Summary of recently declassified documents on Defence nuclear safety

Board of Inquiry into the grounding of HMS Trafalgar on Fladda-Chuain on 6 November 2002

HMS Trafalgar was taking part in a submarine command course in the Fladda-Chuain chain North of Skye. Navigation aids had been deliberately concealed. This was done "to increase the degree of navigational difficulty and hence pressure on the students"[1]. There was confusion on the submarine as to who was formally responsible for navigation. The trainee in control was from a foreign Navy. He was using tracing paper which concealed some of the information on his chart. He did not properly take account of the significant tidal stream around Fladda-Chuain. As a result the submarine struck the bottom heavily at a speed of 14.7 knots.

The Board of inquiry concluded that HMS Trafalgar grounded because of human error. The Commanding Officer and the course teacher were both disciplined in a Court Martial. The inquiry report said "Although a safety organisation was in place [on the submarine] and had worked effectively up until then, it failed to operate when most needed".[2]

The report said that there was "good reason" for depriving the trainee commander of navigation aids and did not recommend that this practice should cease. Submarine Command Courses have continued to take place using nuclear submarines off the West coast of Scotland. The training deliberately places the trainees in difficult and confusing situations. The trainees control the submarine as they conduct a series of exercises some of which are at high speed and close to other vessels.

Board of Inquiry into the collision of HMS Tireless on 13 May 2003

HMS Tireless was carrying out an exercise in the Marginal Ice Zone when she hit the keel of an iceberg 60 metres below the surface.[3]

The submarine manual SMP 27 gave the false impression that an iceberg could be reliably detected by passive sonar. The crew of HMS Tireless assumed that this was correct and were relying on their passive sonar. This system gave no advanced warning of the iceberg which they hit.

After the collision withdrawal from the area was difficult because of the presence of a number of large icebergs in the area. For this reason some damage control checks were not carried out immediately.

The Navy required that specific training had to be carried out before a submarine was deployed under pack ice. But this did not apply to deployments in the Marginal Ice Zone. Fleet HQ had not considered the hazards of icebergs in this zone. No under ice training had been arranged for HMS Tireless for this deployment. The assessment on the vessel was that there was only a faint possibility of small icebergs with drafts not exceeding 30 metres. The submarine was operating relatively close to the surface because the area was poorly charted and there was a danger of running aground.

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[1] Board of Inquiry into the Grounding of HMS Trafalgar on Fladda-Chuain on 6 November 2002, HMS Montrose, 12 November 2002, para 5.
[2] BOI Trafalgar 2002 para 30
[3] Board of Inquiry into the collision of HMS Tireless on 13 May 03, Faslane Flotilla, 5 June 2003.

The Board of Inquiry conclusions includes the following:

"The focus of RN submarine environmental effort is in tactical exploitation and there was insufficient focus (HQ and on board) on the hazards to submarine safety presented by icebergs".[4]

Board of Inquiry into an explosion on HMS Tireless on 20 March 2007

HMS Tireless was operating under the icepack when a Self Contained Oxygen Generator (SCOG) exploded killing two sailors and starting a number of small fires. A large part of the submarine, including the designated damage control headquarters, was out of action because of fumes. There was a delay of 44 minutes before access was gained to the casualties at the site of the explosion, and a similar delay before the submarine was able to surface at a gap in the ice 2 miles from the scene of the explosion.

Two major failings in submarine safety which can be deduced from the Board of Inquiry report are:

(1) It is difficult for the crew to respond to an explosion or fire on a submarine.

A large part of HMS Tireless including the Ward Room, which should have been the Damage Control Centre, could not be used because of fumes. Visibility was limited by smoke and inadequate emergency lighting. Communications after the accident were very difficult because the VHF radios were ineffective and piped messages could not be heard over the background noise. Messages were passed through the submarine by word of mouth.[5] A fire hose was deployed to the wrong room and the nozzle detached, making it unworkable. The team sent to control the fire did not feel competent to fight a fire in the particular circumstances they were faced with.

Submarines crews are not trained how to respond to an accident of this magnitude – "Neither the pre-deployment training package nor general FOST [Flag Officer Submarine Training] safety training exercises a scenario whereby such a large volume of the submarine atmosphere is out of specification from the outset."[6]

The fire on HMCS Chicoutimi in October 2004 should have alerted the Royal Navy to these problems - "Many of the DC&FF [Damage Control and Fire Fighting] lessons identified in the HMCS Chicoutimi incident in 2004 have been repeated in this incident".[7] 3 years later the Navy still failed to properly assess the likelihood of a large part of the submarine being out of action in a fire or explosion.

The report found that this accident could have been much worse - "The small fires caused by the explosion could easily have taken hold and a major conflagration ensued, with very serious consequences, if [name deleted] had not had the stamina and presence of mind to use all available means to extinguish them".[8] The sailor concerned was the one survivor from the compartment where the explosion occurred. He was seriously injured in the accident.

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[4] BOI Tireless 2003 para 26 g.
[5] BOI Tireless 2007 para 48 & 49
[6] BOI Tireless 2007 para 214
[7] BOI Tireless 2007 para 268 x
[8] BOI Tireless 2007 para 8

The ability of the crew to respond to a serious incident is a critical part of the risk assessment for a nuclear accident on a submarine. The problems identified in this report would suggest that the crew's ability to bring an incident under control may not have been properly evaluated in these risk assessments.

(2) The risk of an Oxygen Generator explosion had been ignored.

The inquiry report found that the SCOG had become contaminated with oil and that this was the cause of the explosion.[9]

Before the accident the MoD had commissioned a safety case into SCOGs. This had assessed that the contamination of a SCOG was "non credible", ie that it was "extremely unlikely to occur during operational life of the unit".[10] Following the accident, tests were carried out on a sample batch of 258 SCOGs. 10.5 per cent were found to be contaminated with oil or grease.[11] "Extremely unlikely" is defined in JSP 538 as 1 in 10^9.[12] However the actual occurrence was 1 in 10.

The SCOG safety case did not consider the possibility of a SCOG exploding during operation. This omission was particularly concerning as the manufacturers' safety data sheet for SCOG had described the danger of an explosion resulting from contamination.

One of the Board of Inquiry's conclusions was - "There are many systematic failings that contribute to the TIRL explosion which can be collectively viewed as inadequate risk management of the hazard that SCOGs present".[13]

The inquiry report does not mention the implications of this for nuclear risk assessments. However it would be likely that this risk had not been considered in wider assessments of the risks of nuclear accidents on submarines.

Immediately after the explosion the Captain of HMS Tireless operated the Battleshort, overriding the reactor safety systems. This is a standard Emergency Operating Procedure [EOP]. The inquiry report explains – "The Battleshort switch overrides the automatic reactor protection and is made as part of the flooding EOP because it is deemed that the safety of the submarine cannot be jeopardised by a spurious automatic reactor shutdown".[14] In this case the flood warning was a false alarm triggered by the blast from the explosion. The Captain's ability to override the reactor safety system is a fundamental weakness in the safety regime for nuclear submarines and no equivalent system is permitted in civil facilities.

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[9] BOI Tireless 2007 para 16
[10] BOI Tireless 2007 para 122
[11] BOI Tireless 2007 para 135
[12] JSP 538 Annex F page 6
[13] BOI Tireless 2007 para 268e
[14] BOI Tireless 2007 para 38 and footnote 65.

Regulation of the Nuclear Weapons Programme

This is a substantial document which outlines the basic safety regime for the Nuclear Weapons Programme.[15]

Comparison with civil nuclear risks

The regulations point out that the risks in the nuclear weapons programme are different from those in the civil nuclear industry -

"a. the consequences of unintended yield from a nuclear weapon are of a different order to most other potential nuclear accidents;
b. unlike a reactor/facility accident it is infeasible to take steps to mitigate a developing accident sequence once yield has started;
c. nuclear weapons are commonly positioned in the vicinity of other nuclear and explosive facilities/devices and so yield from an NW [Nuclear Weapon] is likely to cause 'knock on' nuclear accidents;
d. space and weight constraints prevent NW designers from adopting the degree of segregation of lines of protection which would otherwise be desirable."[16]

Annex F also says - "NW [Nuclear Weapon] Systems have the potential to create hazards, specifically nuclear yield and the release of RA [Radioactive] material, the overall consequences of which are significantly more severe than those associated with conventional weapons and most other hazards in society".[17]

The regime differs significantly from the civil industry in its aims. The regulation of safety in the nuclear weapons programme does not seek to prevent a release of radiation in all circumstances. Fundamental Nuclear Weapon Safety Aim 2 is - "Nuclear Weapons systems shall not release RA [RadioActive] material into the environment *except when used in an authorised operational role*".[18]

Exclusion of risks from terrorism

The regulations say that "Authorisees and designers of weapons and plant are encouraged to take the possibility of hostile acts into account as an 'external hazard' in a manner consistent with any threat which may exist, as advised by local and central security departments".[19] However these risks are not addressed in the regulations - "the probabilistic safety requirements in Annex B exclude radioactive releases due to hostile acts";[20] "Hazards associated with security issues and deliberate malevolent acts are not addressed"[21]

As a result, while estimates are made of the probability of an aircraft accidentally falling onto the Faslane shiplift, there is no requirement to quantify the probability of a September 11th style attack. Likewise there is an assessment of the probability of an accidental aircrash onto a convoy, but not a quantified assessment of the risk of a terrorist attack. Quantifying less likely risks and ignoring more likely risks is not a sound basis for carrying out risk assessment.

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[15] Regulation of the Nuclear Weapons Programme, JSP 538.
[16] JSP 538 Annex Q page 3
[17] JSP 538 Annex F page 5
[18] ibid
[19] JSP 538 page 4.16
[20] JSP 538 page 4-16
[21] JSP 538 Annex F page 4

Risk of a significant nuclear yield

JSP 538 acknowledges that the detonation of a series of nuclear weapons can result in a significant nuclear yield. This effect is called popcorning -

"Popcorning can result from a sequence of accidental detonations of nuclear WHs [warheads] in close proximity in which it is possible for a very small nuclear yield from one WH to enhance the yield from another WH in the detonation sequence. .. Although each WH may individually be SPS [Single Point Safe], popcorning may have the potential to produce a significant nuclear yield."[22]

Because of the serious consequences of such a nuclear explosion the regulations say that, in the event of an accident resulting in a series of single-point detonations of nuclear warheads, the probability of a yield should be Very Unlikely, ie less than 10^{-6}. [23] A credible scenario is the accidental explosion of one missile. This could trigger the detonation of the remaining 13 missiles and the 48 nuclear warheads onboard within a fraction of a second. Given the complex sequence of explosions which could occur it will be very hard to meet this probability target. Like other guidelines in Annex G this may be an aspiration rather than a target which is achieved in the current Trident system.

The risk of popcorning depends on the "array geometry", ie the relative position of the warheads. However the Nuclear Weapons Regulator does not have right to know the actual array geometry on a particular Trident submarine. He is given a generic plan where nuclear weapons can be fitted onto a submarine, but he "need not be normally informed of the number and exact location of nuclear weapons on a given platform at any particular time."[24]

Scale of warhead accidents

The Regulations show that some types of nuclear weapons accident can result in very high doses to members of the public within 1 km of the site.

In a Catergory E accident the Effective Dose at 1 km could be between 1 and 10 Sv. An example of such an accident is the uncontained detonation of between 4 and 30 warheads.[25]

In a Category F accident the Effective Dose at 1 km could be between 10 and 100 Sv. An example is the detonation of one or more missiles in a submarine with the subsequent release of radioactive material from warheads.[26]

Justification and risk

The regulations explain that the principle of As Low As Reasonably Practical (ALARP) is "founded upon the achievement of an acceptable balance between benefit and risk".[27] It also states: "An underlying assumption is that the ownership of NW [Nuclear Weapons] is justified and brings a net benefit to society".[28]

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[22] JSP 538 Annex F pages 11
[23] JSP 538 Annex G page 3
[24] JSP 538 Annex B page 38
[25] JSP 538 Annex F page 20
[26] ibid
[27] JSP 538 Annex I page 3
[28] ibid.

Shortfalls in the current Trident system

Annex G of the regulations includes a number of guidelines which the current Trident system does not comply with -

1. "It should be a design objective to make nuclear warheads Multi Point Safe".[29] Trident warheads are not Multi Point Safe.
2. "An Insensitive High Explosive (IHE) ... should be used for the supercharge".[30] Trident warheads use EDC 37 which is not an IHE.
3. The rocket motor should meet the Insensitive Munitions Criteria.[31] Trident D5 rocket motors are not Insensitive.
4. "It should also be the aim that a high order event from the motor should be *Unlikely* to lead to the detonation of the WH's supercharge."[32] The current Trident system is unable to meet this aim.

Procedural Lines of Defence

The regulations state how many Lines of Defence (LOD) should be in place to prevent particular accidents in normal, abnormal and severe abnormal environments. They also say - "physical LOD are preferable over Procedural LOD. Procedural LOD against yield should be avoided whenever practicable".

It is likely that the safety of key parts of the nuclear weapons programme is dependent on procedures rather than physical defences. This is probably the case in the transport of nuclear weapons, the loading of warheads at Coulport and the operation of nuclear-armed submarines.

Access to US design information

Assessing the safety of nuclear weapons when loaded on Trident missiles will depend on the supply of information from the United States. The regulations show that this flow of information is limited and the Regulator does not adequately question any shortfalls in US assessments -

"It is recognised that many components of the Trident Strategic Weapon System are provided by the US under government to government agreements which do not necessarily allow full design disclosure. NWR [Nuclear Weapons Regulator] does not directly address this issue with US authorities; his questioning of US safety justifications seeks to establish the degree to which the UK ADA [Approving and Design Authorities] understand any limitations and if any UK-based work can be done to mitigate their impact".[33]

Reliability of assessments

The Regulations point out the dangers of relying on questionable data - "When conducting a quantitative safety assessment of a NW [Nuclear Weapons] System, where the probability of failure is low and the consequences of failure is high, there is danger of placing over-reliance on figures that cannot be justified with confidence".

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[29] JSP 538 Annex G Page 2
[30] JSP 538 Annex G page 9
[31] JSP 538 Annex G page 11
[32] ibid
[33] JSP 538 page 2-9

The Nuclear Safety Division of HSE should be asked to clarify which Defence nuclear activities are subject to regulation by REPPIR in Scotland and for the basis for their assessment.

To what extent can Scottish Ministers assess risks and provide guidance to local authorities with regard to defence nuclear risks ?

Is the Scottish Government bound by the Memorandum between the HSE and MoD ?

Draft FOI request to HSE

A list of Hazard Identification and Risk Evaluations (HIRE) requested or received from the Ministry of Defence under the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR), an indication of the scope of each of these HIRE including the premises or transport means which they cover, the geographical area covered by any HIRE of nuclear submarines at sea, and the dates when the latest version of each HIRE was received.