REVIEW OF THE EMERGENCY PLANNING MEASURES RELATING TO THE BERTHING OF ROYAL NAVY NUCLEAR POWERED SUBMARINES AT DEVONPORT, PLYMOUTH

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Abstract - Nuclear Safety at the Royal Dockyard Devonport, Plymouth

Part 1 of this Review assesses the hazards, risks and consequences associated with nuclear powered and possibly nuclear-armed submarines when on passage to, manoeuvring about and whilst alongside undergoing refit and refuelling at the nuclear submarine complex in Devonport Dockyard, Plymouth.
The hazards include accidental detonation of a conventional explosive munition carried on board, such as a torpedo round, of sufficient magnitude to damage the nuclear reactor plant and/or the safety systems resulting in a release of radioactivity; fire and fragmentation of a nuclear warhead and the atmospheric release of plutonium from the warhead itself; and serious malfunction of the nuclear reactor plant and release of radioactivity beyond the containment of the submarine hull. Each of these incidents might be triggered by accident, unplanned-for malfunction of equipment and, of course, by terrorist attack.
The Review shows that airborne radioactivity could spread from the incident site necessitating evacuation and sheltering of members of the public far beyond the pre-planned countermeasure zone of 2km radius: For a submarine reactor plant accident, distances extend to 10 km for evacuation, 20 km for sheltering, and up to and beyond 30 km for implementing stable iodine prophylactic measures; and arising from an incident involving a nuclear warhead, public evacuation and/or respiratory protective measures might be required for 10 to 20 km and sheltering for up to 40 km from the accident centre. If the most recent recommendations of the National Radiological Protection Board and the World Health Organisation are adopted, then stable iodate prophylaxis, arising from release from an operational reactor, would be triggered up to distances of 110km from the incident.

Part 2 considers the requirements of *The Radiation (Emergency Preparedness and Public Information) Regulations* (REPPIR) for the local authority to provide an off-site emergency plan in response to all reasonably foreseeable radioactive release incidents – these regulations are now in force and require the local authorities (here Plymouth City Council) to provide adequate off-site emergency plans in contingency for specific and reasonably foreseeable accidents and incidents that could result in the release of radioactivity and the declaration of a radiation emergency. The City of Plymouth has stated its intention to adopt *DevPubSafe* for its REPPIR off-site emergency plan. However, this review considers *DevPubSafe* to be unsuited for adaptation as the REPPIR local authority off-site emergency plan because, fundamentally, it fails to address the severity of all reasonably foreseeable accidents and incidents that could result in a radioactive release.
First, this is because it is shown that the Off-Site Plan would need to put in place robust countermeasures well beyond the present 2km pre-planned countermeasures zone. Because of the rapidity of development of certain scenarios and the very high level of potential radioactive release, the reliance upon ‘extendibility’ of the 2km preplanned countermeasure zone would seem to be impracticable. Moreover, the measures identified in *DevPubSafe* suggest that a submarine reactor incident would be a relatively leisurely affair, running through a prescribed course of events and taking some hours to develop, leak and disperse radioactivity into the environment whereas, in fact, the worst case scenario identified by the Ministry of Defence itself, but not included within *DevPubSafe*, indicates that a very large release of radioactivity could occur within 10 to 20 minutes of the initiating event. It is considered that an Off-Site Plan adapted from *DevPubSafe* could not provide the rapid and sufficiently resourced response necessitated by this scenario and there is, if safeguards and countermeasures cannot be put in place quickly, risk of radiation exposure to large numbers of public.
Second, *DevPubSafe* gives no specific regard to acts of sabotage and terrorism which, obviously, are intentional and intelligent attacks on the system as opposed to accidental events which occur, in the main, by chance. Not only should terrorist attacks be considered to be a certainty, and thus should not be dismissed on the basis of probability alone, but the intelligent nature of the attack would be expected to seek out weaknesses and undefended parts of the nuclear system that may not be at risk from accidental circumstances, natural hazards and situations planned for in the military role. In other words, a terrorist attack might result in an incident and aftermath scenario that had not been previously identified and for which no contingency had been laid.
Third, there is nothing in *DevPubSafe* that specifically relates to a nuclear weapons accident at Plymouth. The involvement of nuclear weapons in incidents and accidents at Devonport must be catered for in any off-site plan because docking of boats and surface ships armed with nuclear weapons is not specifically excluded from operations within the Port or Dockyard.

John H Large

Nuclear Safety at Devonport, Plymouth

Introduction

From September[i] of this year local authorities will have in place off-site emergency plans in order to satisfy the requirements of the *Radiation Emergency Preparedness and Public Information Regulations* (REPPIR).[ii] So that local authorities may prepare adequate off-site emergency plans, the Ministry of Defence (MoD) has a statutory obligation to provide sufficient information on all reasonably foreseeable radiological incidents, including for the nature, rapidity and magnitude of any projected radioactive release. REPPIR will supersede the MoD's obligations of *Regulations 26* and *27* of the *Ionising Radiations Regulations* under which it provides and maintains the existing *Special Safety Scheme* (*DevPubSafe).*[iii]

Plymouth's off-site emergency plan (the Off-Site Plan) will have to include for serious nuclear accidents to the nuclear powered propulsion plant of Royal Navy[iv] submarines at berth; for a submarine manoeuvring in the approaches to, in the river and in the dock basin; whilst in dry dock undergoing refit and/or refuelling; and, because there is nothing that precludes a submarine armed with Trident missiles carrying nuclear warheads berthing at Devonport (or in future with nuclear tipped cruise and/or torpedoes), the Off-Site Plan must also include for incidents involving a radioactive release from a nuclear weapons incident.

Part 1 Hazards, Risks and Consequences of a Submarine Based Accident

Identifying the Hazards

All classes of nuclear powered submarine are armed with conventional weapons comprising high explosive warheads and propellants.[v] In addition to conventional weapons, the *Vanguard* class boats (SSBN) carry ballistic missiles and nuclear warheads.[vi] A nuclear propulsion plant, comprising a nuclear reactor and primary circuit, steam raising generators and steam turbines, powers all Royal Navy submarines.

1) Conventional Weapons – Torpedoes, etc

The catastrophic consequences of an inadvertent explosion of one or more of the conventional weapons carried on board a submarine have been demonstrated by the recent loss of the Russian Federation submarine *Kursk*.[vii] Whilst conducting torpedo firing trials, the propellant of a single, unarmed prototype torpedo ignited and exploded, thereafter triggering a multiple explosion of seven fully armed torpedoes in the magazine of the forward section, devastating the submarine and putting the two nuclear reactors at risk.

2) Trident Missiles and Nuclear Warheads

The hazards arising from the Trident missiles are associated with both the missile propellant and the nuclear warheads. A missile malfunction and ignition of the propellant whilst in its silo could imperil the warheads and trigger detonation of the conventional high explosive charges that surround the fissile pits of the individual nuclear warheads. This accident, even if it did not result in damage to the nuclear reactor plant of the submarine, could result in aerial release and dispersion of particulate plutonium and other materials and substances making up a nuclear warhead assembly.[viii]

In an accident situation, say, involving a fierce fire of the missile propellant in the submarines launch silo, there is risk that the conventional explosive compressive charges making up each of the nuclear warheads may ignite, burn and, in some cases, detonate.[ix] The plutonium fissile core of each warhead is a chemically reactive metal which is pyrophoric at relatively low temperatures (220°C), so a burning weapon core would readily disperse into the atmosphere in the form of finely divided oxides, a significant proportion of which would be of respirable size.

The failure of one to all twelve of the nuclear warheads capable of being carried by a single Trident missile, each liberating between 3 to 5kg of alpha-emitting plutonium, could result in the following radioactive release:[x]

Scenario	Release Mode	Amount TBq	Time Span
Single or all warhead HE on one missile bus - charge ignition and burning of Pu core to particulate oxide form	Radiation shine negligible, respirable sized particles released to atmosphere	11 to 60 (say 130 max) half-life 23,390 yr	< 1 hour

3) Submarine Nuclear Reactor Plant

DevPubSafe identifies three classes or *Categories* of accident. Essentially, each category relates to the failure of one of three containment boundaries with *Category 1* being an event leading to, or which has resulted in, the release of radioactive fission products from the fuel plates cladding boundary but which is confined within the reactor primary circuit; *Category 2 is* where the fission products have escaped from the reactor primary circuit but remain contained within the reactor compartment; and *Category 3* is where there is a release of fission products from the reactor hull to the outside environment.

The progress of the last two of these accident scenarios is a relatively leisurely release from the reactor compartment hull developing over 24 hours. Also, apart from the event that initiated the loss of coolant from the reactor primary circuit the aftermath is relatively non-energetic with, apparently since no details are provided in *DevPubSafe*, the hull containment being physically undamaged with the leakage through the hull assumed to be through the boat's services connections and penetrations.

However, in its internal operating and rules of practice codes, the MoD[xi] also nominates three categories of accident severity arising from malfunction of the reactor plant and its nuclear fuel – these are identified as *BR0*, *BR3* and *BR6*. The first two scenarios seem to correspond to the *DevPubSafe* Category *2* and *3* scenarios but the third and most severe, *BR6*, is not identified in or specifically catered for by *DevPubSafe*.

The amount of radioactivity within the fuel that is available for release during accidents and incidents is determined by the in-core service age (burn-up) of the fuel, which can be up to 10 or more years, together with the recent power operation history of the fuel. For its PWR 1 nuclear plant, the MoD assumes a *Standard Core History*[xii] with a fission product inventory of approximately:

Nuclide Group	Half-Life	TBq[XIII]

The radiological consequences for the three accident categories derive from the following release of fission and (radio)activated products from the fuel core of the reactor:[xi]

MoD Category - Scenario	Release Mode	Amount TBq[XIV]	Time Span
BR0) Fuel Clad Failure	Local g shine only but with reactor primary and compartment hull intact		24 hour seepage
BR3) Loss of Coolant, Core Melt & Fission Products into Reactor Compartment	g shine up to 400m with reactor primary circuit containment failed	400 to 4,000 (400 – 40,000 I^{131})	10-20 minutes or ~3 hours blow out following initial fault, bypassing RC containment, total release in less than one hour.

Assessing The Risks

Setting aside terrorist acts and similar intentional actions, naval propulsion reactors are designed and operated on the basis of a probabilistic assessment of the risk of accident. One criterion relates to the probability of release of volatile iodine, represented by the following Release/Probability criterion for a reactor at full pressure and under power (at reactor power State A):

This criterion suggests that the maximum tolerable release of iodine-131 should not exceed 5000 TBq at a chance in 1 in a million (per reactor operational year) which establishes the *BR3* accident scenario as the *Maximum Design Accident* (MDA). In effect, if *BR3* is the MDA then the frequency of the very much more severe *BR6* scenario, with its very much larger (up to 40,000TBq) potential release fraction of iodine-131, must be sufficiently remote to render its occurrence incredible.

However, the restricted document BR3019[xi] gives another assessment of probability or frequency of the *BR6* scenario in which it is identified as the MDA. The *BR6* frequency for the Valiant/Churchill and Swiftsure/Trafalgar series of PWR 1 reactor, is given to be one in one million operational years. BR3019 also identifies a more probable accident scenario of 40TBq I^{131} release at a frequency of one in 10,000 operational years, this being the *BR3* scenario.

Another way of expressing the risk is by amalgamating the acceptable risk and tolerable consequences. The system of lower and upper *Emergency Reference Levels* or ERLs (see later) for iodine uptake countermeasures which should not be exceeded for evacuation effectively does this. For example, if the radiation exposure is kept below the upper ERL then the consequences to any individual exposed might be considered to be *'tolerable'* (although there is some debate about this), so the *'acceptable risk'* might be defined as:

1) once in 50,000 reactor operating years within the 550m radius automatic countermeasure zone;
2) once in 200,000 years within the 2km radius Pre-Planned Countermeasure Zone; and
3) once in 200,000 years within the Extendibility Zone, including for any other iodine uptake emergency countermeasure.

These ERL-base composites are those adopted by *DevPubSafe.* On the basis of acceptable risk and tolerable consequences, the outcome of the *BR3* scenario is unacceptable in terms of its projected frequency (1 in 10,000 reactor years) so, it follows, the logistics of *DevPubSafe* must be based upon accidents and incidents of lesser severity and frequencythan the outcome of the *BR3* scenario (on frequency), with that of the *BR6* scenario being totally unacceptable (on frequency and consequences).

There is a clear mismatch between the MoD's choice of relatively severe and, in probabilistic terms, frequent radioactive release scenarios (*BR3* and *BR6*) and the risk-consequence criteria set out in *DevPubSafe*. Another difficulty is that there is little more than a 'cliff edge' of circumstances between the *BR3* event and this developing into the very much more severe *BR6* scenario – that is the conditions and circumstances of the *BR3* scenario are precursory to *BR6* (ie *BR3* could run into *BR6*).

Following the events of 11th September terrorism cannot ruled out and, indeed, recent reports suggest that a Morocco based terrorist cell was contemplating suicide attacks against US and Royal Navy warships off Gibraltar. Obviously surface warship design includes defences against hostile attack with redundancy being built into the structure for survivability.[xvi] Submarines, on the other hand, depend upon a great deal on stealth of operation to evade detection and attack, and these boats are particularly vulnerable when on the surface, being cumbersome in operation with little or no defensive firepower against a small, fast moving attacker such as an explosive packed Zodiac dinghy, as contemplated by the Moroccan group. Breaching the reactor compartment hull containment of a surfaced submarine, by explosion or sarab penetrator could initiate a *BR6*-like scenario.

Consequences - Implementation of Mitigation and Countermeasures
In radiation emergencies mitigation and countermeasures are implemented in order to avert levels of radiation dose exposure to individuals and critical groups of individuals. These levels are prescribed by the NRPB[xvii] and are referred to as *Emergency Reference Levels* (ERLs), being applied to the total exposure or *whole body dose*, and the *single organ dose* which is particularly applied to the thyroid uptake of radioactive iodine (I^{131}).
The lower ERL is defined to be the level of dose below which no benefit would arise if countermeasures were implemented. The upper ERL is the level of dose that should be averted and not exceeded by the implementation of appropriate countermeasures. Both ERLs by far exceed the natural background radiation levels and individuals subject to these levels of radiation exposure would in a relatively short time be exposed much above that permitted annually (1 mSv/year).[xviii]
The effectiveness of operating ERL based countermeasures is critically dependent on being able to accurately forecast the development of the radiation dose from the onset and throughout the aftermath of the accident. If countermeasures are introduced too early, below the lower ERL, then scarce human and equipment resources may be wasted but, triggering the countermeasures too late could result in high and unacceptable dose receipt by critical groups of the exposed population.

i) Application to a Submarine Accident
Evacuation: The prescribed ERLs for evacuation of members of the public are set at 30mSv lower and 300mSv higher for whole body exposure. Applying these ERLs to the three categories of damage severity identified for the submarine nuclear reactor power plant, requires population evacuation downwind of the *BR6* accident out to 9.5km[xix] - see Graph 1 (of the slide presentation).
Importantly, the development of the *BR6* reactor compartment blow out scenario, in its extreme, takes place over the very short time period of 10 to 20 minutes from the occurrence of the initiating loss of coolant in the reactor plant. So, depending on wind speed and development of the radioactive fall-out plume downwind of the accident centre, advising and organising members of the public nearby, say out to 10km, would have to be implemented quickly if the consequences are to be minimised. Obviously, the rapidity of the *BR6* accident and its radioactive release could result in sectors of population having to be evacuated from areas where unacceptably high radiation levels are already established. In other words, the prescript of dose limit *aversion* may not be practicably possible for the *BR6* event.
Sheltering: Further downwind of the incident centre the public would be required to shelter up to a distance 20km for the *BR6* scenario and out to 2km for the *BR3* accident – Graph 2.
Organ Dose: The ERL thresholds for individual organ doses are applied separately from the whole body dose. This is because the accident circumstances might require specific prophylactic measures to be implemented to protect members of critical groups before those individuals reach the whole body dose ERL.
For a reactor plant that has a recent history of power operation, any radioactive release will include the gaseous fission product iodine (I^{131}) that, via inhalation, is available for reconcentration in the thyroid gland. This, to a certain extent, may be countered with iodine introduced by potassium iodate tablets (PITs) taken orally in advance of the arrival of the plume carrying the radioactive iodine.
Applying the present NRPB ERL recommendations (lower/upper 30/300mSv), for the *BR3* scenario PITs would have to be issued out to 1.1 km. For *BR6* PITs would have to be issued out to 30 km downwind from the accident scene – Graph 3. Again, depending on meteorological conditions and the development of the downwind plume, it may not be practicable to avert exceeding the iodine organ dose upper ERL in the immediate aftermath of the *BR6* event. Moreover, if the recent recommendations of WHO and the NRPB[xvii] are applied, the ERLs revise to 10mSv lower and 100mSv upper for which the *BR3* scenario requires PITs to be consumed by those within a 3km radius of the incident and for *BR6* by those out to a radius of 110km.[xx]
The presentation graphs and maps show the application of the Whole Body and Organ (I-131) Dose evacuation and sheltering ERLs for *BR3* and *BR6* accidents centred at Devonport Royal Dockyard. Much the same radial distances for public evacuation, sheltering and iodine prophylaxis measures would apply to radioactive releases occurring if the submarine was stricken in the approaches to the Dockyard.

ii) Application to a Nuclear Warhead Accident
As previously explained, two mechanisms exist within the warhead to provide for this dispersion, these mechanisms are detonation of the warhead high explosive charge and or burning of the charge and plutonium. Burning of the missile propellant in the launch silo or by some other disruptive event within or external to the submarine might precede these events.
Subject to detonation or fire, the plutonium pit of the warhead will aerosolise into small particles[xxi] that are readily borne aloft and dispersed in the atmosphere. In the immediate aftermath of the incident, where the high explosive has detonated or burnt, the plutonium particles are available for direct inhalation by individuals downwind.[xxii] In the short, medium and longer terms, plutonium particles deposited on the ground, on building and other surfaces could enter the human metabolism by ingestion, open wounds and other routes or, if resuspended by disturbance, inhaled. [xxiii], [xxiv]

The primary task of the emergency services in dealing with a nuclear weapons accident is that of evacuating people out of zones where the inhalation hazard prevails.[xxv] The United States adopts an immediate total evacuation zone of 2km, a 10km zone in which respirator protection is required, where sheltering is in place and evacuation should be considered, and a zone extending to 40km where the expectation is that the general public exposure will exceed the annual whole body dose and where sheltering is recommended – Map 2 relates these zones to a nuclear weapons incident at Devonport Dockyard.

In Summary: Nuclear powered submarines are armed with powerful conventional high explosives weaponry and the accidental detonation of a single round (such as a torpedo, Harpoon missile, or Tomahawk cruise missile) could be sufficient to severely damage the submarine and put the nuclear reactor plant at risk. The Vanguard class of submarine is armed with nuclear weapons.[xxvi] The accidental burning or explosive break-up of a single nuclear weapon could result in a release of plutonium (and other radioactive substances) requiring an emergency response in attempt to mitigate the health consequences to the population over a relatively large area up to, if not in excess of 40km from the scene of the event.

The MoD acknowledges and plans for three levels of damage severity arising from malfunctioning of the nuclear propulsion plant. When at sea and in the approaches to port, and when at berth when the nuclear reactor plant is maintained at operational pressures and temperatures at *Reactor State A*. When at berth, although the power output from the reactor may be low, the physical environment (temperature and pressure) of the reactor plant is the same as that of a fully operational submarine at sea so, it follows, the risk and severity of accident are generally the same as that when the submarine is at sea.

Once that the reactor has shut down, depressurised to *Reactor State B* and undergone some days and weeks of cooling to dissipate the continuing activity of the short-lived fission products within fuel core, the risk of catastrophic accident and radioactive release reduces very significantly. On one hand, accidents and incidents when the reactor is in a closed down state will generally require a very energetic external event but, on the other hand, if the submarine is in refit or, particularly during refuelling of the reactor core, the levels of separate containments may be reduced thereby adding to the risk of radioactive release.

For the worst case *BR6* event to an operational nuclear propulsion plant, triggered either by some accident circumstances, because of operational malfunction or by terrorist act, evacuation of the general public could be required out to 10 km from the scene of the event, sheltering may be required beyond the evacuation zone out to 20 km, and to suppress radioactive iodine take-up and reconcentration prophylactic stable iodate tablets might have to be introduced out to 30km from the incident centre under the present NRPB ERL recommendations. If, in future years, the NRPB's recommendation for revising the iodine ERLs downwards is adopted, the iodine prophylaxis might have to be introduced out to 100km from the incident centre.

As discussed in *DevPubSafe*, the *Category 1* and *2* scenarios are not, in themselves end points, because there is a probability that these could cascade into the external release *Category 3* scenario[xxvii] and, moreover, the development of the scenario may not follow a pre-planned logic.[xxviii] So, if there is risk of an accident/incident cascading into a radioactive release, which is acknowledged in *DevPubSafe*, then the severity of the final endpoint must be established in order to set the extent of the emergency planning zones.

The point here is how and on what basis was the Pre-planned Countermeasure Zone (PCZ) of 2km radius set? If the *BR3* scenario is taken as the MDA (putting aside that it fails on projected frequency of occurrence) then the present *DevPubSafe* PCZ might be held to be valid because it covers the sheltering requirement out to 2km. If, however, it is accepted that the radioactive release could be significantly greater than *BR3*, rising up to the worst case of *BR6*, then a much extended PCZ is required out to 10km for evacuation, 20km for sheltering and 30km for iodine prophylaxis (under the present ERLs). If incidents involving release from nuclear weapons is taken into account a PCZ for respiratory protection and sheltering might be required to extend 10 to 40km or so for the incident centre, with total evacuation being required within 2km.

Part 2 REPPIR Compliant Off-Site Plan for the Plymouth Berth

Radiation Emergency Preparedness and Public Information Regulations
REPPIR requires separate involvement of both the operator, here the MoD (and DML for non-operational aspects), and the local authority, Plymouth City Council (and other local authorities), in the preparation of emergency plans to deal with radiation incidents.

Plymouth City Council: *Regulation 9* requires the local authority to prepare the Off-Site Emergency Plan to cover all reasonably foreseeable radiation emergencies and that it shall do this on the basis of information placed before it by the MoD. Amongst other things, *Regulation 16* requires the off-site plan and other media to include prior and specific information about the actions to be taken and the behaviour to be adopted by members of public in the event of a radiation emergency.
The off-site emergency plan, including the prior information to members of the public, has to be ready and in place by mid-September 2002.[i]

Adaptation of Existing DevPubSafe Plan to the REPPIR Off-Site Plan
The local authority of Argyll and Bute in Scotland has already published a draft off-site emergency plan in advance of the enactment of REPPIR.[xxix] The Argyll and Bute off-site area covers the X and Z berths of the submarine operations centre on the Clyde that is presently subject to the *ClydePubSafe* public safety scheme, which is very similar to *DevPubSafe* scheme. Argyll and Bute's off-site emergency plan is a pared down version of *ClydePubSafe* so it seems, if this is taken as a trend setting example, the MoD will be encouraging local authorities to adopt the existing local public safety scheme as the basis for their REPPIR off-site emergency plan.
It is considered that adopting a semantically adapted version of *DevPubSafe* for the Off-Site Plan would be inappropriate because, in a general sense, *DevPubSafe* provides a reactive rather than proactive approach to contingency planning. This is because, first, it does not specifically identify the type and severity of the accidents/incidents that might evolve to a radioactive release and, second, it does not determine the amount and quality of the radioactive release emanating from all reasonably foreseeable accidents.
Although the MoD has yet to make public its *Report of Assessment* it is unlikely that this will provide details of the nuclear reactor core (radionuclide) inventory, make reference to severe *BR6*-like incidents, and include account and assessment of a nuclear weapons accident. However, the MoD has stated[xxx] that terrorist acts are not required to be specifically considered for the purposes of emergency planning and that these would, however, be managed through extension of the pre-planned countermeasures, although that said, there is nothing in REPPIR that specifically excludes terrorist and other malicious acts from being excluded from the *Report of Assessment*.

Submarine Based Accidents
Although the MoD itself nominates three categories of accidents applicable to a nuclear submarine, none of these are specifically related to the 550m evacuation zone and the 2km preplanned countermeasures zone cited in *DevPubSafe*.
How these MoD scenarios fail to relate to the *DevPubSafe Category 1, 2* and *3* scenarios and the ERL frequency criteria has been previously considered. Moreover there is no acknowledgement in *DevPubSafe* of the rapidity with which *BR6*-like scenario might develop, that is with the radioactive release commencing within 10 to 20 minutes of the initiating event. **[xxxi]**

Nuclear Weapons Accident
For the radioactive release deriving from a nuclear weapons accident, where plutonium particles are released to the atmosphere, the profusion of radiological limits, and the variation in these, would render difficult the tasks of the emergency services of ensuring people are evacuated from unsafe areas or that the immediate decontamination is done to acceptably safe levels. The response to a nuclear weapons accident could not wait to be ERL initiated and the automatic action of issuing stable iodine tablets would be entirely inappropriate.[xxxii]
The reactive countermeasure implementation approach adopted by *DevPubSafe* includes none of the nuclear weapons specific processes and procedures required to protect members of the public in the event of a nuclear weapons release. It would be a difficult task indeed to make such amendments during the course of an incident and there is risk that the emergency personnel on the ground may misinterpret monitoring data and implement inappropriate actions as a result.
ERL Approach and Dependence upon the MoD
In setting out the approach to protection of the public within the pre-planned zone, *DevPubSafe* relies upon ERL triggering countermeasures actions, setting aside that the iodine based ERLs are entirely inappropriate for a nuclear weapons accidents in which any fission process is most likely to be absent.
DevPubSafe seems to be dependent upon MoD personnel (Royal Navy) carrying out an assessment of the severity of the accident, undertaking monitoring and, from these, determining (projecting) the radiological impact of the event in the public sector. Because the MoD acknowledges that there will be some hours of delay before monitoring results are available,[xxxi] [xxxiii] *DevPubSafe* reactively triggers a range of automatic countermeasures.

This means that for the pre-planned countermeasure zone (2km) *DevPubSafe* does not relate to the actual radiation exposure dose of individual members of the public (actual or projected) at the time that the countermeasure is initiated, but somehow extrapolates this from the *Category* assessment of the condition of the reactor fuel which is assessed by Royal Navy personnel. Since the definition of accident *Category* is vague and, moreover, it unlikely that the Royal Navy would wish to share sensitive information about the condition of a submarine propulsion reactor with a local authority, for their well-being members of the

public in the 2km PCZ are entirely dependent upon the uncorroborated assessment of the condition of the reactor fuel by naval personnel.
Nothing at all is set out in the present edition *DevPubSafe* relating to the means and criteria by which Royal Navy personnel undertake this assessment. For example, how much cognisance is given to critical groups[xxxiv] within the public population; what is the hierarchy of reporting within the MoD organisation and beyond; and could any restraint, 'steerage' or spin be introduced prior to its communication to the local authorities. Since countermeasures are triggered (or held back) on the basis of this MoD sourced information it is particularly important that the decision to implement countermeasures is drawn from sound information, if not resources may be deployed too early or too late, at incorrect locations and/or in the wrong mode.[xxxv]
Part 2 of *DevPubSafe* states that the MoD Naval Emergency Monitoring Organisation (NEMO) will undertake the radiation monitoring but it is not clear whether NEMO is sufficiently resourced to extend its monitoring capability into the public sector. Obviously, in the short time scales afforded by both the submarine *BR6* and nuclear weapon dispersion scenarios, additional or *'back up'* from nuclear power stations in the region will not be available. NEMO's orders were originally defined by the classified MoD document BR3025[xxxvi] to include for *"Revised Emergency Reference Levels"* by *'selective sampling'*. The reliance upon *'selective sampling'* of an urban area would be doubtful because of the vagrancies associated with dispersion over and within townscapes[xxxvii] and how the MoD would interpret and apply the results of this to larger areas is not available.
According to BR3025, the MoD segregates its post-accident monitoring into three stages:-
Stage I: Measures the direct gamma shine from the submarine hull at a number of preselected monitoring points. Providing that the submarine is berthed this is likely to be undertaken automatically by the Dockside Installed Radiac System (DIRS). [xxxviii] Some delays may occur if the submarine is not berthed and, particularly, where the hull shine is obstructed by another vessel or building.
Stage II: Establishes whether a fission product release has occurred, to determine the direction of the release plume, local deposition of radioactive particles and if the release is continuing. Some part of this release monitoring is likely to be undertaken automatically by the Perimeter Monitoring System (PMS)[xxxviii] but the ground contamination dose rates and smear samples will require NEMO health physics personnel involvement. In the immediate aftermath of the release, the Local Emergency Monitoring Team (LEMT) could undertake Stage II monitoring during the period of up to one hour that the mobile NEMO team has prepared and arrived on site.
Stage III: Determines the extent and magnitude of ground contamination in the public areas surrounding the berth. Under Stage III checkpoints are located radially about the dockyard in 60° sectors, although in practice these follow the roads radiating from the berth out to a distance of 20 to 30 km.
DevPubSafe provides little information on how NEMO undertakes off-site monitoring, how it arrives at the dose exposures necessary to trigger the ERL countermeasures and, importantly, on how and in what form this information is to be passed to the civilian authorities. Unless the monitoring and dose assessment practices of BR3025 have been substantially revised, then the monitoring must be confined to ground contamination so, it follows, gamma shine dose from the overhead release plume and thyroid dose for inhalation of the iodine content of the release must be extrapolated from hand-held monitoring and analysis around the berth as the radioactive release progresses, which may or may not have gamma spectrometry capability.[xxxix]

In fact, monitoring activities immediately around the submarine or weapons accident site are likely to dominate the initial stages of the emergency response to any accident. This approach is set out in a Royal Navy training course on submarine reactor accidents:-[xl]

". . .
Stage III monitoring is started as soon as emergency monitoring teams (LEMO or NEMT) can be spared from Stage I or Stage II monitoring, or on the arrival of "back up" monitoring teams from CEGB, UKAEA etc. This should be some six hours or so after the initial report and may take several days to complete, depending on the number of teams that can be deployed for this task.
. . ."

(my emphasis)
It is not at clear from *DevPubSafe* how the appropriate countermeasures are to be implemented in the absence of reliable radiological information being available [eg "*six hours or so"*].
Part 3 Devonport Dockyard at Plymouth - Conclusion
This Review identifies and assesses the potential severity of *i)* a loss of coolant event on board a Royal Navy nuclear-powered submarine when in the approaches to, manoeuvring within or berthed at the Plymouth Z berth; and *ii)* of a nuclear warhead accident occurring in the silo of a Vanguard class of nuclear powered submarine whilst docked or in proximity to Devonport Dockyard. It has not considered incidents arising when a submarine is under refit and/or refuelling, although it is noted that with the reactor closed down and depressurised, the risk of a significant release of radioactivity is very much reduced.
The *Radiation (Emergency Preparedness and Public Information) Regulations* (REPPIR) require that the operator (here the MoD) identify *hazards* and evaluate the *risks* (*Reg 4*) and that there is to be *co-operation between the parties* (*Reg 8*) relating to the preparation and maintenance of emergency plans in which '*the emergency plan shall be designed to secure the restriction of exposure to ionising radiation and the health and safety of all persons identified by the assessment*' (*Reg 8*).
The local authority (here Plymouth City Council and others) shall *'prepare an adequate off-site emergency plan'* (*Reg 9.1*) which *'shall address each reasonably foreseeable emergency identified by the operator* (*Reg 9.2*) and *'which shall be provided to the local authority by the operator'* (*Reg 9.4*).

Reference to all Reasonably Foreseeable Accidents

Put simply, there is a duty placed upon the MoD to provide the local authority with sufficient information so that it, Plymouth City Council, can put in place adequate off-site emergency arrangements should a radiation emergency arise.

The types and severities of accidents (*BR3* and *BR6*) identified in Part 1 of this Review are considered to be reasonably foreseeable and, indeed, have been adopted by the MoD for its own accident response planning. Since both the *BR6* submarine reactor plant scenario and the nuclear weapons atmospheric radioactive release of plutonium are modelled and planned for by the MoD, it is surprising that these are not specifically cited in *DevPubSafe*.

In this important respect, it is considered that a *DevPubSafe*-based Off-Site Plan would not address each reasonably foreseeable radiological emergency as required by REPPIR. Furthermore, to have in place an off-site emergency plan for the management of the consequences of a radioactive release, but which has virtually no information about the type of incidents that could occur, the severity and scale of these incidents, and the quality and rates of radioactive release resulting therefrom, would seem to be a fundamental shortfall.

Monitoring, Countermeasure Triggering and Actions of Members of Public

In providing the radiological monitoring role, particularly as to where and how the initial monitoring is to be undertaken, the Royal Navy adheres to the pre-planned priorities of the MoD BR3019. Yet, BR3019 or its present equivalent is not publicly available so it is not at all clear when and how, and to what effect, the public areas of the pre-planned countermeasure would be monitored.

Another publicly restricted BR document, BR3025, assigns least priority to monitoring of public areas since Royal Navy personnel are instructed to delay Stage III monitoring, viz *"Stage III monitoring is started as soon as emergency monitoring teams (LEMO or NEMT) can be spared from Stage I or Stage II monitoring, or on the arrival of "back up" monitoring teams.*".

In other words, a *DevPubSafe*-based Off-Site Plan could be overly dependent upon MoD personnel and resources monitoring the on- and off-site sectors and reporting and advising the local authority on when and which countermeasure to implement. If the accident is severe then MoD personnel are likely to be prioritised to the immediate (on-site) locality of the accident, but a severe accident also requires early monitoring in the (off-site) public areas if the consequences to the much larger public group are to be mitigated

Grouping actions of members of public to each of the three *Categories* of accident (Annex B to Chapter 12 of *DevPubSafe*) assumes that the event will somehow conform to well defined areas and boundaries of the PCZ (which itself seems to have no basis of definition). For the *Category 3* scenario it states that

". . .

People outside the 2km Pre-Planned Countermeasure Zone need take no special action if a Category 3 event has been declared, unless informed otherwise by the DPH. The most likely other action recommended will be to seek shelter and listen to local radio and TV stations for further news.

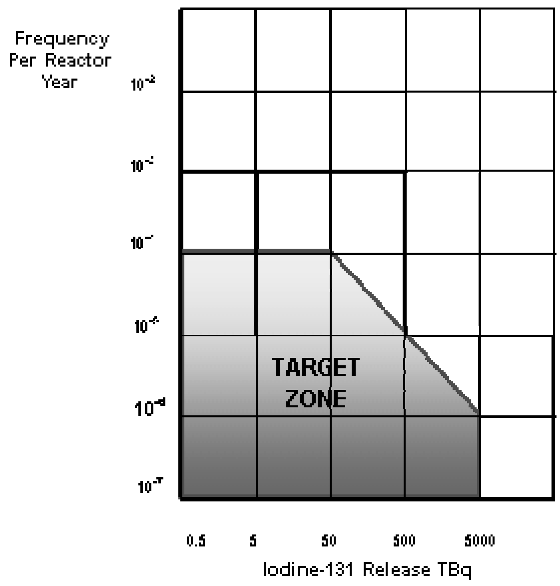
. . ."

In effect, this almost entirely dismisses the possibility that a *Category 3* incident could develop into some proportion of the severity of the *BR6* scenario. If the *BR3* and *Category 3* scenarios are assumed to align in terms of size of release, then the release from a *BR6* scenario is reckoned to be 100x to 1000x greater (whole body basis). As shown by Graph 1, the whole body ERL evacuation [not *'sheltering"*] distance for *BR6* would extend out to 9.5km, that is well beyond the 2km PCZ and touching on the limit of the 10km Extendibility Zone.

Reliance of the Local Authority on the MoD

For the implementation of evacuation and all other countermeasures, the local authority seems to be overly dependent upon the MoD for radiological information and advice. This is particularly so for the pre-planned countermeasure zone where the countermeasures are triggered by the Royal Navy's assessment of the condition of the reactor fuel or nuclear weapon involved in the incident.

Reliable projection of the assessment of the condition of the fuel



or the nuclear weapon to the radiological hazard that this represents to members of the public is absolutely critical in safeguarding public health and property. The procedures employed for this assessment,[xi] and the means of communicating it through the MoD organisational structure to the local authority is not be included within a *DevPubSafe* based Off-Site Plan documentation and, in the main, these are not publicly available. This almost blind reliance of the local authority upon unpublished MoD procedures, criteria and judgements might be, perhaps, considered to disqualify the commanding role of the local authority in implementing its off–site emergency plan. Moreover, there is no provision to check and corroborate the Royal Navy's decision-making until involvement of the NRPB or Government representative, which will be several hours or more into the accident aftermath.

In Conclusion: The application of *DevPubSafe*-like off-site emergency plan may give rise to a number of uncertainties, namely:
1) The MoD is unlikely to publish its own emergency plans and a full version of its Report of Assessment, so the identification of the hazards and assessment of the risks remains concealed from the public. In this respect, members of the public might consider themselves denied opportunity to judge whether the off-site emergency plan is adequate for the severity of accident/incident, risks and consequences associated with operations at Devonport Dockyard.
2) The MoD on-site plans will concentrate resources within the immediate area of the incident and will not extend far into the public domain, and it may not have assessed the manpower and equipment resources required to cover larger areas of population as required by accidents and incidents extending beyond the *Category 3* scenario. Indeed, the MoD may regard the transfer of *DevPubSafe* to the local authority to result in a freeing up of its resources for on-site activities.
3) And, the methods and criteria deployed by the MoD to assess and project forward radiation doses in the public sector are not publicly available and may, indeed, assume means of health and risk assessment (and valued judgements) that would be unacceptable in the public (civilian) domain.
Finally, as part of its duty in preparing the REPPIR off-site emergency plan, the local authority is required, *Regulation 9(12)*, to consult with members of the public *["as the local authority considers appropriate"]* and this should present individuals and groups opportunity to further address any concerns that this Review and Presentation may have raised.

Notes & References

[i] The Local authority has to have a written plan in place within six months of being notified by the HSE and it may apply for an extension to complete its Off Site Plan.
[ii] These regulations supersede the requirements of the *Ionising Radiations Regulations* that place a duty on the nuclear operator to assess the nature and extent of the hazard and the radiation exposure and health and safety relating thereto. *Regulation 18* provides opportunity for exemption although it is believed that the Secretary of State for Defence will not seek this.
[iii] This Review considers the present edition of *DevPubSafe* (Issue 1, Amendment 0, July 1999 – Uncontrolled Copy) – there may have been subsequent editions and, of course, if and when adopted for REPPIR *DevPubSafe* is likely to include amendments relating to the emergency planning organisational structure and it may include other amendments on dose limits and ERLs, etc..
[iv] It is assumed that berths at Devonport are also available to nuclear powered submarines and surface ships of the United States with the most recent being the nuclear powered USS Oklahoma berthing at Southampton in July 2000.
[v] Both SSN (attack) and SSBN (missile) submarines carry a complement of torpedoes and surface skimming missiles (Harpoons) and the Trafalgar Class SSN are being fitted with cruise missiles (Tomahawks). The Tomahawk is nuclear capable and may, in the near future, be fitted with low yield nuclear tips.
[vi] The SSBN is also armed with 16 Trident ballistic missiles, each capable of carrying 12 independently targeting nuclear warheads (MIRVs), although this was limited to a maximum per vessel of 96 in 1993 and subsequently to 48, although a single missile might still carry 12 warheads with other missiles reserved for decoys, etc.. In times of heightened tension it is likely that the SSBN's available would be armed with a complement of nuclear warheads to match the situation. For maintenance and refit/refuel activities it would be expected that the SSBN would be completely disarmed of all weapons systems but it cannot be excluded that a SSBN might develop a fault whilst at sea on sea duties that necessitated it making to Devonport for emergency repairs – this was the situation with HMS Tireless that run into Gibraltar unscheduled when it developed a reactor fault in 2000.
[vii] The Russian Federation SSGN *Kursk* was lost as a result of a torpedo round explosion following fire and explosion of the torpedo propellant and, earlier in 1989, following sinking the SSN *Komsomolets* was rendered a total loss when a torpedo

round exploded in the bow compartment storage racks - *Dispersal of Radioactive Materials from the Komsomolets Submarine*, Large & Associates, August 1993

[viii] Typically, a nuclear warhead includes 30 to 50 kg of conventional high explosive which is sufficient in accidental detonation conditions to oxidise and disperse the 3 to 5 kg of plutonium (Pu^{239}) and other radio and chemo-toxic materials of the warhead assembly, including tritium, depleted uranium and beryllium - *The Hazards of Transporting Nuclear Weapons Through Urban Areas*, Large & Associates, National Steering Committee of Nuclear Free Zone Local Authorities, January, 1990

[ix] *Guidance and Information on Nuclear Weapons, Accident Hazards, Precautions and Emergency Procedures*, WASH 1274, US Department of Defence and Atomic Energy Commission, October 1973

[x] Partial nuclear detonation of a warhead arising from the accident circumstances is considered just feasible, although not considered here.

[xi] Book of Reference BR3019 – Appendix 4 *Nuclear Reactor Accidents*, see also *MAPC Hazards of a Reactors Accident*, Royal Naval College, Department of Nuclear Science and Technology (S)CM/13/88/WM, October 1992

[xii] The MoD Standard Core History assumes the reactor core to be at the end of its service life, that is highly irradiated, and that it has operated at full power for the immediately previous 100 hours and at 25% power for the remainder of its life.

[xiii] 1 TBq = 10^{12} Becquerel

[xiv] For highly irradiated fuel, such as the submarine reactor fuel of a high burn-up, a higher proportion of both elemental and oxide fission products will release because the volatile elements tend to accumulate in bubbles and voids formed in the fuel 'meat' which volumetrically increase with extending burn-up and the threshold temperature at which this break through occurs is about 1,000°C:

	% Fraction Released at 1200°C at Specimen Irradiation Levels - n/cm^2		
Radionuclide	10^{14}	10^{18}	4.10^{20}
Xenon	70%	95%	100%
volatile Iodine	60%	85%	98%
Caesium	30%	60%	80%
Tellurium	65%	65%	65%
moderately Strontium	0.5%	0.5%	0.5%
volatile Barium	0.5%	0.5%	0.5%
Volatile Ruthenium	0.1%	0.1%	4.0%
Oxides Molybdenum	~0%	0.1%	4.0%
Zirconium	0.03%	0.03%	0.03%
Cerium	0.01%	0.01%	0.01%
Non Neptunium	~0%	0.05%	~0%
Volatile Plutonium	~0%	~0%	0.04%
Uranium	~0%	~0%	0.03%
Oxidised Uranium	70%	70%	90%

[xv] The sequence of events for the *BR6* scenario commences with the reactor operating at power when a complete guillotine failure occurs of a main primary circuit pipe at a point at which it cannot be isolated, that is inboard of the main isolating valves at a not dissimilar locality to the defect on HMS Tireless at Gibraltar – the guillotine failure is complete and the coolant cannot flow across it so the emergency core cooling system is rendered ineffective. There occurs an instantaneous drop in primary circuit pressure, water in the loop and reactor core immediately flashes off into steam and fills the reactor compartment within which the pressure rises rapidly but which remains within the design capability of the hull and bulkheads of the reactor compartment. Although the reactor should by then be shut down, the large amount of decay heat generated by the fuel will raise the fuel temperature rapidly and at 2 minutes or thereabouts the fuel temperature exceeds 900°C with the oxygen stripping zirconium-steam exothermic reaction liberating hydrogen – fuel melt commences at about 3 minutes when fuel temperature closes in at 1700°C. This heating creates a second pressure surge within the reactor compartment and fuel temperatures increase further to 2000°C at which the fuel liquefies. At this stage there is risk of a hydrogen explosion which could breach the hull containment and, quite independently, the liquid fuel could plunge into the shield tank water with a molten metal resulting is a very large pressure pulse (>500 to 600 atmospheres).

[xvi] As example, the attack on USS Cole of 12 October 2000 which completely disabled the warship although it remained afloat.

[xvii] National Radiological Protection Board, which acts as the advisor to Government. Recently the NRPB Working Group on Stable Iodine Prophylaxis reported its concern on the vulnerability of young children following an accidental release of radioiodine. This is because young children's thyroids are more radiosensitive.. The Working Group's recommendations gave prime focus to emergency planning should be the protection of neonates, children under 10 years, and pregnant and nursing women and for this the ERL Upper Limit should be reduced to 100mGy (~from 300mSv to 100mSv) since the present upper ERL is considered too high to provide adequate protection to the young In addition the World Health Organisation has recommended reducing the lower ERL to 10mGy (from 30mSv to 10mSv).

[xviii] Regulation 15 of REPPIR permits the disapplication of dose limits once that a Radiation Emergency has been declared, although the disapplication is conditional on the state of the emergency.
[xix] All the graphs are plotted for average weather conditions and take little account of the local terrain or urban centres within the path of the plume – terrain, weather and, particularly, plume wash out from precipitation can introduce variations of x5 to x10 and the plume development, its direction and coverage area will depend on the wind direction and strength. The whole body and organ doses are expressed in terms of the 50 year committed dose.
[xx] Ideally, the iodine prophylaxis should be initiated prior to the arrival of the source of exposure – the radioactive cloud – so that the thyroid is swamped with the administered iodine thus minimising competition with absorption of the unstable radioactive iodine. Obviously, in rapid release scenarios, such as *BR6*, it may not be possible to administer the iodine prophylaxis sufficiently ahead of the arrival of the radioactive source.
[xxi] Particles of plutonium oxide down to below 10 to 1 micron, or smaller, in equivalent diameter are formed during the ignition and these may disperse freely of combine with or attach to other particles of debris or emulsions of the propellant etc., to be carried away from the site of the accident.
[xxii] The United States acknowledges that two incidents have resulted in release of plutonium from nuclear weapons in the past – these related to aircraft crashes at Thule (Greenland) and Palomares in Spain, both in the 1960s. Britain conducted a series of experimental trials in Australia at Maralinga during the late 1950s and 1960s where nuclear weapons assemblies were subject to deliberate burning and contrived accidents to determine the plutonium aerosol release plume.
[xxiii] The United States adopts a Radiation Protection Guide (RPG) that sets the maximum concentrations in air and water following a nuclear weapons accident for the various component parts of a nuclear warhead, with the Pu^{239} airborne maximum at 6.10^{-14} micro-curies per millilitre. [xxiii] Because of the rapidity of events, the likely high energy of dispersion and, particularly, the difficulties of measuring airborne concentrations of plutonium, initiating sheltering, evacuation and inhalation protection countermeasures at the onset of ERLs is not adopted in the response to a nuclear weapons accident.
[xxiv] The scale of consequence in the aftermath of a nuclear weapon accident obviously relates to the severity of the accident. The United States authorities openly acknowledge that there is risk, albeit remote, that a warhead could undergo partial nuclear detonation in an accident and, if so, this accident would be accompanied by the release of fission products and nuclear blast, both related to efficacy of the partial nuclear yield. In scale of severity the next conceivable accident could involve conventional detonation of the HE charges of one or more warheads (not accompanied by a partial nuclear yield), dispersing the plutonium aerosol over a wide area, estimated by the US authorities to extend 40km or more from the accident site. Ignition and burning of the HE charge (and plutonium) would also serve to disperse the plutonium over a wide area, estimated by the US to extend out to 5 to 10 km of land beyond the immediate accident site.
[xxv] Nuclear Weapons Accident Response Procedures (NARP), US Defence Nuclear Agency, January 1984
[xxvi] The United States SSN boats (eg USN Oklahoma City) are believed to be armed with nuclear capable cruise and anti-submarine missiles.
[xxvii] For example see p26-28 of Section 2, Part A *DevPubSafe* (the public safety scheme for Devonport) assumes the cascading of the incident through severity Categories 1, 2 and 3.
[xxviii] For example, the 1957 Windscale accident took several hours to develop but those operating the atomic pile did not realise what was happening, so although the *'category'* of events were cascading in seriousness, the operators did not realise that counter actions were necessary. At Three Mile Island in 1978 the operators misunderstood what was happening and implemented the wrong counter actions. At Chernobyl in 1986, the cause of the accident was rooted in actions taken 24 or more hours before the explosion, only when the train of events approached the terminal situation did the operators realise that something was desperately amiss, but by then little less than one minute remained before the reactor was completely destroyed.
[xxix] The Argyll and Bute Off Site plan is presently being reviewed by the Scottish Parliament: *Review of the Emergency Planning Measures Relating to the Berthing and Maintenanceof Royal Navy Nuclear Powered Submarines at Faslane, Coulport, Lochgoil, Rothesay and Loch Striven*, Petitions Committee, Scottish Parliament, Large & Associates, April 2001.
[xxx] Letter 20 June 2002, D/WSA/Sec/038/0076/7327, C McLaughlin MoD to Large & Associates
[xxxi] Other public safety schemes, such as ClydePubSafe and the draft Argyll and Bute Off-Site Plan note it will take the Royal Navy *"some hours before monitoring teams can gather sufficient information to make possible a realistic appreciation of the course of an accident"* which for the *Category 3* accident may (will likely) be too late to implement ERL or other dose specific countermeasures. *DevPubSafe* states (*Part A, 2.5.2.4.a*) that the local emergency monitoring team would not be adequate to deal with the situation over a prolonged period and back up support will be required from Scotland and the Civilian authorities.
[xxxii] Unless the warhead underwent a partial detonation or 'fizzle', no iodine-131 would be present and hence no need for PITs consumption – *Transportation of Nuclear Weapons through Urban Areas in the United Kingdom*, Large & Associates, National Steering Committee Nuclear Free Local Authorities, January 1990
[xxxiii] Again, ClydePubSafe states that "*is imperative that there is some form of predetermined plan to protect those who may be at risk in the period before definitive monitoring information becomes available".*
[xxxiv] See footnote xvii for critical groups relating to iodine uptake (eg neonates and nursing mothers).
[xxxv] An example of error in *DevPubSafe* is the requirement (Section 2.9.7) that emergency services personnel will under exceptional circumstances adopt a dose limit of 1000mSv (whole body). This is contrary, first, to standing orders for firefighters who presently have single incident dose limits of 50mSv at the fire scene and 100mSv for lifesaving (but see DevPubSafe Devon Fire Service Annex, para 15.6) and, second, it does not comply with the requirement of REPPIR *Regulation 14*. If key emergency services personnel, the firefighters, had to withdraw during the progress of an incident then the specialist resources assumed to be available for *DevPubSafe* would be considerably depleted. Also, whether employees of the local authorities

involved would wish to operate under such high radiation dose rates and, indeed, if all such employees could be sufficiently trained and informed to agree to such involvement and risk (*Regulation 14(5b)*) is doubtful.
[xxxvi] BR 3025 (c1976) may now have been superseded and it refers specifically to NEMO (Naval Emergency Monitoring Organisation) – the BR documents are generally not available to organisations outside the MoD because permission for their release follows through a vetting system in which the sanction of a *'Sponsor'* is required but to determine if the documents are available, first, the documents have to be ordered so that the Sponsor may consider the request.
[xxxvii] In the immediate aftermath of Chernobyl radiological surveys of the nearby town of Pripyat (6km from the powert station) recorded vary large variations of gamma-beta deposition – USSR Report on the Accident at Chernobyl, June 1986
[xxxviii] It is unlikely that Plymouth City Council will have direct access to the DIRS and PMS systems installed at Devonport and thus it will be reliant upon navy personnel for first notification and assessment of any incident underway.
[xl] *Reactor Accidents Course Notes*, Royal Naval College Greenwich, Department of Nuclear Science and Technology, 1992
xli] The procedures are set out in a series of MOD documents (BR 3030 – Radiological Controls, BR 3020 Radiological Protection, BR 3019 Nuclear Reactor Accidents, BR3025 – Naval Emergency Monitoring Organisational Orders) none of which are available in the public domain.