has a bi-lateral agreement with the UK MoD salvage department that allows it to call on the MoD to undertake maritime recovery on its behalf. Hence the UK MoD Salvage department is, effectively, the recovery authority for all UK military and civil registered aircraft from the maritime environment; this includes lakes, rivers and reservoirs. It is also recognised that in the event of a civil aircraft involving a fatality, this is a police matter as much as a technical investigation. This has very specific implications for the wreckage recovery protocols as what is being undertaken is a forensic investigation of 'scene of crime' and all the rules of evidence apply to the recovery process. This can easily extend the duration of any normal recovery process by a very extensive period. It may also require the presence of police officers on board the recovery vessels.

Unlike in the case of military wrecks, there is no automatic designation of civil crash sites and this can lead to legal complications. In the case of the ***AF447***, the lead lies with the French government and judiciary, given the flag of the carrier, but there are many fatalities of varying nationalities. The crash happened in international waters and there a large number of direct interests in the property and the insured risk it represents. The complexities of these diverse relationships can seriously complicate what would ordinarily be a straightforward task.

CONSIDERATIONS FOR MARINE ORGANISATIONS ENGAGING IN RECOVERY

I would suggest that the primary consideration for any maritime organisation engaging in this kind of activity is to recognise the technology and risks to reputation involved. The complexity of the task generates a number of work streams, many of which have no previous experience of the constraints of the maritime domain, given that they are almost wholly land-centric.

Likewise, the maritime contractor has little knowledge or experience of the customer requirements or expectations for this type of task. It is impossible for a maritime contractor to achieve the 'time, cost, quality' parameters that the investigating authorities consider to be the norm for a crash recovery and expectation. Simple things such as weather delays are almost an alien concept. The search technology is incoherent and, whereas some aspects are very advanced, the physics of the environment will always present profound limitations that are not well understood by all the parties. This can very quickly lead to frustrated expectations, especially when the societal group has a perception based upon land-orientated response models.

Given that air accidents inevitably involve fatalities (in some cases mass fatalities), criminal sanctions, massive fiscal liabilities and overwhelming media interest, there is a tendency to try and make scapegoats of third parties in the event of failure. It is interesting to note that in the case of the ***AF447*** much has been made of the failure to locate the wreckage, but little has been said about the global aviation industry's approach to fitting obsolete location beacons to the aircraft. This must be a difficult position to defend, given that they are after all low-cost, low-technology items that do not require integration into the onboard avionics. It is arguable that the problem would be greatly eased by the installation of a float-free FDR fitted with an ERPIRB that would not only indicate impact with water, but also identify crash locations and make the FDR immediately available for surface recovery. The need for subsequent subsurface recovery could then be rapidly established. This particular approach would lend itself to the recovery of vessel voyage data recorders (VDR), many of which appear to be incorporated into the vessel structure, making recovery very problematic as was experienced by the Uk MoD salvage team recovering the VDR from the ferry ***Al Salaam*** in the Red Sea.

Many platform providers rely upon third party groups for the search sub-systems and integration into the prime platform can be fraught with complications ranging from platform incompatibility with tow fish operating parameters (extended slow steaming on main engines) through to electrical 'spikes' corrupting electronic signal return from the towed body. Thus systems integration becomes a critical skillset and much of the work needs to be done at the contract setting stage to ensure clear deliverables are identified. The physical recovery of objects from depth is a routine activity and there are several highly competent contractors who specialise in this. However, when fatalities are involved, police engaged and forensic issues come to the fore, the whole process can become extremely prolonged and staff engagement may persist for a long time after the recovery operation has been completed, especially if staff become involved with legal proceedings as witnesses of fact. This should also be considered at the contract stage.

The handling of human remains, storage and sorting can also generate severe problems. Employers have a duty of care in this respect for both the physical and mental health of the staff involved. The consequential impact of post-traumatic stress disorder can be life changing and if staff are not adequately prepared and managed throughout the process the impact on them and the employer can be very damaging. My practical experience is that firms are often quick to tender without full realisation of the scope of risks and responsibilities that accrue. However, it does provide a lucrative opportunity and all the risks are manageable. The UK MoD has extensive experience in this kind of operation and regularly charters in commercial systems to undertake the task. The Salvage and Marine Operations' (S&MO) team role is to de-risk this kind of activity and produce a credible deliverable that is within the scope and ability of the chartered systems at a price that is acceptable to both. It is to be hoped that ***AF447*** is found in due course, the issues arising from its loss lead to a better global location capability and that the maritime and aviation communities can actually work together in developing this capability – something we appear to have avoided for many decades.

REFERENCES

[1] Henry R Richardson and Laurence D Stone, Daniel H Wagner associates, *Operations Analysis During the Underwater Search for* **Scorpion**. Naval Research Logistics quarterly Vol 18 No2, June 1971.

[2] FAA Advisory circular 21.10A, *Flight Recorder and cockpit Voice Recorder Underwater Locating Devices*, 19 April 1993.

[3] Red disappears first then through the rainbow sequence until violet disappears; then the only 'colour' is black.

[4] ***U684*** was carrying over 60 tons of metallic mercury bound for Japan from Germany when it was sunk by a British submarine operating in Norwegian waters; it is a German war grave and potentially an environmental disaster. This presents a significant political, legal and sociological challenge before the technology issues are even considered.

[5] UK MoD Def Stan 00-970 Issue 2, Part 1

[6] Hexcel Aerospace composite products manufacturer's guide.

[7] EH101 manufacturer's handbook.