The Strange Case of the *Richard Montgomery*:

On the Evolution of Intractable Risk

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In August 1944, the American Liberty Ship *SS Richard Montgomery* ran aground and wrecked in the Medway Channel, near Sheerness, Kent (England). She carried a cargo of 6,225 tonnes of bombs and other explosive war materiel. Only part of the cargo was salvaged and the rest, amounting to 14,571 bombs weighing 3,105 tonnes, remains in situ to this day. This paper offers an account of the shipwreck, its aftermath and the debate over managing the risk, which has continued for three quarters of a century. The narrative builds up a picture of the numerous uncertainties in the characterisation of risks associated with the wreck. This makes it very difficult to define the most appropriate strategy for dealing with the problem. Both official and unofficial accounts have been marred by inaccuracy and exaggeration. The conclusion of this investigation is that the data needed for a rigorous assessment of risk using standard procedures do not exist and probably cannot be collected. However, there is no doubt that a clear and present danger exists. The case of the *Richard Montgomery* is thus a relatively rare example of ungovernable risk for which there are no easy solutions.

KEY WORDS: SS Richard Montgomery; munitions; explosion risk; maritime hazards; shipwreck; unexploded ordinance (UXO); Second World War

Introduction

At the mouth of the rivers Medway and Thames close to London, England, a sunken ship lies undisturbed in shallow water. It is uncomfortably close to a major shipping channel and to urbanised, industrialised coastlines. It contains a very large cargo of bombs and other munitions. If all of these were to explode at once, the result would be absolutely devastating. Yet for three quarters of a century very little has been done to remedy the situation.

Much has been written about this decidedly strange tale, but the resultant body of literature is rife with distortion, misestimation, speculation and exaggeration. This article attempts to provide a reasonably accurate account of the problem as it has developed from 1944 until 2019. This is not easy, as some information is withheld from the public domain by the authorities and much of the rest is patently inaccurate. However, careful triangulation and checking of the sources has provided some sort of a route towards accuracy. Establishing the right narrative is an essential basis for understanding and evaluating the risks involved and discussing possible strategies for reducing or eliminating them. This endeavour occupies the second part of the paper.

The wreck of the *SS Richard Montgomery* exemplifies a very visible, alarming risk, but one which cannot be analysed with any degree of sophistication and accuracy because there are simply not enough reliable, accurate data. Moreover, at this point in time they practically cannot be compiled. The best that can be achieved is a rational discussion of the options, limitations and possible outcomes of different scenarios of impact or risk reduction.

Documentation for this analysis comes from a wide variety of official and unofficial sources (e.g. BMT 2000), including journalism (e.g. BBC 2011) and extending as far as the entertainment industry (e.g. Action Plus Media 2014) and literature (e.g. Johnson 1982). The UK Maritime and Coastal Agency (MCA) is perhaps the most prominent official source (MCA 2017), but there are many others, including the proceedings of the UK Parliament (e.g. UK Parliament 1973). Local historians and activists have provided much incidental information, although its quality is highly variable (Wildfire III 2018). The UK National Archives were consulted for official documentation of the wreck.

This paper will begin with the narrative story, which explains what happened, what the consequences appear to have been and what is the current risk situation. Facets of this include the nature and state of the ship and its cargo, the apportionment of responsibility for managing the wreck, and the comparison of various scenarios for the future. This narrative is followed by a consideration of different risk factors and the means of reducing them that have been either proposed or adopted. Weaknesses in the current strategy for managing the problem are identified. I argue that a proper risk analysis is well-nigh impossible. Although this most certainly reduces the value of my work in this paper, it is nevertheless interesting and instructive to consider a case in which the risk is large and prominent, the solutions are difficult and hotly debated, and the outcomes are remarkably unpredictable. To all intents and purposes, this is a case of intractable risk, but recognising that fact will not banish clear and present danger.

The literature on shipwrecks, unexploded ordinance and the marine environment

There is a broad literature on the risks posed by wrecks and munitions resting on the sea bed, including a special focus on World War II. As Monfils (2005, p. 1049) observed, “World War II was the single, largest loss of shipping in a relatively short period of time the world has ever witnessed.” Moreover, the War itself is not the only source of problems: “Current estimates indicate over 300,000 tonnes of chemical warfare agents in the waters around Europe alone, mostly dumped deliberately after the war.” (Monfils 2005, p. 1052). For example, the British Government is believed to have dumped more than one million tonnes of ordinance in Beaufort’s Trench, an area of deep water between Scotland and Northern Ireland. The material dumped includes quantities of Sarin gas and two tonnes of nuclear waste (Saward 2000). However, the majority of the literature deals with issues that are peripheral to the scope of the present work, namely the potential for and effect of oil spills, chemical pollution, underwater cultural heritage (archaeology, conservation and graveyards), tourism (diving), marine environmental protection, and risks to new installations, such as off-shore wind-farms.

Concerning oil pollution, Landquist et al. (2013, p. 91) concluded that “there is currently no comprehensive generic framework for risk assessment and management of potentially polluting shipwrecks.” Regarding chemical pollution, Beck et al. (2018) noted that the Baltic Sea is probably currently experiencing maximum release of chemicals from WWII munitions that have reached peak corrosion. This includes millions of tonnes of explosive material, “a chemical point source of very poorly constrained magnitude” (Beck et al. 2018, p. 17). MacLeod (2016) provided a methodology for calculating the corrosion rate of shipwrecks and their contents, albeit in a tropical marine environment. Ventikos et al. (2016) focused on oil leaks but included a decay function for corrosion of a submerged ship’s hull. These authors recommended dynamic fault tree analysis of the condition of a wreck.

As Howard et al. (2012) noted, there are various notorious cases of unsalvaged shipwrecks that contain unexploded ordinance (UXO). These authors calculated the severity of the consequences as a function of property damage, damage to the environment, indeterminate location, and injuries, exposure or death. They offered a UXO pathways diagram. However, this assumes a situation for which enough data can be collected to be able to construct a risk matrix and make reasonably accurate decisions. Sayle et al. (2009) endeavoured to establish priorities for risk management of underwater UXO, but at multiple sites. It appears that most of the methodologies proposed in the literature are not well suited to assessing the risks posed by the *Richard Montgomery*. The reasons for this may become apparent in the following narrative.

A narrative of evolving risk

The *SS Richard Montgomery* is a Liberty Ship (class EC2-S-C1). She is named after General Richard Montgomery (1738-1775), an Irish émigré who converted to the cause of American independence and died at the Battle of Quebec City. The ship was built by the St John's River Shipbuilding Company of Jacksonville, Florida, which operated only over the period 1942-1945 exclusively for emergency wartime service. The company built a total of 94 vessels, 82 of them Liberty Ships, and the seventh of these was the *Richard Montgomery* (number 243756, call sign KOAA).

Authorised by the 1936 American Merchant Marine Act and dedicated to Transatlantic convoy work, over the period 1941-1945 some 2,710 of these vessels were built at a total of 18 US shipyards (Williams 2014). Modifications of the original British design of the ships brought the construction time down from 244 days to a minimum of 42 days. However, as the hull plating was welded rather than riveted, it was susceptible to cracking. This was exacerbated by piecework contracts for welders, which put the emphasis on speed rather than quality, and the use of low-grade steel which became brittle in the cold waters of the North Atlantic Ocean. Liberty Ships were expendable war materiel and were not built to last (Thompson 2001).

In terms of dimensions, the *Montgomery* had a displacement of 14,474 tonnes and was 134.5 metres long and 17.3 metres wide at beam. She was a steam ship with a triple-expansion oil-fired engine, a single screw and a top speed of 11 knots. Her purpose was to carry cargo to a maximum load of about 9,000 tonnes, or up to 10,000 tonnes with additional stowage on deck. The keel of the *Richard Montgomery* was laid on 15 March 1943; the ship was launched on 15 June and she was delivered on 29 July, a total construction time of 137 days. She went straight into service, sailing with a convoy that left New York for Liverpool on 14th August 1943. The Liberty Ships were lightly armed with bow and stern Örlikon cannon emplacements. They had a maximum complement of 44 merchant sailors and 25 marines, although it is stated that the *Montgomery* sailed with 52 seamen and 30 gunners (Atkinson et al. 1972).

In August 1944, at Hog Island, on the Delaware River in Philadelphia, Pennsylvania, the *Montgomery* took on a cargo of 6,225 tonnes of high explosive bombs and detonators. She sailed as part of convoy HX-301 to the River Thames estuary, outside London, where she was to join another convoy in order to deliver the munitions to the US Air Force at Cherbourg. When she arrived she came under the jurisdiction of HMS Leigh, which was actually a control centre located on Southend Pier. From here, the King’s Harbourmaster, Lt Cdr R.J. Walmsley, ordered her to drop anchor at Sheerness Middle Sands, in about 10 metres of water at low tide.

Unfortunately, the *Montgomery* was trimmed abaft to a draught of 9.45 metres, 90 cm more than was usual for a Liberty Ship, and she had a full cargo. The Assistant Harbour Master, Lt Roger Foley, remonstrated with his superior officers and asked them to switch berthing between the *Montgomery* and a ship with a draft of only 7.3 metres, which was anchored nearby in deeper water. The error of judgement was so obvious to Lt Foley that he refused to transmit the order to drop anchor to the *Montgomery* unless he received it in writing. For his pains he was overruled, considered insubordinate and two days later transferred to another posting. On Sunday, 20th August 1944, in a force-eight gale, the *Richard Montgomery* dragged her anchor and ran aground on a sandbank.

As the tide ebbed the ship's plates began to buckle and crack with penetratingly loud noises. Captain Willecke and his crew, alarmed at the situation and aware of what could happen to the cargo, took to the lifeboats and, on reaching the shore, obtained lodgings in the town of Southend. Meanwhile, the Department of the Director of Salvage at the British Admiralty engaged Messrs Watson & Gill, Shipbrokers, to conduct salvage operations. At 3 a.m. on Tuesday, 22 August 1944, a master stevedore, Mr T.P. Adams, was called out to inspect the ship and its cargo and check the latter against the stowage plan, which he obtained from the ship's chief officer. The cargo hatches were undamaged and the vessel was not taking in water. At 10 a.m. on Wednesday 23rd August stevedores from Rochester began the salvage operations, assisted by some US sailors. They unloaded cases of bombs using the ship's derricks powered by a steam-line from the tug *Atlantic Cock*, which assisted the salvage vessels, *Empire Nutfield* and *Flathouse*.

A few days later, a Board of Enquiry met for six hours in the saloon of the *Montgomery* under the chairmanship of a Lieutenant Commander of the US Navy. As the Board sat, fuel oil leaked from the ship and the groans and cracks of rending metal mingled with the noise of the salvage operation. The proceedings were summary. At dawn on Sunday 20th August 1944, nearby ships had seen the *Montgomery* drift towards the sandbanks and had sounded warning sirens. The Chief Officer failed to rouse the captain, who was sleeping. Both were indicted for hazarding their ship and their licences were suspended for a year (despite the fact that Captain Willecke had objected to the berthing and, when his objections were overruled, had asked to be roused if there were problems). The Assistant Harbour Master was not asked to present evidence. He was, instead, ignored.

On Friday 24th August a crack opened in the fore end of one of five holds, no. 3, which led to the flooding of holds 1-3. Salvage was concentrating on holds 4 and 5, abaft, which were eventually cleared of most munitions. On Friday 8th September, the ship broke her back, leaving the three forward holds permanently submerged. Salvage was hazardous and difficult. For example, a passing destroyer (no. D11 of the 'Hunt' class, *HMS Impulsive*--aptly named) was signalled to reduce speed in order to attenuate her bow wave. She did not. Two salvage vessels broke their moorings, the *Flathouse* rolled and clanged alarmingly against the side of the *Montgomery*, inside which the cargo shifted. Days later, the British Admiralty would object to the fact that the stevedores were paid danger money! After removal of some of the cargo, the Admiralty tugs *Firm* and *Empire Ben* endeavoured to drag the *Montgomery* off the sandbank, but she was stuck fast.

The wind and waves became stronger, and the ship creaked and groaned, with loud reports as cracks opened up due to stress on the hull caused by its settlement on Sheerness Sands. The removal of the cargo from holds 4 and 5 increased the buoyancy of the aft section, which led it to separate. It moved 15 metres away from the loaded holds and slewed 12 degrees clockwise, thus helping marine currents to scour the sands under the fore section, which finally came to rest on the Gault Clay 'bedrock' under the sands (Astley et al. 2014).

On Monday 25th September, Watson & Gill decided that the salvage operation had become too dangerous and thus they abandoned it--in great haste, apparently, as they left nets and slings behind. Since then, very little has changed and the wreck, which lies in 15 metres of water, has remained untouched, except for some pruning of its rigging in October 1999 (MCA 2014). Its three masts protrude above water at all times (Figure 1), and at very low tides part of the remaining superstructure is visible. The wreck is about 2.4 km from the town of Sheerness (population 11,936 at the 2011 census) on the Kentish Isle of Sheppey (population 40,300). Some 3-5 km to the southwest is the Isle of Grain, upon which is sited an oil-fired electricity generating station and four storage tanks for liquefied natural gas, each of which has a capacity of 190,000 cubic metres. These were constructed over the period 2002-2018. Nearby, there are 18 oil storage tanks of standard design. The wreck is situated less than 200 metres from a busy shipping lane called the Medway Approach Channel (in reference to the adjacent River Medway estuary, which feeds into the River Thames estuary).

Figure 1. The wreck of the SS Richard Montgomery

(photo: Clem Rutter, Wikimedia Commons).

A 100 metre-wide polygon was established around the wreck, delineated by four hazard buoys. This is an exclusion zone in which only an official survey vessel is allowed. Radar and visual surveillance are maintained. Nevertheless, many people have invaded this space. In the 1960s people would sit on the wreck and fish. Local fishing boats that brought up Second World War bombs in their nets would abandon them in the vicinity of the *Montgomery*, even on its decks. In the 1960s, pleasure boats regularly took parties of tourists around the exclusion zone, and at intervals they still do. At some point in the mid- or late-20th century, persons unknown looted copper and brass from the wreck. In 2017 a paddle-boarder posted to social media a picture of himself balanced on the wreck. Other photographs and videos of close approaches can be found on the Internet, although it should be noted that web-based accounts of the Montgomery are commonly decorated with inaccurate and misleading pictures.[1] On 2nd January 1969, as a prank, students from Kent University telephoned Sheerness police and threatened to blow the wreck up, provoking a massive security operation. Another such operation was mounted during the 2012 London Olympic Games. The wreck has inspired documentaries, films and novels, especially about terrorist activity (e.g. Barlay 1977). So far, it has not motivated terrorists to act.

The proximity of shipping is a more worrying factor. More than 5,000 vessels pass the wreck each year. By 1978, 24 near-misses had been logged (according to the now defunct *Police Review* journal): the current total is not made public. The worst instances occurred in foggy conditions in late May 1980. First, the British-registered *MV Fletching* (2,880 dwt) grazed the no. 7 Medway buoy and came within 15 metres of the wreck. On 22 May 1980, later in the same week, the Danish-registered *Mare Altum* (IMO registration 7381829), a chemical tanker of 1,597 gross tonnage carrying low-flashpoint toluene, entered upon a collision course. With poor visibility and difficult radio contact, she received an Immediate Action Order to turn hard to starboard only six minutes before she would have entered the exclusion zone and hit the wreck. Her captain was taken to court and fined for careless navigation.

The cargo and what remains of it

Ever since the stevedores left the *Richard Montgomery*, there has been intense speculation about the exact nature of the cargo. In 1972, in one of the first attempts to

[1]https://www.reddit.com/r/submechanophobia/comments/3svvva/man_paddle_boards_to_the_wreck_of_ss_richard/
https://www.youtube.com/watch?v=JqOKJc6tt_4
http://www.pbase.com/luckytrev/image/74364564

resolve the issue, a report was written by three local people, a councillor, a historian and a member of a local chamber of commerce (Atkinson et al. 1974). Their work was meticulous and, as far as possible, it seems to have been rigorous. They carefully compared the original cargo manifest with the daily reports of the salvage team. Their report also gave details of the storage conditions of the bombs and other devices, and it detailed their content of high explosives. A facsimile of the report was eventually placed on the privately-run website www.ssrichardmongomery.com. The analysis suggests that at Philadelphia the vessel took on 35,943 individual explosive items, of which 13,961 remain. For 'individual items' it should be noted that some are cases of bombs rather than single explosive devices. Atkinson et al. (1974, p. 15) concluded that 88 per cent of the remaining munitions are loose GP and SAP bombs (see Table 1). Of 5,986 tonnes of explosive materiel, 51.9 per cent by weight (3,105 tonnes) remains (Atkinson et al. 1974). The 1944 salvage achieved some of the greatest reductions in smaller items, but the forward holds are still packed with loose bombs, many of them of large size, situated on racks orientated fore-to-aft and separated by dunnage boards.

[Table 1 here]

Other attempts to calculate the residual cargo have come up with different numbers. For example, one of the most detailed of these (Williams 2016, p. 258) stated that there are 15,906 bombs of various sizes and cases of explosives, amounting to 3,910 tonnes of materiel containing 1,560 tonnes of trinitrotoluene (TNT). Southworth and Da Costa (1997, p. 3) reported that 630 tonnes of munitions remain in hold no. 1, 483 tonnes in hold 2 and 359 tonnes in hold 3, for a total of 1,472 tonnes in the form of 14,340 bombs or cases of bombs (MCA 2000. p. 20). Nearer to the present day, the owner of a private website (http://www.wildfire3.com/richard-montgomery.html) reanalysed the salvage records and concluded that 5,434 tonnes of munitions remain on board. However, although his analysis is detailed, it fails to account for three weeks (5th-25th September 1944) in which salvage continued, according to the detailed record preserved in the UK National Archives. UK Government correspondence from August 1952 suggests that Hold 4, which was marked off as clear of munitions, may instead contain 830 cases of fragmentation bombs, located at the back of the between-decks area.[1] All things considered, it is prudent to accept the estimates given in Table 1, *cum grano salis*. There is no evidence to suggest that the organisations which are responsible for the wreck have any more reliable data on its contents.

Ownership and responsibilities

For three quarters of a century the US Government has been the owner of the wreck.[2] In 1948 and 1967 it offered to make it safe (if that were possible), but the British Government turned down both offers. From 1944 until 1973 surveillance of the wreck was the responsibility of the Port of London Authority. After the passage of the Protection of Wrecks Act in 1973, the UK Inland Revenue became responsible. The *Richard Montgomery* was the first wreck to which this legislation was applied. In a further reorganisation, twenty years later, responsibility was passed to the "Receiver of the Wreck", based with the local coastguard. Surveys were initially conducted under

[1] **Error! Main Document Only.**Treasury Solicitor and HM Procurator General 1952. Registered Files, Admiralty Series. SS Richard Montgomery: removal of wreck from Sheerness Naval Dockyard [sic]. Survey Report August 1952 National Archives no. TS 32/601

[2]Except for the period 1949-1952, when the wreck was (rather bizarrely) sold for salvage to the American firm Philips Craft & Fisher. The sale was eventually rescinded and the US Government regained ownership of the vessel, having stated in an official communique that the ship had been raised, transported to the Port of Rochester and cut up for scrap.

the auspices of the UK Ministry of Defence, and since the mid-1990s have carried the *imprimatur* of the Maritime and Coastguard Agency, an office of the UK Department for Transport, although the actual work has been carried out by contractors.

A pattern of 'buck-passing' was established not long after the ship sank. A question asked in Parliament about what responsibilities the Admiralty held for the wreck of the *Richard Montgomery*. The answer received was an abrupt "none". A similarly weak response was given in answer to a Parliamentary question in 1965.[3] In 2010, one activist, Mr Mike Barker, mounted a campaign against the UK Department for Transport (DfT) in relation to its alleged failure to provide information and protect the public against the hazards of the wreck.[4] The DfT's response was cautious and cited numerous exemptions from the UK Freedom of Information Act. The campaign, which included an attempt to sue the UK Government for negligence, does not appear to have produced any useful results. Responses from other Government departments were bland and non-committal.

Surveys and the condition of the ship

For the first 20 years, the presence and condition of the SS Richard Montgomery were an Official Secret of the British Government, despite the glaringly visible evidence to the contrary (Williams 2006, p. 6). In the mid-1990s the decision was taken to conduct an annual survey of the wreck, to be carried out by divers and professional marine assessors from boats and a small ship. At least 17 of these reports (or summaries of them) from the past 24 years have been placed on the Internet in the

[3]Hansard Deb. 24, November 1965, vol. 721, cc 489-490.

[4]See https://www.whatdotheyknow.com/user/mike_barker_mbe

public domain (MCA 2017). Others were suppressed, perhaps as a hang-over from the official policy of secrecy, and they were eventually released to the National Archives in the early 2000s.

Divers have periodically visited the wreck. I can recall seeing on television an underwater film sequence of the bomb racks in about 1966, but this particular clip appears to have been suppressed. Generally, the water is too turbid for photography inside the wreck to be very successful. Diving inside is extremely hazardous due to the bombs, the risk of structural collapse, the opacity of the water and the presence of many sharp obstacles. Robots could be used, but they might disturb the cargo and thus increase the risk of explosion.

Early attempts to visualise the condition of the wreck involved a wooden model in a box of sand. Then came sonar, upgraded to an ultra-high resolution multi-beam echo sounder (MBES) technology, laser scanning, GNSS positioning systems and powerful software. The Port of London survey vessels *SV Yantlet* and *SV Galloper* used in the latest available survey (MCA 2016) thus achieved a very high degree of accuracy in surveying the bathymetry of the sands, the external condition of the ship and the exact position of everything that could be surveyed without entering the wreck. There are 96 survey points which are repeatedly monitored for changes. Over the years, the wreck has remained stable, but its structure has slowly deteriorated. In mid-2015, there was a minor collapse on one of the decks (on the port side of hold no. 2), and the propagation of some cracks in the hull (MCA 2016). Sediment has shifted around the wreck, changing the pattern of stress on the structure (Astley et al. 2014). Crack propagation has continued unabated.

It seems that some bombs have, at an unknown point in time, fallen out of the wreck and now lie on the sea bed. It is assumed by the authors of surveys and most other commentators that, left to its own devices, the wreck will eventually disintegrate, with what consequences no one knows. This will probably begin with the collapse of decks, which has already begun in a minor way. In the meantime phosphorus has escaped in the disintegration of wooden cases of the phosphorus bombs. After floating up to the surface, and on drying out in contact with the atmosphere, it has caught fire. More than 40 instances of this have been reported to the authorities,[5] who, in a response from Parliament, stated that there was no such phenomenon (Hansard, 25th January 2010). Experts argue that the phosphorus ignitions do not pose a threat to the rest of the munitions on board.

Scenarios

A risk assessment of the *SS Richard Montgomery* was conducted in 1999 but remains a classified, inaccessible document. Elements of it can be gleaned from leaked conclusions and a disparate collection of available reports (BMT 2000, MCA 2001). In 1970, munitions experts at the Royal Military College of Science were asked to prepare a scenario for the explosion of the entire cargo (Hawkins 1970). If this were to happen, the result would be a 3,000-metre high column of water and debris and a five-metre tsunami. The town and port of Sheerness, less than 2.5 km away, would be overwhelmed. The water wave would also reach the petrochemical installations of the Isle of Grain, with possibly catastrophic consequences: the liquid natural gas

[5] https://www.theyworkforyou.com/wrans/?id=2010-01-25c.312645.h#c25384

containers have dimensions similar to that of the Royal Albert Hall, and they are surrounded by petroleum tanks. Various tsunamis, including the March 2011 event in northeast Japan, have caused major fires in such situations. The Isles of Sheppey and Grain are difficult of access in the event of the need for a mass convergence reaction by the emergency services, or rapid post-event evacuation by survivors. It is possible that the wave would travel up the River Thames and flood London.

All reputable authorities agree that the ‘top event’ is highly unlikely (MCA 2014, p. 3). On the other hand, they may be underestimating a well-planned act of deliberate sabotage by terrorists or an accidental collision by a ship with a dangerous cargo, as nearly occurred in 1980. It is likely that the maximum scenario was a factor in the decision not to construct London’s next airport on the Isle of Grain a few kilometres east of the wreck (Telegraph 2011).

Lesser scenarios mostly involve smaller and more limited versions of the ‘top event’. An explosion at low tide would be the most dangerous, but munitions experts at the Royal Military College of Science estimate that the damage radius of the blast would be limited to 2.5 km, encompassing Sheerness, but not the Isle of Grain (Johnson 2004).

There have, of course, been major explosions of munitions ships in the past. The example most often compared to the *Richard Montgomery* is that of the *SS Kielce*. This was an American-built ship of 1,780 tonnes displacement that was ceded during the war to the Polish Navy-in-exile. In 1946 she sank 6.4 km off the coast of Folkestone with a mixed cargo of munitions and equipment. The wreck lay on its side in less than ten metres of water. In July 1967 efforts to salvage the cargo included three attempts to penetrate the hull with limpet mines. The third detonation, on 22 July, set off the cargo of explosives, causing a magnitude 4.5 earthquake, a 47-metre long, six-metre deep hollow in the sea bed, a half-metre tsunami and a 150-metre high column of water. Pandemonium and damage prevailed in Folkestone, but there were no casualties. An enquiry established that about 100 tonnes of explosives were detonated. On the basis of the earthquake, other sources, perhaps less believable, suggest a yield of 2,000 tonnes of TNT (MCA 2000, p. 22). Such discrepancies vividly illustrate the uncertainties of scenario-building regarding marine explosions.

Other munitions ship explosions occurred in Bari, southern Italy, in 1943 (2,000 dead, Reminick 2001) and Texas City, Texas, in 1947. In the latter case, the *SS Grandcamp*, a Liberty Ship loaded with 1,985 tonnes of ammonium nitrate exploded, setting off further explosions in the port area and killing 581 people (Stephens 1997). However, from the point of view of this analysis, the most interesting case is that of the *SS Mont Blanc*, which on 6th December 1917 collided with another vessel, the *Imo*, in Halifax Sound, Nova Scotia. The *Mont Blanc* was fully loaded with munitions and had barrels of fuel on its deck. She caught fire and after 20 minutes exploded. Some 1,963 people were killed, 9,000 were injured and the city of Halifax was devastated (Cuthbertson 2017). The *Mont Blanc* was entirely blown into small fragments, some of which landed more than 5 km away. The water wave caused by the explosion was large and destructive. It was severely constrained by the topography of Halifax Sound, which induced it to rise as high as 18 metres. The yield of the explosion was estimated to be equivalent to 2,900 tonnes of TNT. Interestingly, it can be argued that the Halifax explosion marked the start of sustained academic studies of disasters (Prince 1920, Scanlon 1988).

A further example of considerable relevance is that of the explosion of the Liberty Ship *E.A. Bryan* at Port Chicago, California, on 17 July 1944. She was being loaded with a cargo of bombs not unlike the manifest of the *Richard Montgomery*. The loading equipment was defective and the sailors doing the loading were very poorly trained. The explosion totally destroyed the *E.A. Bryan* and spectacularly dismembered an adjacent Victory Ship, the *Quinault Victory* (a slightly larger version of Liberty Ship). Some 320 sailors were killed and 390 were injured. The explosion caused a magnitude 3.4 earthquake (Sheinkin 2014).

In 2004, the magazine New Scientist published an article which suggested that the presence of water, by infiltration or condensation, could generate hydroazoic acid in fuses on the Montgomery, which might corrode them to the point at which the slightest jolt would cause explosions (Hamer 2004). This theory has been discredited, as it is argued that the lead azide necessary for this transformation will have leaked away decades ago (Southworth and Da Costa 1997, p. 2). Moreover, it seems likely that some of the cluster bombs (Table 1) are not fused (Williams 2016, pp. 94-126). Nevertheless, whether structural collapse, physical alteration of the bombs, collision by a ship, deliberate detonation by terrorists or other causes are involved, no one doubts that serious risks remain. Some argue that they are increasing, not diminishing, with time. In February 2018 a World War II bomb was found during excavations in King George V Dock. A 214-metre exclusion zone was established around the site, involving the closure of London City Airport for a day. The bomb was removed and detonated at sea by artificers in a spectacular explosion (BBC 2018).

Proposed solutions

The preferred solution to the problem of the *SS Richard Montgomery* has been to do nothing. Surveillance is kept up, but, as this account shows, it is not entirely effective. Controlled detonation of the cargo is out of the question. To build a sarcophagus, Chernobyl-style, over the wreck would probably cause structural collapse onto the bomb-racks. Similarly, to build an 1,800-metre-long coffer dam around the wreck would disturb the stability of the ship's superstructure (Figure 2). On the other hand, extracting the bombs and making them safe would take at least six months and would, following normal procedures, necessitate the evacuation during all of that time of about 40,000 people. It would be a hazardous occupation that would require different techniques for different kinds of bomb. These options are (apparently) evaluated in the 1999 risk assessment, and it is of note that the executive summary of this document states that "Experience from other similar wrecks indicate [sic] that the explosion of one munition on the wreck is likely to result in mass explosion" (MCA 2001).

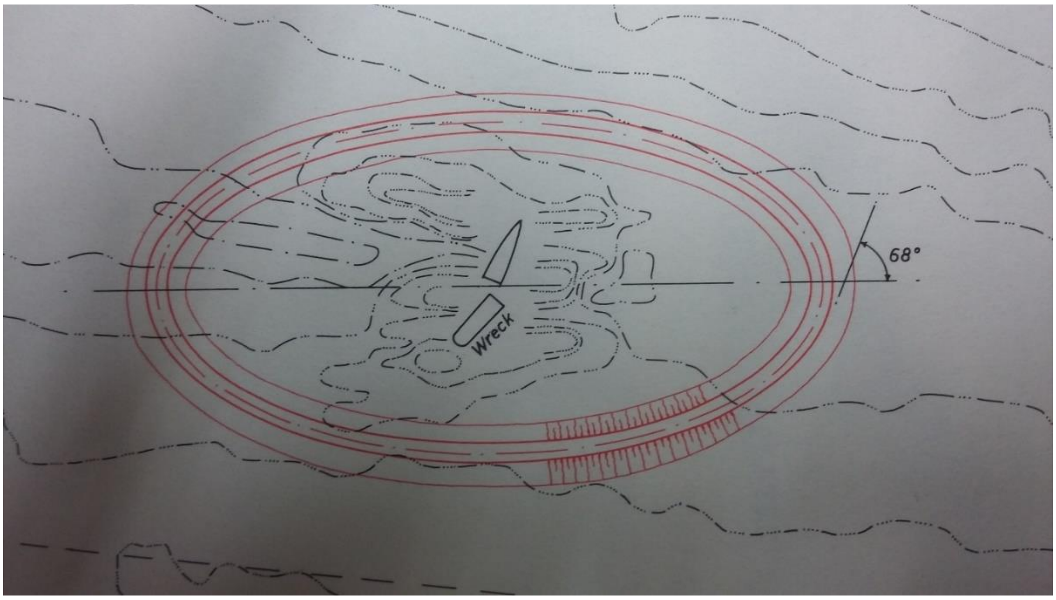

Figure 2. The 1971 plan to build a coffer dam around the SS Richard Montgomery (Hawkins 1971.) (author's photograph).

Analysis

In the case of the Richard Montgomery, the level of uncertainty virtually precludes any kind of rigorous assessment of risk, which would be a necessary first step in determining the right course of action to govern it. The main uncertainties can be divided into those that are epistemic, i.e., amenable to being known and validated, and those that are aleatory, i.e., a function of innate uncertainty (Kiureghian and Ditlevsen 2009). Examples of the former are as follows:-

- the exact complement and proportions by type of munitions aboard the wreck
- whether fuses are in place in some of the bombs
- the physical condition of all munitions regarding their susceptibility to explosion
- what alternative explosion scenarios are worth considering
- how and when structural collapse might occur on the wreck
- the attenuating or enhancing effect of an explosion in shallow water.

Aleatory risk includes the following:-

- the proportion of the munitions that would be involved in any explosion
- whether collapse, collision, fire or explosion would provoke the simultaneous detonation of virtually all munitions aboard the wreck, and exactly what effects that would have on the surrounding area
- whether the entrance of holiday-makers and thrill-seekers into the exclusion zone could provoke an explosive incident
- the likelihood of a successful terrorist attack
- the gravity and extent of consequences if an explosion were to occur.

Some risks appear to be indeterminate regarding whether they are epistemic or aleatory (Kiureghian and Ditlevsen 2009), for example the probability of a collision between a ship and the wreck and whether a highly inflammable, unstable cargo in such a the ship might detonate the bombs. The passage of such ships could be monitored, along with their cargoes, and encounter probabilities could be computed from logs of known incidents under analogous conditions to those of the Medway estuary. However, the precise consequences of a collision are much less easy to envisage. By and large, the aleatory risks overshadow the epistemic ones.

The epistemic risks could be investigated by creating detailed scenarios supported by modelling on the basis of known parameters, for example from munitions explosions. As with much scenario modelling, there would need to be a range of outcomes, including the worst plausible case (Alexander 2000). To judge by the accessible documentation on the case, there is no indication that this has been done. Presumably, the authorities would regard it as unduly alarmist. One senses that there is also a reluctance to draw attention to the *Montgomery*.

Behind the scenes, measures have been put in place that are designed to limit the uncertainties:-

- very accurate periodic survey of the external condition of the wreck and the local bathymetry
- expert opinion on the likelihood of mass explosion (Hawkins 1970, Williams 2016)
- 24-hour surveillance
- modern navigational aids, including accurate GNSS, and modern telecommunications.

Technology thus helps avoid the wreck and understand the process of its deterioration in minute detail. However, the sum total of these measures is obviously not enough to render the Montgomery harmless, or to ensure that an appropriate intervention would stop a potential collision, attack or explosion in a timely manner. In fact, the weaknesses or drawbacks of the current strategy can be summarised as follows:-

- the presence very close to the wreck of a major shipping lane (and a town and a petrochemicals complex)
- performance of shipping in adverse weather (waves, wind and fog)
- inability to act promptly enough in the case of a deliberate attempt to board the wreck
- reluctance to engage in a radical and very expensive strategy, such as prolonged mass evacuation and unloading of the *Richard Montgomery's* cargo (which is understandable in terms of the cost - scores of millions of pounds - and the disruption incurred).

The final element in the balance sheet for the *Richard Montgomery* explosion scenario concerns the problems of assessing the risk. These are broadly as follows:-

- the risk of accidental collision is too dependent on specific errors of judgement or action to be calculable on the basis of the record of incidents that have happened elsewhere
- unless covert intelligence were to give a very clear warning, the risk of terrorist attack is essentially unfathomable; in any case, relevant information is not in the public domain, nor is it widely shared at an institutional level

- the consequences of a collision or other physical interference with the wreck are difficult to assess without a much more detailed understanding of the condition of the munitions on board
- the timing, modality and effects of spontaneous structural collapse are not predictable other than in a vague and highly generalised manner.

UK institutions implicated or involved in this story have been adept at ignoring the risk, shrugging it off or transferring it from one agency to another. Activist residents of the Kent coast have asserted that officialdom has little concern for their safety. Politicians and some public administrators have repeatedly argued that the risk of explosion is low. Those few British Army experts in defusing unexploded ordinance (UXO) who have spoken out have regarded the risk of explosion as much more serious.[6] The deaths of three experienced bomb disposal officers in the explosion of a large, unstable World War II bomb on the night of the 1st June 2010 in Göttingen, Germany, suggests that the risks posed by UXO are far from negligible.

Conclusions

In August and September 1944 V-1 and V-2 pilotless flying bombs rained down on southeast England in large numbers (before the end of the conflict, 1,358 of the latter were to fall on London). Wartime induces a sense of relativity to incidents and casualties that would be unthinkable in peacetime. Extraordinary risks are taken with little thought for the consequences; major losses are born with only the most summary attempt to learn lessons. In the English Channel, beset by danger, chaos and damage,

[6]For example, retired Royal Engineer Major A.B. Hartley, interviewed by *New Wide World* Magazine in April 1964.

shipwreck clearance went on at a frantic pace in the final months of the War and first phase of the peace. It is a pity and something of an anomaly that the *Richard Montgomery* was left behind.

The current situation is very much a case of “damned if you do, damned if you don’t.” The socio-economic costs of prolonged mass evacuation would be excessive and, apparently, have not even been properly estimated. On the other hand, a major explosion could result in carnage and the propagation of a wave of massive damage towards London. Another worrying possibility is a series of powerful but smaller explosions as the wreck is destabilised and becomes too dangerous to approach under any circumstances, disrupting major shipping lanes and coastal life. It seems that a tacit assumption by decision makers is that, left alone, the wreck would slowly become harmless. There is no evidence to support this idea. Instead there is a glaring disparity between the measures usually taken to neutralise individual Second Word War bombs when they are discovered (evacuation of tens of thousands of people and closure of major venues) and the continuing presence of the *Montgomery* close to the Medway Approach Channel.

The case of the *SS Richard Montgomery* does not show up inadequacies in normal risk estimation methods (Baum 2015), but it may suggest that there are simply a few very dangerous cases for which conventional techniques of risk assessment and analysis are unable to give authoritative answers. Over almost three quarters of a century, both the risk and knowledge of it have evolved, the former because the condition of the ship is deteriorating and the latter because modern methods reveal this in great detail. However, this has not led to any improvement in strategies for containing, reducing or otherwise managing the risk. Despite the co-evolution of the risk and knowledge of it, the ship continues to be an intractable problem for which risk analysis cannot supply adequate answers.

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Table 1: The estimates by Atkinson et al. (1972) of the original and remaining cargo of the S.S. Richard Montgomery

General purpose (GP) bombs

	remaining number	total weight (tonnes)	original no.	original weight (tonnes)
250 lb (113 kg)	2,021	215		
500 lb (227 kg)	1,407	306		
1000 lb (454 kg)	1,844	742		
2000 lb (907 kg)	206	249		
Total	5,558	1,512	13,064	2,763

Semi-armour piercing (SAP) bombs

	remaining number	total weight (tonnes)		
500 lb (227 kg)	1,925	408		
1000 lb (454 kg)	2,178	894		
Total	4,103	1,303	7,739	2,326

	remaining number of cases	total weight (tonnes)	original number of cases	total weight (tonnes)
Cluster fragmentation bombs	2,618	159	9,022	571
Phosphorus smoke bombs	1,429	97	1,429	97
Pyrotechnical devices	638	21	895	31
Fuses	225	11	1,522	78
Fins (non explosive)	11,613 (no.)	122	21,619 (no.)	240
Demolition 100 lb bombs	0	0	1,427	82
Small arms ammunition	0	0	817	36
Bursters	0	0	28	2