

## Memorandum from Richard L Garwin

1. On December 4<sup>th</sup>, Prime Minister Blair announced in Parliament his Government's decision to replace Britain's four *Trident* ballistic-missile submarines with a successor fleet. He asserted that the service life of these submarines can be extended to only 30 years, which would mean that the submarines would have to be retired in 2023 (*Vanguard*), 2025 (*Victorious*), 2026 (*Vigilant*), and 2029 (*Vengeance*)[\[1\]](#)

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Pentagon, Dr. Postol helped to build a program at Stanford University to train mid-career scientists to study developments in weapons technology of relevance to defense and arms control policy. In 1990 Dr. Postol was awarded the Leo Szilard Prize from the American Physical Society.

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2. In this Comment we explain why we believe it likely that the *Vanguard*-class submarines can safely and economically be operated for 40-45 years rather than 30. This would not only save funds for other defence needs but would provide valuable flexibility in the decision whether or not to maintain the nuclear deterrent for another 40 years beyond 2035, to build smaller SSN-size strategic submarines for a smaller long-range ballistic missile, or to introduce new technology to the submarine design and build process. We touch also on the question of the submarine industrial infrastructure, the pace of manufacturing, and the skill base for Britain's nuclear submarines. Finally, we observe that the security of the UK, like that of the US, is more imperiled than supported by the existence of nuclear weapons, and that the elimination of nuclear weapons, or at least of national nuclear weapons, is a possibility.[\[2\]](#)

3. Given that the service lives of US *Trident* submarines were extended in 1998 from 30 to 44 years,[\[3\]](#) one obvious question is whether the UK could do the same. (In 1998, the oldest US *Trident*, the *Ohio*, was 17 years old, three years older than the *Vanguard* is today.) Also the US *Tridents* spend approximately two thirds of their lives at sea with two crews for each submarine while the UK requires that only one out of four of its *Tridents* be at sea at any time. The lower usage rate of the UK *Tridents* might be expected to *increase* their life expectancy relative to the US *Tridents*.

4. The White Paper on *The Future of the United Kingdom's Nuclear Deterrent* submitted to Parliament by the Secretaries of State for Defense and Foreign and Commonwealth Affairs (hereafter Defense/Foreign Affairs, for short) argues, however, that a life extension is not possible for Britain's *Tridents*:

"We have undertaken detailed work to assess the scope for extending the life of those submarines. Our ability to achieve this is limited because some major components on the submarines - including the steam generators, other elements of the nuclear propulsion system and some non-nuclear support systems - were only designed for a 25-year life. The submarines have been, and will

continue to be, subjected to a rigorous through-life maintenance regime and we believe that, by revalidating those components, it should be possible to extend the life of the submarines by around five years."[\[4\]](#)

Since the UK *Tridents* are still relatively young, however, it may be that improved management of their water chemistry could drastically extend the steam generator lives. The US has a major R&D program in that area whose results could presumably be shared with the UK[\[5\]](#). More fundamentally, we are skeptical that the submarines "were only designed for a 25-year life". More likely, they have a "minimum design life" of 25 years and are likely to be operable for a much longer time. A similar misunderstanding was prevalent about the longevity of US nuclear warheads, with some arguing that because experience with the core of the nuclear weapon primary—the sealed metal "pit"—was limited to, say, 45 years, one needed to plan and operate pit-manufacturing plants to provide replacement pits as a 45-year echo of the original build. The US Science-based Stockpile Stewardship Program has recently determined that pit lifetimes are at least 85 years, as announced by the US National Nuclear Security Administration (NNSA).[\[6\]](#) Since the pit is the most specialized part of the nuclear weapon and the element most critical to its performance, it is of great significance that its life exceeds 85 rather than 45 years. This certainly does not imply that the entire nuclear warhead will remain operable for 85 years, but the remainder of the warhead is more readily testable and replaceable. The lesson for the submarine replacement program is that continued monitoring of the submarines in service may show well in advance that the service life, with proper maintenance and corrective action, can much exceed the 25-year minimum.

5. In particular, replacing the steam generators and other limited life components should not be casually dismissed as an option if it would allow a ten to fifteen-year extension of the UK *Trident* submarine service lives and a corresponding deferral of the replacement decision. It is a routine if major operation to replace steam generators in civilian nuclear power plants. A proper evaluation should be made of the cost of access through the *Trident* hulls and replacement of their steam generators, if that is required.

6. Major refurbishments in the *Trident* submarines are routine and replacements of major systems are assuredly involved. As the Prime Minister stated to Parliament on December 4<sup>th</sup>:

"Our deterrent is based on four submarines. At any one time, one will be in dock undergoing extensive repair and maintenance, usually for around four years."

The *Vanguard* spent three years in refit at the Devonport Naval Base including a new reactor core between 2002 and 2005, i.e. between year 9 and 12 of its life. The *Victorious* began refit in 2005, the tenth year of its life.[\[7\]](#) The new cores should be longer lived,[\[8\]](#) so it is not clear when the next major refit would be scheduled.

7. The Prime Minister stated that the cost of building four replacement submarines would be £15-20 billion. The real discount rate used for U.K. indexed gilt-edged bonds by the U.K. Debt Management Office is 2.5 percent. A delay in this expenditure by 10-15 years would be worth about £5 billion. Alternatively, extending the lifetime of the submarines from 30 to 40 or 45 years would reduce the annual capital cost by £150-200 million per year. Obviously, the possibility of such life extension is worth in-depth study.

8. Our experience is that it is useful to challenge statements such as those made in the Defense/Foreign Affairs White Paper. For want of deep analysis of the options, real national military capability often takes second place to parochial service and contractor interests.

9. For example, in the 1960s when one of us (RLG) chaired the Military Aircraft Panel of the US President's Science Advisory Committee, the US Air Force was arguing that the B52 could not operate much beyond the 1970s because of the accumulation of metal fatigue in its wings, and for other reasons. The B52, of course, still operates 40 years later, as a result of life extension programs.

10. At the time, the US Air Force was arguing for a replacement aircraft- the B70 and then the Advanced Manned Strategic Aircraft-AMSA-with the claim that an aircraft with somewhat higher subsonic speed would not be as vulnerable as the B52 to the Soviet-supplied surface-to-air (SAM) systems that were spreading around the world and that were, in fact, operating at that time in Vietnam.

11. Detailed discussion with the Air Force revealed that the relative invulnerability of the newer aircraft depended on the assumption that the SAM-2 system needed to track the aircraft for a much longer period before launch than we knew to be the case.

12. Indeed, the United States did build two new strategic aircraft- the B-1 and the B-2, and similar lawyerly arguments were made in favor of each of these. The B-1, in particular, was for the strategic role in competition with the B52 and with the cruise-missile carrier, since it was finally recognized that it was both inefficient and too vulnerable to have an aircraft make the rounds to deliver a dozen or more strategic nuclear weapons against individual targets in the heavily defended Soviet Union. Instead, long-range strategic cruise missiles would be launched from aircraft outside or near the border of the Soviet Union, in order to be able to carry out the retaliatory strike and allow the aircraft system to serve as a component of the strategic deterrent.

13. Congressional testimony exposed the Air Force assumption that the cruise missile carrier would spend one hour (alternatively, two hours) flying along the border of the Soviet Union to release its 40 or so cruise missiles; the ballistic-missile submarines launch their missiles undersea at a 15-second cadence-a much more difficult task. The problem was resolved by equipping the old B-52

with air-launched cruise missiles that allow it to launch from outside defended areas. In addition, the Air Force discovered that the strategic cruise missile could actually be carried internally by the proposed B-1 bomber-despite Air Force early antagonism to the cruise missile.

14. As a further example, imminent improvements in Soviet antisubmarine warfare similarly were cited as the reason why it was urgent to proceed with the *Trident* submarines because the larger submarines could carry larger missiles with intercontinental range-hence a much larger ocean operating area. When one of us (RLG) testified in support of an extended-range Poseidon missile to be deployed in the existing Poseidon submarines, the US Navy countered that the accumulation of hull corrosion and metal fatigue in the Poseidon submarines strictly limited their life in any case.

15. This led RLG to write a letter to the Assistant Secretary of the Navy for Research, Engineering, and Systems to try to obtain a straightforward definitive answer as to the "compelling argument" that submarine hull corrosion and metal fatigue required the urgent replacement of the *Poseidon* submarines.

16. RLG's letter to David E. Mann and his reply are attached. Mann's reply was that, in fact, an intensive monitoring program had shown that hull corrosion and metal fatigue of US strategic submarines were *not* major problems and, further, that to the extent they occurred, there were low-cost, effective solutions.

17. We cite this not because we believe that the Naval officers who had given the false statements were lying, but rather that, for years, they must have been ignorant of technical reality. The same may be true of the authors of the UK White Paper on *The Future of the United Kingdom's Nuclear Deterrent*.

18. That UK Government White Paper does not cite metal fatigue and hull corrosion as life-limiting factors for the UK *Trident* submarines. It simply indicates that (pp. 9,10)

"... some major components of the submarines- including the steam generators, other elements of the nuclear propulsion system and some non-nuclear support systems- were only designed for a 25-year life...There have been some suggestions that we should replicate US plans to extend the lives of their Ohio-class SSBNs from 30 to over 40 years. A substantial life extension of this kind would need to have been built into the original design of the Vanguard Class and into the subsequent manufacture, refit and maintenance of the boats. Unlike with the Ohio class this was not the case."

In systems designed conservatively to ensure a minimum life of 25 years, it is common to find from experience that the system or component can be operated safely for a much longer time; often it is the advent of smaller, cheaper options that cause the scrapping of equipment, as is certainly the case with computers. Here, however, the replacement would carry the same large missiles and fulfill the same mission, so that the benefits of newer technology are minimal-or at least unstated in the White Paper. Certainly, a

much more detailed consideration of the options than is offered in the Defense/Foreign Affairs White Paper would be required to make a judgment between a life-extension program and a program for building new submarines.

19. In our experience, until these matters are properly prepared for outside review, they are not adequately formulated for inside decision makers. We see no reason why questions such as the possibilities for control of the corrosion of steam generators cannot be fully discussed in public. As for the "other elements of the nuclear propulsion system and some non-nuclear support systems ... only designed for a 25-year life" not otherwise detailed in the White Paper, these are surely replaceable in case surveillance shows the need to do so, and it is only a matter of cost-to-replace compared with the proposed program for replacement of the fleet itself.

20. Beyond the potential cost savings in choosing life extension of the *Vanguard* fleet over total replacement of the submarines, there is great merit in postponing the initiation of a replacement program even if that were to be the ultimate choice. The Trident D-5 missile is greatly oversized for its current loading that averages 3 warheads for a missile that can accommodate 12 and in US SLBMs the average is now down to 6.<sup>[9]</sup> To permit the delivery of a single warhead, it is likely that some of the UK missiles are fitted with a single warhead and some with considerably more than the average of 3. Because of the enormous evolution in computer technology and the miniaturization of guidance systems, there is the opportunity to use small, single-warhead missiles of range comparable with the Trident D-5, but those missiles would need to be developed, together with a potential suite of appropriate countermeasures to ballistic-missile defense systems. A resulting major benefit would be the much smaller strategic submarine that could be operated by the much smaller crew enabled by modern information technology; the UK could consider a fleet of 6-8 such submarines that would permit keeping two at sea at all times. For instance, a version of the *Astute* class SSN might be built as an SSBN with the small, single-warhead missiles. A hasty commitment to a simple *Vanguard* replacement would foreclose such an opportunity.

21. Parliament has recently published a report on the manufacturing and skills base for the UK's SSBNs.<sup>[10]</sup> Industry has stated and the Government seems to accept that an interval of 22 months—a rhythm or "drumbeat"—is the minimum rate needed to maintain a healthy nuclear-submarine design and production base in the UK. The Royal Navy now operates the 4 *Vanguard* SSBNs and 9 SSNs ( 2 *Swiftsure* and 7 *Trafalgar* ), with 3 *Astute* SSNs in the pipeline. If the program would maintain a pace of one ship every two years, then with a 30-yr operating life, there would be 15 submarines in the Navy; with a 45-yr operating life there would be 22 ships. The pace demanded by industry does not seem to be compatible with the funds and planning of the Government, but one does see a lack of motivation to extend the operating life.

22. The explicit premise for the continuation of the *Vanguard* program - either by life extension or replacement-is that the submarine is invisible and invulnerable in the open ocean. With the end of the Soviet Union and of committed enmity between East and West, there is no longer the deep-seated fear that Soviet science and technology would put the patrolling SLBMs at risk of preemptive destruction, but the US- and we presume the UK- has intensive programs to evaluate the possibility that Russia or other states will be able to use satellite observations or other approaches to track or to detect the submarines at sea. Another potential vulnerability arises from the surreptitious attachment to the submarine hull of a tracking aide as the submarine leaves port, and the fleets must exercise constant vigilance to avoid this.

23. The purpose of the UK SSBNs is evidently very different from what it was during the Cold War, aside from the simplistic statement that it is to prevent the destruction of the country and to guarantee security. Against whom could the "strategic nuclear deterrent" effectively be oriented? This is, of course, the central question, which is difficult to answer at a time of international confusion about the future of nuclear weapons. A decade delay in the replacement decision might produce a clearer answer.

24. With conservatives and liberals alike (for example see footnote 2) now calling for renewed effort towards the goal of a world free of nuclear weapons, the United Kingdom has a unique opportunity for world leadership as it considers the role and value of its nuclear force. An unnecessary and premature decision to build new submarines could lock the United Kingdom into a more costly and dangerous future for the next 50 years, while a decision to extend the life of its existing submarines opens a variety of options for the UK.

25. To maintain the UK security it is essential that the future of the nuclear deterrent be decided with full consideration of the options and of their cost, in view of the other needs in the defence budget. The White Paper is only a start on that process. As we have indicated above, much more remains to be done, both within the Government and in Parliament.

10 January 2007

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[1] These are the commissioning dates given at <http://www.naval-technology.com/projects/vanguard> plus 30 years,. For some reason, the Prime Minister's statement has the retirement dates one year earlier.

[2] "A World Free of Nuclear Weapons," by George P. Shultz, William J. Perry, Henry A. Kissinger and Sam Nunn, Wall Street Journal, January 4, 2007.

[3] See e.g. *Nuclear Posture Review*, Submitted by the US Department of Defense to the US Congress, 31 December 2001, p. 42, excerpts available on [globalsecurity.org](http://globalsecurity.org).

[4] *The Future of the United Kingdom's Nuclear Deterrent*, White Paper presented to Parliament by the Secretary of State for Defense and the Secretary of State for Foreign and Commonwealth Affairs, December 2006, para. 1-3.

[5] See e.g., the US Department of Energy discussion of this program in the justification of the naval reactors portion of its proposed Fiscal Year 2004 budget: "Maintaining steam generator integrity over the full service life, especially as we extend the service life of ships, requires improving understanding of high temperature corrosion processes, assessment of potential causes and corrective actions, and development of alternative water chemistries which can inhibit or abate corrosion. Trace impurities become highly concentrated by the boiling process in areas of low flow and form deposits. The concentration of impurities in these deposits can become corrosive and threaten the integrity of the unit. Development work focuses on evaluating corrosion mechanisms, devising methods to locate and remove deposits, minimizing input of impurities, and evaluating and testing water chemistries and corrosion inhibitors for benefits and drawbacks to ensure they mitigate the consequences of impurities over the life of the plant, "

<http://www.mbe.doe.gov/budget/04budget/content/nvlreact/nvlreact.pdf>, p. 818

[6] "Overall, the weapons laboratories studies assessed that the majority of plutonium pits for most nuclear weapons have minimum lifetimes of at least 85 years." (NNSA Press Release, November 29, 2006, at [www.nnsa.doe.gov](http://www.nnsa.doe.gov)).

[7] <http://www.naval-technology.com/projects/vanguard/>

[8] Rolls Royce indicates that its new reactor core design "lasts the entire life of the submarine, eliminating costly mid-life refueling," <http://marine.rolls-royce.com/nuclear-reactor/>

[9] Robert S. Norris and Hans M. Kristensen, NRDC: Nuclear Notebook, U.S. nuclear forces, 2006; January/February 2006, pp. 68-71 (vol. 62, no. 1)

<[http://www.thebulletin.org/article\\_nn.php?art\\_ofn=jf06norris](http://www.thebulletin.org/article_nn.php?art_ofn=jf06norris)>

[10] House of Commons Defence Committee, "The Future of the UK's Strategic Deterrent: the Manufacturing and Skills Base," Fourth Report of Session 2006-07, 12 December 2006.