Retiring Trident: An alternative proposal for UK nuclear deterrence

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About the author
Toby Fenwick began his involvement with CentreForum in 2011, and he published “Dropping the Bomb: A post-Trident Future” in March 2012. A CentreForum Research Associate, Toby holds graduate degrees in international law and international relations from University College London and the London School of Economics, and undergraduate degrees in law from Birkbeck College, University of London, and politics from Middlebury College, Vermont, USA. A former HM Treasury and DFID civil servant, he served in the RAF intelligence reserve from 1995 to 2009, has written for Chatham House and the Parliamentary Assembly of the Council of Europe. He was elected as a Fellow of the RSA in 2013.

Acknowledgments
The author is profoundly grateful to Paul Ingram of BASIC and Jeffrey Lewis of the Middlebury Institute of International Studies at Monterey, Monterey, California, for their expertise, support and good humour, and without whom this paper would not exist.

Input and challenge from all points of the debate has been critical in teasing out the nuances and stress-testing the assumptions in this paper. The author is therefore very grateful to Peter Burt, Julie Cantalou, Hugh Chalmers, Malcolm Chalmers, Mike Fenwick, Tim Fox, Eric James, Tim Hare, Garry Porter, Nick Ritchie, Jennifer Smith, Tim Street, Phil Williams and those serving officers and civil servants whose valuable contributions cannot be publicly recognised at this time. He is indebted to Karl L. Swartz and the Great Circle Mapper (www.gcmap.com) for producing the mapping.

As ever, special thanks are due to the CentreForum team of Patrick Day, Russell Eagling, Tom Frostick, India Keable-Elliott, Ashley Hibben, James Kempton, Stephen Lee, Tom Papworth, Anthony Rowlands, Nikki Stickland, Holly Taggart, Chris Thuong, and Nick Tyrone for their assistance and support.

Finally, heartfelt thanks to Professor Russell Leng, the Emeritus James Jermain Professor of Political Economy and International Law at Middlebury College, Middlebury, Vermont, USA, who inspired my early interest in international relations and emphasised the central role of international law. Without his patience and guidance, none of this would have been possible.

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Cover image: F-35C of US Navy test and evaluation squadron VX-23 “Salty Dogs” performs the F-35C Lightning II carrier variant’s first carrier landing aboard the USS Nimitz (CVN 68) on 6 November 2014. U.S. Navy official photo courtesy of Lockheed Martin by Alexander H Groves
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Executive summary

Shortly after the May 2015 election, the British Government will face the key “Main Gate” investment decision when will decide whether or not to replace the UK’s Trident submarine-launched ballistic missile (SLBM) carrying Vanguard-class nuclear-powered ballistic missile submarines (SSBNs) with Successor-class submarines.

A decision to proceed will lock the UK into capital spending of up to £33.1bn by 2032 on the new submarines, and this will likely translate into the UK operating Trident beyond 2050 at a total through-life cost of approximately £109bn. As the major UK parties refine their policies for the 2015 manifestos, CentreForum has revisited its 2012 paper Dropping the Bomb: A Post Trident Future, in order to revise our policy recommendations.

We began our reassessment of the issue by considering what a UK policy of credible, minimum independent nuclear deterrence requires. In line with the declassified 1978 Duff Group deterrence criteria, our view is that minimum deterrence requires a potential adversary to have limited confidence that they can stop the UK inflicting unacceptable damage on targets that matter to them.

In concrete terms, this means the destruction of ten or more of their major urban areas, or the threat of delivering 30 warheads against targets of value. This requires a considerably lower level of capability than is currently underpins the requirement for Trident, and recognises that the UK can achieve deterrence with a considerably less capable nuclear weapons system, saving money and contributing to long-term multilateral nuclear disarmament.

As Trident alternatives come with different costs, value for money assessments can – and should – be made. Given that the defence budget is unlikely to grow substantially in the next decade, we need to consider the opportunity costs that purchasing a system as expensive as Trident would impose on the UK conventional forces between now and 2030.
Building on the UK’s 2013 Trident Alternatives Review (TAR), recognising the changes in the international situation and the USA’s decision to proceed with modernisation of the North Atlantic Treaty Organisation (NATO) B61 free-fall nuclear weapons, CentreForum recommends that the UK scrap plans for Successor-class ballistic missile submarines (SSBNs) and move to a free-fall nuclear capability based on Lockheed Martin F-35 Lightning II / Joint Strike Fighter (JSF) that the UK is currently procuring and the forthcoming US B61 Mod 12 (B61-12) bombs that will arm NATO nuclear Dual-Capable Aircraft (DCA) from 2020.

CentreForum estimates that an alternative nuclear force based on 100 anglicised B61-12s, has a capital cost of approximately £16.7bn. This includes:

- associated nuclear storage, command and control;
- conversion of both of Queen Elizabeth-class aircraft carriers to operate catapult launched, arrested landing aircraft;
- five additional Astute-class nuclear-powered but conventionally armed fleet submarines (SSNs) to protect the UK submarine industrial base and meet the full range of SSN missions;
- four additional Type 26 frigates to support the carrier group;
- six shipborne airborne early warning and control (AEW&C) aircraft and four carrier capable transport aircraft (COD);
- converting the 14 RAF Voyager in-flight refuelling tankers to receive and to supply fuel via the high speed flying boom refuelling method; and
- eight long-range maritime patrol aircraft / multi-mission aircraft (MPA / MMA).

Crucially, all of these non-nuclear investments will significantly enhance the UK’s conventional force projection capabilities and precision conventional strike capability, in addition to providing nuclear strike capability, and protecting the UK’s submarine industrial base.

Our optimal solution saves a further £4.8 – 13.1bn to reinvest in the conventional forces between 2015 and 2032. It does so whilst ensuring that the UK can deter nuclear powers outside of the nuclear Non-Proliferation Treaty (NPT) beyond 2040, and hold many targets in existing UN Security Council nuclear powers (P5) “at risk” over the same time horizon.

In implementing this package, the UK would be contributing to existing NATO nuclear burden-sharing arrangements, enhancing its conventional capabilities, and take a concrete step down the nuclear ladder and to-
wards future nuclear disarmament as the international situation allows in accordance with the UK’s nuclear Non-Proliferation Treaty obligations.

**Specific Recommendations**

- Scrap the *Successor*-class SSBN producing gross capital savings of between £21.5 – 29.8bn;
- Procure 100 anglicised B61-12 free-fall nuclear weapons;
- Offer to share the hosting of NATO’s forthcoming B61-12 free-fall nuclear weapons at RAF Lakenheath, Suffolk with Italian AF Base Aviano as part of NATO nuclear burden-sharing;
- Share the costs of modifying F-35C to allow for the nuclear mission with the USA and NATO’s F-35A operating NATO Dual-Capable Aircraft (DCA) states;
- Retrofit the *Queen Elizabeth*-class aircraft carriers with conventional take-off and arrested landing equipment;
- Convert UK F-35 orders from F-35B short-take off vertical landing (STOVL) variant to F-35C aircraft carrier Catapult Assisted Take-Off But Arrested Landing (CATOBAR) variant.
- Field anglicised B61-12 with the lead RAF F-35C squadron from land-bases from 2021;
- Field anglicised B61-12 with the lead RN F-35C squadron from the *Queen Elizabeth*-carriers from the mid-2020s
- Field an additional five *Astute*-class SSNs in order to safeguard the submarine industrial base;
- Field an additional four Type 26 frigates to support the carrier group;
- Field six E-2D Advanced Hawkeye shipborne airborne early warning and control (AEW&C) aircraft to protect the UK carrier group;
- Field four C-2A Greyhound carrier capable transport aircraft to maximise UK carrier group operational flexibility;
- Convert the 14 RAF Voyager in-flight refuelling tankers to receive and to supply fuel via the high speed flying boom refuelling method;
- Field eight long-range Maritime Patrol Aircraft for UK and carrier group protection missions;
- Retire the *Vanguard*-class SSBNs by 2024;
- Roll the net capital savings of between £4.8 – 13.1bn from the *Successor* programme into the re-equipping the UK’s conventional forces.
<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (£bn*)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 UK B61-12 derived nuclear weapons @ ceiling price of US$60m / weapon</td>
<td>3.0</td>
<td>This ceiling price is twice the maximum unit price of US B61-12 production.</td>
</tr>
<tr>
<td>CATOBAR conversion of two <em>Queen Elizabeth</em> class aircraft carriers</td>
<td>4.2</td>
<td>£2.0bn estimate for one carrier conversion in 2012 deflated to £2.1bn in 2014. Significant enhancement to <em>Queen Elizabeth</em>-class conventional capabilities.³</td>
</tr>
<tr>
<td>F-35B to F-35C conversion</td>
<td>-1.2</td>
<td>At $156.8m F-35B is $14.2m more expensive per aircraft, than the F-35C. Saving computed over 138 aircraft buy.</td>
</tr>
<tr>
<td>F-35C nuclear avionics conversion</td>
<td>0.2</td>
<td>Assumes $350m cost of conversion of F-35C as F-35A and no cost-sharing⁷</td>
</tr>
<tr>
<td>Purchase of <em>Astute</em>-class boats 8 – 12</td>
<td>&lt;5.0</td>
<td>Assumes maximum cost of £1.0bn per SSN. Savings to come from ordering all five at a faster production drumbeat. Does not assume any further savings from increased production to meet export orders.</td>
</tr>
<tr>
<td>Purchase of Type 26 frigate hulls 14 – 17</td>
<td>2.0</td>
<td>Assumes that Type 26 meets its target unit cost of £0.5bn.⁶</td>
</tr>
<tr>
<td>E-2D Advanced Hawkeye AEW x 6</td>
<td>0.9</td>
<td>Assumes no savings from Crowsnest cancellation⁷</td>
</tr>
<tr>
<td>C-2A Greyhound Carrier Onboard Delivery (COD) x 4</td>
<td>0.2</td>
<td>Includes conversion to single-point AAR tankers.</td>
</tr>
<tr>
<td>Long-range Maritime Patrol Aircraft (MPA) x 8³</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Conversion of Voyager KC2 / KC3 to include centreline refuelling boom and to be able to receive fuel in-flight</td>
<td>0.7</td>
<td>Cost limit of £50m per airframe</td>
</tr>
<tr>
<td>UK nuclear infrastructure (C2, physical)</td>
<td>&lt;1.0</td>
<td>This centres on the reactivation of nuclear C2 and associated storage facilities at RAF Marham, Norfolk.</td>
</tr>
<tr>
<td>Maximum cost of free-fall option</td>
<td>&lt;16.7</td>
<td></td>
</tr>
<tr>
<td>Range of likely like-for-like costs <em>Successor</em>-class costs</td>
<td>24.8 – 33.1</td>
<td>2005 prices discounted to 2014 prices inflated by <em>Astute</em> experience (30.4%).</td>
</tr>
<tr>
<td>o/w spent by 2016</td>
<td>3.3</td>
<td>December 2014 update to Parliament¹⁰</td>
</tr>
<tr>
<td>Gross savings from <em>Successor</em>-class cancellation</td>
<td>21.5 – 29.8</td>
<td></td>
</tr>
<tr>
<td>Net savings from free-fall option</td>
<td>4.8 – 13.1</td>
<td></td>
</tr>
</tbody>
</table>
* In 2014 pounds using HM Treasury deflators. Rounded up to the nearest single decimal place. Amounts may not add to 100% due to rounding.

\(^{\dagger}\) Estimated Type 26 unit cost in 2014 pounds.\(^{11}\)

\(^{1}\) Given the need to modify the F-35A for NATO nuclear-sharing, cost sharing is likely. As a result, this is likely to be a significant over-estimate of the conversion cost.

\(^{1}\) Based on 2013 E-2D Advanced Hawkeye Aircraft (E-2D AHE) Selected Acquisition Report PAUC, 16 April 2014. Crowsnest is a surveillance radar system to be carried aboard RN Merlin HM2 helicopters to provide airborne early warning. Main Gate is expected in 2015, and Crowsnest is expected to cost between £230 – 500m. As it is not clear what savings would accrue from cancellation, none are assumed for these current purposes.

\(^{\odot}\) Costings based on Boeing P-8A Poseidon.\(^{12}\)

GBP 1 = USD 1.68 (10 Jun 2014)
Acronyms used in this paper

AAR  Air to Air Refuelling
AB   Airbase
ABM  Anti-Ballistic Missile (System)
AD   Air Defence
AEW  Airborne Early Warning
AEW&C Airborne Early Warning and Control
ALCM Air-Launched Cruise Missile
AIP  Air Independent Propulsion for non-nuclear powered submarines.
ARBS Air Refuelling Boom System
AWACS Airborne Warning And Control System (UK Boeing E-3D Sentry)
AWE Atomic Weapons Establishment, Aldermaston, Berkshire, UK
B53  US free-fall 9Mt unguided thermonuclear bomb designed for attacking heavily fortified buried targets; replaced by B61-11. Last weapon dismantled October 2011
B61  US tactical variable-yield thermonuclear free-fall bomb family deployed on US and NATO Dual-Capable Aircraft (DCA). By 2025, B61-11 and B61-12 will be the only B61 variants in service
B61-3 B61 Mod 3: Variable-yield (0.3kt/1.5kt/60kt/170kt) US thermonuclear free-fall bomb. Currently deployed as part of the NATO nuclear-sharing programme. To be replaced by B61-12
B61-4 B61 Mod 4: Variable-yield (0.3kt/1.5kt/10kt/45kt) US thermonuclear free-fall bomb. Currently deployed as part of the NATO nuclear-sharing programme. To be replaced by B61-12
B61-7 B61 Mod 7: 360kt US thermonuclear free-fall bomb. To be replaced by B61-12
B61-11 B61 Mod 11: Ground-penetrating 440kt US thermonuclear free-fall bomb which replaced 9Mt yield B53 in the heavily buried target role
B61-12 B61 Mod 12: Precision-guided replacement variable-yield (0.3kt/1.5kt/10kt/50kt) US thermonuclear free-fall bomb using the warhead of B61-4 to replace B61-3, B61-4 and B61-7 in US and NATO DCA service
BASIC British-American Security Information Council
BIOT British Indian Ocean Territory
C2   Command and Control
CASD Continuous At-Sea Deterrence
CATOBAR Catapult Assisted Take-Off But Arrested Landing
<table>
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<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>COMAO</td>
<td>Composite Air Operation</td>
</tr>
<tr>
<td>CTOL</td>
<td>Conventional Take-Off and Landing</td>
</tr>
<tr>
<td>CEP</td>
<td>Circular Error Probable</td>
</tr>
<tr>
<td>COD</td>
<td>Carrier On-board Delivery (CATOBAR carrier-capable cargo aircraft)</td>
</tr>
<tr>
<td>DoD</td>
<td>US Department of Defense</td>
</tr>
<tr>
<td>DCA</td>
<td>Dual Capable Aircraft; an aircraft capable of delivering both conventional and nuclear munitions</td>
</tr>
<tr>
<td>DPRK</td>
<td>Democratic People’s Republic of Korea (North Korea)</td>
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<tr>
<td>ELF</td>
<td>European Liberal Forum</td>
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<tr>
<td>ELINT</td>
<td>Electronic Intelligence</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EUCOM</td>
<td>US European Command</td>
</tr>
<tr>
<td>F-35A</td>
<td>Conventional Take-Off and Landing (CTOL) variant of the Lockheed Martin F-35 JSF family</td>
</tr>
<tr>
<td>F-35B</td>
<td>Short Take-Off / Vertical Landing (STOVL) variant of the Lockheed Martin F-35 JSF family</td>
</tr>
<tr>
<td>F-35C</td>
<td>Catapult Assisted Take-Off But Arrested Landing (CATOBAR) variant of the Lockheed Martin F-35 JSF family for use on conventional aircraft carriers</td>
</tr>
<tr>
<td>FAA</td>
<td>Fleet Air Arm, the Royal Navy’s aviation branch</td>
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<tr>
<td>FOB</td>
<td>Forward Operating Base</td>
</tr>
<tr>
<td>FOC</td>
<td>Full Operational Capability</td>
</tr>
<tr>
<td>FY</td>
<td>US Fiscal Year, running from October 1 – September 30.</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HAS</td>
<td>Hardened Aircraft Shelter(s)</td>
</tr>
<tr>
<td>HMNB</td>
<td>Her Majesty’s Naval Base</td>
</tr>
<tr>
<td>HMS</td>
<td>Her Majesty’s Ship</td>
</tr>
<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<tr>
<td>ICBM</td>
<td>Intercontinental Ballistic Missile</td>
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<tr>
<td>IDS</td>
<td>Interdictor / Strike</td>
</tr>
<tr>
<td>IOC</td>
<td>Initial Operational Capability</td>
</tr>
<tr>
<td>IRBM</td>
<td>Intermediate Range Ballistic Missile</td>
</tr>
<tr>
<td>ISD</td>
<td>In-Service Date</td>
</tr>
<tr>
<td>ISIL</td>
<td>Islamic State in Iraq and the Levant</td>
</tr>
<tr>
<td>JDAM</td>
<td>Joint Direct Attack Munition, a GPS-guidance kit to allow unguided bombs to be GPS guided.</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>JFH</td>
<td>Joint Force Harrier</td>
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<tr>
<td>JSF</td>
<td>Lockheed Martin F-35 Joint Strike Fighter series</td>
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<tr>
<td>kft</td>
<td>feet, thousand (of altitude)</td>
</tr>
<tr>
<td>kt</td>
<td>Kiloton, equivalent explosive power to 1,000t of TNT</td>
</tr>
<tr>
<td>LO</td>
<td>Low Observable (of aircraft: “stealth”)</td>
</tr>
<tr>
<td>MDA</td>
<td>1958 US – UK Mutual Defence Agreement</td>
</tr>
<tr>
<td>MIRV</td>
<td>Multiple Independently-targeted Re-entry Vehicle</td>
</tr>
<tr>
<td>MOB</td>
<td>Main Operating Base</td>
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<tr>
<td>MoD</td>
<td>UK Ministry of Defence</td>
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<tr>
<td>MMA</td>
<td>Multi-Mission Aircraft</td>
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<tr>
<td>MP</td>
<td>Member of Parliament</td>
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<tr>
<td>MPA</td>
<td>Maritime Patrol Aircraft</td>
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<tr>
<td>MPA / MMA</td>
<td>Maritime Patrol Aircraft / Multi-Mission Aircraft</td>
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<tr>
<td>MRBM</td>
<td>Medium Range Ballistic Missile</td>
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<tr>
<td>MRV</td>
<td>Multiple Re-entry Vehicle</td>
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<tr>
<td>Mt</td>
<td>Megaton, explosive power equivalent to 1,000,000t of TNT</td>
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<tr>
<td>MUNSS</td>
<td>USAF Munitions Support Squadron</td>
</tr>
<tr>
<td>MX</td>
<td>Missile eXperimental, the programme name for the USAF’s advanced ICBM programme in the 1970’s that became the LGM-118 Peacekeeper.</td>
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<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organisation</td>
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<tr>
<td>nm</td>
<td>nautical mile</td>
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<tr>
<td>NPT</td>
<td>1968 Nuclear Non-Proliferation Treaty</td>
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<tr>
<td>NWS</td>
<td>Nuclear Weapons State as defined by the NPT: PR China, France, Russian Federation, United Kingdom of Great Britain and Northern Ireland, United States of America</td>
</tr>
<tr>
<td>NNWS</td>
<td>Non-Nuclear Weapon State as defined by the NPT.</td>
</tr>
<tr>
<td>NSA</td>
<td>Negative Security Assurance</td>
</tr>
<tr>
<td>NTI</td>
<td>Nuclear Threat Initiative</td>
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<tr>
<td>OPPLAN</td>
<td>Operational Plan</td>
</tr>
<tr>
<td>ORP</td>
<td>Operational Readiness Platform</td>
</tr>
<tr>
<td>OSD</td>
<td>Out of Service Date</td>
</tr>
<tr>
<td>PGM</td>
<td>Precision Guided Munition(s)</td>
</tr>
<tr>
<td>PJOB</td>
<td>Permanent Joint Operating Base</td>
</tr>
<tr>
<td>PSGI</td>
<td>Public Sector Gross Investment</td>
</tr>
<tr>
<td>psi</td>
<td>Pounds per square inch</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>QRA</td>
<td>Quick Reaction Alert</td>
</tr>
<tr>
<td>RAF</td>
<td>Royal Air Force (UK)</td>
</tr>
<tr>
<td>RAAF</td>
<td>Royal Australian Air Force</td>
</tr>
<tr>
<td>RAN</td>
<td>Royal Australian Navy</td>
</tr>
<tr>
<td>RCN</td>
<td>Royal Canadian Navy</td>
</tr>
<tr>
<td>RCS</td>
<td>Radar Cross Section</td>
</tr>
<tr>
<td>RN</td>
<td>Royal Navy (UK)</td>
</tr>
<tr>
<td>RNAD</td>
<td>Royal Navy Armaments Depot</td>
</tr>
<tr>
<td>RNAS</td>
<td>Royal Naval Air Station</td>
</tr>
<tr>
<td>RUSI</td>
<td>Royal United Services Institute</td>
</tr>
<tr>
<td>RV</td>
<td>Re-entry Vehicle (of ballistic missile warheads)</td>
</tr>
<tr>
<td>SA</td>
<td>Situational awareness</td>
</tr>
<tr>
<td>SA-21 GROWLER</td>
<td>NATO designation for S-400 Triumph Surface to Air Missile (SAM) system</td>
</tr>
<tr>
<td>SAC</td>
<td>USAF Strategic Air Command (1947-1992)</td>
</tr>
<tr>
<td>SAM</td>
<td>Surface to Air Missile</td>
</tr>
<tr>
<td>SDR98</td>
<td>UK 1998 Strategic Defence Review</td>
</tr>
<tr>
<td>SDSR</td>
<td>UK Strategic Defence and Security Review</td>
</tr>
<tr>
<td>SDSR10</td>
<td>UK 2010 SDSR</td>
</tr>
<tr>
<td>SDSR15</td>
<td>UK 2015 SDSR</td>
</tr>
<tr>
<td>SLBM</td>
<td>Submarine Launched Ballistic Missile</td>
</tr>
<tr>
<td>SLCM</td>
<td>Submarine Launched Cruise Missile</td>
</tr>
<tr>
<td>SSA</td>
<td>Special Storage Area (nuclear weapons storage facility)</td>
</tr>
<tr>
<td>SSBN</td>
<td>Nuclear-powered, ballistic missile armed, submarine. It is assumed that the ballistic missiles are nuclear armed.</td>
</tr>
<tr>
<td>SSK</td>
<td>Diesel-electric submarine</td>
</tr>
<tr>
<td>SSN</td>
<td>Nuclear-powered but conventionally armed, submarine.</td>
</tr>
<tr>
<td>STOVL</td>
<td>Short Take-Off and Vertical Landing</td>
</tr>
<tr>
<td>TAR</td>
<td>UK 2013 Trident Alternatives Review</td>
</tr>
<tr>
<td>TLAM</td>
<td>BGM-109 Tomahawk Land Attack Missile, conventionally armed cruise missile.</td>
</tr>
<tr>
<td>TNW</td>
<td>Tactical nuclear weapon</td>
</tr>
<tr>
<td>TOF</td>
<td>Time Of Flight (of weapon)</td>
</tr>
<tr>
<td>TTW</td>
<td>Transition To War</td>
</tr>
<tr>
<td>TuAF</td>
<td>Turkish Air Force</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
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<tr>
<td>UAARSI</td>
<td>Universal Air Refuelling Receptacle System Installation (allows an aircraft to receive fuel from a “flying boom” equipped AAR tanker).</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
<tr>
<td>USAFE-AFAFRICA</td>
<td>United States Air Force Europe – Air Force Africa</td>
</tr>
<tr>
<td>USMC</td>
<td>United States Marine Corps</td>
</tr>
<tr>
<td>USN</td>
<td>United States Navy</td>
</tr>
<tr>
<td>USSTRATCOM</td>
<td>US Strategic Command, US major command currently responsible for US nuclear forces</td>
</tr>
<tr>
<td>V-Boat(s)</td>
<td>UK <em>Vanguard</em>-class SSBN(s)</td>
</tr>
<tr>
<td>VfM</td>
<td>Value for Money</td>
</tr>
<tr>
<td>WE.177</td>
<td>UK free-fall variable yield thermonuclear weapon family in service 1966-98.</td>
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<tr>
<td>WMD</td>
<td>Weapons of Mass Destruction</td>
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<td>WS3</td>
<td>Weapon Storage and Security System (US nuclear weapon storage vaults within hardened aircraft shelters that can hold up to four B61 series weapons)</td>
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1 - Introduction

Since CentreForum published Dropping the Bomb: A Post-Trident Future in March 2012, there have been significant developments affecting UK nuclear policy. These include:

- 2013 Trident Alternatives Review (TAR);14
- Progress on US-led NATO free-fall B61 nuclear weapon modernisation;15
- Illegal Russian purported annexation of Crimea, and Russian actions in eastern Ukraine;16
- UK moving towards an F-35B Joint Strike Fighter purchase;17
- Confirmation of further spending cuts to come in the 2015 – 2020 Parliament;18
- British American Security Information Council (BASIC) Trident Commission Report;19 and
- Liberal Democrat party policy adopted at Glasgow Conference, September 2013.20

Together, these developments make it timely to review the UK’s policy options ahead of the 2015 General Election. We will consider the impact of each change and make policy recommendations.

Strategic Backdrop

The 2010 Strategic Defence and Security Review (SDSR10)21 is predicated on the fact that UK faces no conventional symmetrical military threat. As shown in Ukraine, though President Vladimir Putin’s Russia pursues policies antithetical to western interests, Russia is not capable of projecting conventional force at range, nor is it prepared to risk a new Cold War through overt use of force in the former Soviet states that it describes as the “near abroad”.22 Further, Putin’s policy choices reflect structural Russian demographic weakness and economic over-reliance on hydrocarbons, making a new Cold War unaffordable. Hence, the SDSR10 judgement that the UK faces no conventional symmetrical military threat
holds.
Nonetheless, the case for the UK’s global interests to be covered by global expeditionary capabilities remains clear, as shown in the UK contributions to operations in Libya, support to the French in Mali, renewed operations against Islamic State in Iraq and the Levant (ISIL)\textsuperscript{23} in Iraq, and humanitarian operations in Iraqi Kurdistan and South Sudan since 2010 – in addition to on-going operations in Afghanistan. Nonetheless, continued austerity and the implementation of the cuts to the UK’s conventional forces that were outlined in the SDSR10 have left the UK with both a scale problem and a number of critical capability gaps – for example, long-range Maritime Patrol Aircraft / Multi-Mission Aircraft (MPA / MMA).\textsuperscript{24}

Rather, current geopolitical trends place a premium on the UK’s conventional expeditionary capabilities. These offer the capability to reassure our allies, work in concert with our European Union (EU) partners regionally and in the wider EU neighbourhood, to intervene in small-scale conflicts worldwide without relying on the USA, or alongside the USA in larger scale operations. In the UK’s resource-constrained environment, funds invested in Trident will come at the expense of the conventional forces. This opportunity cost means that Trident replacement needs to demonstrate that it is a better investment in Britain’s security than a similar amount split between a credible minimum independent nuclear deterrent and the UK’s conventional forces.

**US – UK Mutual Defence Agreement**

Following joint work on the US-led WWII Manhattan Project that developed the atomic weapons used against Japan in 1945, the United States Congress passed the MacMahon Act that excluded the UK and Canada from nuclear weapon developments in 1946. Following the Soviet Union’s successful launch of Sputnik and the UK’s successful thermonuclear test in 1957,\textsuperscript{25} the 1958 Mutual Defence Agreement (MDA) eased MacMahon Act restrictions on the UK. All subsequent British nuclear weapons have been based on American designs, and are constructed at the Atomic Weapons Establishment (AWE) facilities at Aldermaston and Burghfield, Berkshire.\textsuperscript{26}

Proposed for renewal until 31 December 2024 by President Obama in July 2014,\textsuperscript{27} the MDA facilitates the sharing of technical warhead information, nuclear materials and non-nuclear weapons components.\textsuperscript{28} As such, the MDA complies with Article I of the Nuclear Non-Proliferation Treaty (NPT), as MDA cooperation does not involve the transfer of nu-
clear weapons or “other nuclear explosive devices” between NPT-recognised nuclear weapons states (NWS). Consequently, the US could provide similar design assistance to the UK for a future free-fall weapon.

**Fiscal realities: continued UK austerity to 2020**

UK Budget 2014 provided confirmation that further fiscal consolidation will be required in the 2015 – 20 Parliament. Departmental current spending will fall from £317.8bn in 2014-15 to £289.1bn in 2018/19 – a 9.9% reduction in real terms over the forecast period. If, as expected, the departmental budgets of Health, Education and International Development are protected, this fall of £28.7bn in current spending will fall disproportionately on non-protected departments. Labour plans slower fiscal consolidation, but it would be very unlikely that Labour would prioritise Ministry of Defence (MoD) spending over ameliorating coalition welfare cuts. The largest of these unprotected budgets is the MoD, which accounts for 16% of unprotected current spending. This matters, as spare current spending budget could be vired to make good a capital shortfall, but further cuts to the MoD’s current spending makes any such current spending headroom unlikely.

Recent work from the Royal United Service Institute’s (RUSI) Professor Malcolm Chalmers confirms this, and demonstrates that not only is it unlikely that the UK will meet NATO’s 2% of GDP spending target in 2015/16, but that if current plans are assumed, it is unlikely that the UK will meet the 2% target in any year of the 2015 – 20 Parliament. Indeed, if another five years’ austerity cuts are imposed, the UK defence budget will fall to around 1.5% of GDP by 2020/21. This would translate into effectively a “flat cash” budget though the next Parliament, with spending in cash terms rising from £35.4bn in 2015/16 to just £35.8bn in 2020/21, some £10.8bn (23.2%) lower than the 2% NATO target implies.

Budget 2014 projects Public Sector Gross Investment (PSGI) to increase by £1.7bn (4.5%) between 2015/16 and 2019/20, but even in the unlikely event that all of this increased capital spending were provided to the MoD, it would still not be enough to cover the full costs of the Successor-class SSBNs which is expected to cost £21.5 – 29.8bn between 2016 and 2032. A more realistic scenario is that this small increase in PSGI covers the previously announced policy of a 1% increase in the MoD equipment programme in the 2015 – 20 Parliament that would add £0.3bn per annum to the MoD’s equipment budget by 2019/20. Thus, though departmental spending totals will not become clear until the 2016 Spending Review, as the Successor-class SSBN programme is likely
to consume an average of 22% of the MoD equipment budget between 2015 and 2032, it can reasonably be concluded that it will crowd out conventional elements of military capital investment.

Faced with such fiscal pressures, Trident replacement needs very careful consideration from strategic and value for money (VfM) perspectives. We will consider in detail how capable a nuclear force the UK needs in Chapter 2.

**Party Policies**

At the time of writing opinion polls continue to show a tight contest between the Labour Party and the Conservative Party in the May 2015 UK General Election; a second hung parliament and a coalition remains a distinct possibility. Consequently, it is important to consider the positions of those parties that have a serious chance of joining a coalition, or supporting a minority administration: the Green Party, Plaid Cymru / Party of Wales (PC), the Scottish National Party (SNP), the UK Independence Party (UKIP).

**Conservatives**

Conservatives have long supported like-for-like replacement of Trident. A Conservative majority government elected in 2015 would proceed with the *Successor*-class SSBN programme and commit the UK to maintaining Continuous At-Sea Deterrence (CASD) Trident operations beyond 2040. It is unclear whether three or four SSBNs would be procured, but given the attachment to CASD and the limited incremental cost of the fourth SSBN, a four-boat procurement seems most likely.

Given fiscal constraint and pressure in Conservative ranks for tax cuts, it remains unclear how a Conservative government would fund the projected modernisation of the conventional forces in the 2020s in addition to a CASD Trident force. As a result, Conservative policy increases the risk that the UK conventional forces’ post-Afghanistan modernisation needs will be unfunded, and further contraction in manpower resulting in a British Army potentially of 60,000 a more than 25% reduction from the arguably already inadequate strength of 82,000. Cuts on such a scale to pay for like-for-like Trident replacement risking the UK emulating the détente-era Soviet Union that The Economist magazine memorably lampooned as “Upper Volta with rockets”.

**Labour**

The July 2014 Labour National Policy Forum committed Labour to a “minimum, credible independent nuclear deterrent, delivered through a
Continuous At-Sea Deterrent” noting, however, that “It would require a clear body of evidence for us to change this belief.” Speaking at the General Election Campaign launch in January 2015, Ed Miliband noted that he wanted to see “multilateral disarmament. I’m not in favour of unilateral disarmament....That means we’ve got to have the least-cost deterrent we can have.”

This leaves Labour the flexibility to move away from Trident in the period between the 2015 General Election and the putative Successor-class Main Gate decision in mid-2016, probably as part of the 2015 Strategic Defence and Security Review (SDSR15) process. It is hoped that this paper provides the “clear body of evidence” that a “minimum, credible independent nuclear deterrent” need not be Trident based, and that there are alternatives that protect the UK submarine industrial base, and provide savings to recapitalise Britain’s conventional forces.

**Liberal Democrats**

At their September 2013 Glasgow conference, Liberal Democrats adopted a policy that was touted as both a “step down the nuclear ladder”, and one that would deliver major cost savings. This would be achieved through replacing the four existing Trident SSBNs with two or three Successor-class SSBNs. This smaller force (“Trident Lite”) would not adopt a CASD posture except in times of tension, and would routinely be sailed either disarmed, or with unarmed missiles.

Depending on how many Successor-class SSBNs were ultimately procured, the savings versus like-for-like replacement are estimated at £4 – 8bn through-life out of a total cost of approximately £109bn. In other words, the policy would deliver the something similar to the existing Trident capability for approximately half the time at 93 – 96% of the cost of like-for-like replacement.

However, from a potential adversaries’ perspective, these are at best disarmament baby-steps. The Liberal Democrats’ policy would allow for CASD to be resumed for periods, and would have a theoretical maximum load of 112 100kt warheads per submarine. Thus, the limiting case for a UK nuclear response is two SSBNs at sea simultaneously providing 224 independently targeted 100kt warheads accurate under optimal conditions to a Circular Error Probable (CEP) of less than 100m.
As a result, the planning assumptions of a potentially hostile power planning a nuclear strike under the Liberal Democrats proposals are scarcely different to like-for-like replacement. The fact that UK declaratory policy would not support a 224-warhead force is irrelevant; without an intrusive, on-demand, inspection regime, a potential adversary would be wise to plan against the reasonable worst-case scenario.

Worse, as that unarmed submarines may have to return to arm their missiles or be sailed in time of crisis, the Liberal Democrats’ policy would likely be escalatory in a crisis — and therefore the policy increases crisis instability as opposed to the CASD alternative. Interestingly, moving away from CASD was considered and rejected as long ago as the 1998 Strategic Defence Review (SDR98), which deemed the risk of escalation from sailing SSBNs during a crisis too dangerous. This concurs with Robert Powell’s work on crisis stability, where in a bilateral game, the greater the first strike advantage, the greater the incentive for a first strike, increasing crisis instability. Given the potential repercussions of miscalculation in a crisis, there must be a strong presumption against any policy that increases crisis instability.

Hence, though presented as a major shift, Liberal Democrat policy is neither a major disarmament step nor does it deliver major cost savings. Against non-CASD optionally-armed “Trident Lite” which is more unstable and offers very small savings, like-for-like replacement and maintaining CASD is far more attractive.

**Scottish National Party (SNP)**

The SNP currently have six MPs, and despite losing the September 2014 referendum in Scottish Independence, opinion polls suggest that it could gain more than 25 Westminster seats in the 2015 General Election, largely at the expense of the Liberal Democrats and Labour. In a close election, there are circumstances in which the SNP could hold the balance of power in Westminster. Significantly, new SNP leader and Scottish First Minister Nicola Sturgeon has ruled out a coalition with the Conservatives. Speaking at the SNP Conference in November 2014, Sturgeon has reiterated the SNP’s long-standing opposition to Trident, and if it were to be replaced, a demand the replacement not be based at HM Naval Base (HMNB) Clyde, Faslane. Though, as Hugh Chalmers and Professor Malcolm Chalmers of RUSI have demonstrated, this is technically feasible, such a relocation would cost £3 – 4bn, would take several years to accomplish and would be very difficult politically. As a result, however unlikely, a Labour – SNP coalition or a Labour minority government re-
liant on an SNP confidence-and-supply arrangement is likely to face a significant early decision on Trident.

Plaid Cymru / Party of Wales (PC)
Currently with three MPs and a realistic maximum of five in the next Parliament, Plaid Cymru may feature in a future coalition. Speaking in 2013, Leanne Wood, Plaid Cymru’s leader made clear that she opposes Trident replacement. In particular, Plaid Cymru has made clear its opposition to any option that involves relocating the SSBNs from Faslane to Milford Haven, Pembrokeshire.

UK Independence Party (UKIP)
UKIP currently has two MPs, elected in by-elections after defecting from the Conservatives. It is projected that UKIP has, a realistic maximum up to 10 seats in the next Parliament, meaning there are circumstances (e.g. significant Liberal Democrat losses and a Conservative near-majority) where UKIP could hold the balance of power in Westminster. In this case, it is most likely that UKIP would form a coalition with the Conservatives, or support a Conservative minority administration.

UKIP policy is populist and prone to short-notice changes: UKIP leader Nigel Farrage disassociated himself from the entirety of UKIP’s 2010 manifesto in January 2014, famously describing it as “drivel”. However, Farrage has also made clear that UKIP supports Trident replacement, and would presumably therefore support the Conservatives’ position of like-for-like Trident replacement maintaining CASD in a House of Commons vote.

Green Party
Currently with a single MP and the realistic maximum of three to six seats in the next Parliament, the Greens may support a Labour minority government under a confidence and supply arrangement, though they have ruled out joining a formal coalition. The Green Party have consistently opposed UK nuclear weapons in general and Trident replacement in particular, and Green Party Leader Natalie Bennett made it clear in January 2015 that the Green Party will vote against Trident renewal – and, by inference, against other nuclear weapons options. Interestingly, the current Green Party mini-manifesto mentions neither Trident nor defence issues.
Summary

To date, the Liberal Democrats have taken the most distinctive position on Trident replacement of the national parties, and in so doing, have opened up the debate in a manner that would not have otherwise happened. However, in a coalition negotiation after the 2015 General Election, Conservative and Labour positions means that the internal contradictions of Liberal Democrat policy makes compromise on it in any post 2015 general election coalition negotiations very likely.72

However, the sheer fluidity of UK politics ahead of the 2015 General Election does mean that there are credible scenarios in which there may no combination of two parties – outside a scarcely credible Conservative/Labour grand coalition – could command a working majority in the Commons. In this scenario, the Government would rely on parties that were to a greater extent anti-Trident. Under these circumstances, alternatives to Trident become much more likely.
2 - Deterrence Theory

Deterrence is as old as warfare itself; if warfare is “politics by other means” in Clausewitz’s famous formulation, then deterrence may be considered “warfare by other means”. Through the Cold War, colloquial usage linked deterrence almost exclusively to the overwhelmingly bi-polar world characterised by the Superpower nuclear confrontation, as the UK Chief of Defence Staff General Sir Nicholas Houghton pointed out in his 2014 RUSI lecture, deterrence in the broadest sense remains a key role for the UK’s conventional forces.

However, the sheer destructive potential of nuclear weapons places them in a class apart from conventional warfare. When this unprecedented destructive potential was married to essentially uninterceptable ballistic missile from the early-1960s onwards, nuclear deterrence morphed into Mutual Assured Destruction (MAD).

The UK’s nuclear forces have always been described as a deterrent, rather than a militarily useful weapon in the conventional sense; the 2013 Trident Alternative Review (TAR) describes the UK nuclear force as “a political tool of last resort rather than a war fighting capability”. It is clear that if the UK’s nuclear arsenal were used, it would be because deterrence had failed and the UK was likely to have been destroyed. Thus, though UK declaratory policy continues to allow for first-use of nuclear weapons in line with NATO’s 2012 Deterrence and Defence Posture Review, there is no evidence that the UK developed a doctrine for starting, fighting and winning a nuclear war. Instead, the focus of UK nuclear policy has been on deterring war between nuclear-armed states/alliances, through the fielding of credible nuclear forces.

This means that to assess the required capability of a future UK nuclear weapons system, we need to determine the UK’s deterrence requirement. At its core, successful deterrence is coercive: deterrence makes the cost of attacking the UK greater than the advantage to be gained from the attack. This highlights an important feature of successful deterrence: it requires the active cooperation of the presumptive oppo-
ments against whom it is targeted.\textsuperscript{82} This coercion can be overt or can amount to self-censorship: State B may “self-deter” even though State A’s deterrent position may be against State C. For instance, Pakistan may be deterred by India’s nuclear posture, even though India’s nuclear posture is ostensibly designed to deter China.\textsuperscript{83}

Seen another way, successful nuclear deterrence does not require the certainty of unacceptable loss, but with the inability of a potential aggressor to exclude the likelihood of unacceptable loss. In other words, given the level of destruction of nuclear weapons, the level of confidence required that a UK attack would succeed is actually quite low in order to deter a potential aggressor.

Finally, deterrence is distinct from pre-emption. As Sir Lawrence Freedman points out, deterrence is State A influencing State B’s decisions: pre-emption involves State A removing State B’s capacity to make decisions.\textsuperscript{84}

The success or failure of the UK’s coercion is driven by the perceptions of risk by a potential aggressor state\textsuperscript{85} the UK is attempting to deter. As a result, as BASIC’s Paul Ingram notes, “deterrence as a subject is one replete with symbolism, potential and vagueness.”\textsuperscript{86} Freedman agrees, commenting, “all deterrence-based strategies are subject to doubt.”\textsuperscript{87} This is because deterrence involves two levels of calculation: first, does the UK have the technical and operational capability to kill a large number of people and inflict severe physical damage – what the TAR refers to as “unacceptable loss”?\textsuperscript{88} – on another State? Second, does the UK have the intent to use its nuclear weapons if required to do so? We will consider each in turn; first, however, we need to briefly consider the concept and effect of extended deterrence.

**Extended deterrence**

Deterrence may be direct – British nuclear weapons deter an attack on the UK – but through the provision of security guarantees to third countries, nuclear weapons can offer them extended deterrence. Extended deterrence suffers from all the same ambiguities as direct deterrence, with the added uncertainties of whether the guaranteeing power would, in the final analysis, launch their nuclear forces in defence of a third country in a MAD world where this would guarantee their own destruction. Ultimately, it was the uncertainty of US extended deterrence guarantees that provided the strategic logic behind the British and French nuclear programmes in the 1950s and 1960s.
Since the establishment of NATO in April 1949, the UK has benefited from extended deterrence from the American nuclear arsenal under NATO’s Article V guarantee that an attack on one is an attack on all. Moreover, since the fielding of the UK’s first BLUE DANUBE atomic bombs in 1956, the UK has also been contributing to NATO’s extended deterrence to other nuclear and non-nuclear NATO Member States. These complex relationships make isolating the unique deterrent contribution of the UK’s nuclear weapons difficult. For clarity, therefore, this discussion considers the worst possible case of the UK deterrent force acting alone, with the UK not benefitting from the extended deterrence of any NATO members, especially the USA. This is an analytical artifice and should not be taken to mean that the author considers that NATO’s nuclear guarantee to the UK has no deterrent effect. Indeed, the reverse is true.

Development of UK deterrence requirement

Historically, British nuclear doctrine has defined “unacceptable loss” as the ability to have certainty of destroying a potential adversary’s most heavily defended targets. As John Ainslie’s meticulous analysis of the declassified documentation shows, UK perceptions of what constituted unacceptable loss and damage from 1962 to the late 1970s was the destruction of Moscow and the next four largest Russian cities in a demonstration of classic countervalue strategy. By demonstrating that the UK could destroy targets of its choosing, and in the process inflict unacceptable loss, the Soviet Union would be deterred from attacking the UK. As Moscow was the most heavily defended Cold War target, and most highly prized by the Soviet Union, the ability to destroy it became known as the “Moscow Criterion”. Meeting the “Moscow Criterion” became the planning requirement for successive generations of the UK’s nuclear-armed aircraft and submarine-launched ballistic missiles (SLBM).

Duff Group Report

By the late-1970s, then-Foreign Secretary David Owen was privately questioning the continuing relevance of the “Moscow Criterion”, which led to the creation of a study group under the Joint Intelligence Committee (JIC) chairman, Sir Antony Duff. The Duff Group concluded that though destruction of command centres inside and outside Moscow (Option 1) provided the optimum deterrence, destruction of Moscow, Leningrad and two other large Russian cities (Option 2), and target sets excluding Moscow (Options 3a and 3b) would provide an “adequate” level of deterrence.
The records suggest that Margaret Thatcher’s 1979 decision to purchase Trident I (C4) did not make a decision between these options; a single Trident I C4 SSBN could meet the Duff Group’s Options 2, 3a and 3b, but two SSBNs at sea were required to meet the requirements of Option 1. The 1982 decision to move to the more accurate Trident II D5 was driven by commonality with the USN, but ensuring that a single SSBN could fulfil Duff’s Option 1 targeting plan was described as “a valuable but incidental advantage”.

**What level of nuclear capability does the UK require?**

For the purposes of this paper, unacceptable loss is the Duff Group’s Options 3a or 3b. These options were designed to be sufficient to deter the Cold War Soviet Union, through an attack on the sources of Soviet power, and the means of state control. Against today’s Russia, which lacks the coercive power of the Soviet state, or against smaller or less developed nuclear states – e.g., Pakistan or North Korea – the state’s power structure is less survivable as the former Soviet Union, meaning that the amount of damage representing unacceptable loss – when deterrence is achieved – is likely to be smaller.

However, demonstrating how conservative the assumptions in this paper are, we will continue to use the Duff Group’s Options 3a or 3b. That is, deterrence will be achieved if a potential adversary does not have a high level of confidence that it can stop the UK destroying at least ten of its cities, or that it can stop the UK delivering 30 warheads to target.

**Value for Money (VfM)**

If two competing nuclear systems can meet this requirement, and in so doing, that they can inflict unacceptable loss on a potential adversary, then public sector VfM considerations dictate that the less expensive system is adopted.

**Trident II Capability**

Trident II’s Multiple Independently-targeted Re-entry Vehicle (MIRV) capability was designed in the 1980s to provide a highly survivable first strike capability against very heavily hardened targets – e.g. Intercontinental Ballistic Missile (ICBM) silos – from SSBNs for the first time. Prior to this, the inaccuracies of SLBM warheads and their comparatively small yield meant that counterforce targeting could only be delivered by USAF ICBMs with larger warheads (335kt – 9Mt) to create the necessary overpressure to guarantee the destruction of the most hardened targets. The challenge was to meet similar performance criteria to
the ICBM programme then being developed, codenamed MX. In the counterforce role, Trident II D5 SLBM combines greater accuracy (a CEP under 100m), and a much higher-yield warhead (the 475kt W88) than is required for countervalue targets.

In British service, Trident II carries an anglicised version of the 100kt W-76 series warhead. In cases of “supreme national emergency”, UK declaratory policy is to use Trident as a second-strike countervalue weapon, designed to destroy an adversary’s cities in line with the results of the Duff Group’s 1978 recommendations. At all other times, UK Trident is subordinated to NATO and the US Operations Plan 8010 (OPLAN 8010), “Strategic Deterrence and Global Strike”. As such, UK Trident is in the unusual position of being a second-strike countervalue weapon nationally, and a component of a US / NATO planning which under some scenarios retains first-strike counterforce components.

Trident II’s MIRV capability allows a single UK missile to carry up to 14 100kt deliver separate warheads to relatively closely spaced targets inside the so-called “MIRV ellipse”. In reality, therefore, a set of closely spaced urban targets could be destroyed by a single Trident missile delivering fewer warheads to a greater range of targets.

Figure 1 shows a single Trident missile delivering one to three 100kt UK Trident warheads against Bedford, Bletchley, Milton Keynes, Northampton, Rugby, Coventry, Solihull, Birmingham, Dudley and Wolverhampton. Before the fallout, fire or wider humanitarian effects are considered, such a single-missile attack is estimated to cause 1.00m fatalities and 2.37m injuries as well as widespread physical destruction. MIRVs therefore significantly increase the number of countervalue targets that can be held at risk by a Successor-class SSBN.
Figure 1: Hypothetical single Trident SLBM max-MIRV targeting example: Wolverhampton to Bedford

Note: attacks are by UK W76 variant 100kt warheads airburst at 4,750ft in order to maximise the 5-psi overpressure area.

Key:
- Inner ring (Yellow): Fireball: radius 380m;
- Second ring (Green): 500 rem radiation dose: radius, 1110m;¹¹⁷
- Third ring (Grey): 5-psi airblast: radius, 3260m;¹¹⁸
- Fourth (Orange): Third degree burns due to thermal radiation: radius 4380m;¹¹⁹

Source: CentreForum analysis based Alex Wellerstien’s Nukemap 2.42 model.¹²⁰
Most large urban areas would suffer unacceptable damage with two to six 50kt warheads. Figure 2 shows the effect of such an attack in London. In this example, it is estimated that there would be 0.51 million deaths and 1.20 million injuries, as well as widespread destruction. More densely populated cities would have proportionately higher casualties: the same six 50kt warhead attack on Karachi is estimated to kill 1.86 million and leave 3.92 million injured. Realistic fear of losses on anything like this scale would be unacceptable to all rational governments, resulting in deterrence being achieved. As a result, *Successor*-class SSBN’s Trident-delivered ability to destroy a minimum of eight cities with 14 100kt warheads each is a gold-plated solution that clearly overmatches the UK’s deterrence requirement.
If Trident were no more expensive than the alternatives and/or the UK was fiscally unconstrained, this gold-plated overmatch of the deterrence requirement is arguably immaterial. However, in a period of continued fiscal retrenchment, public sector VfM considerations require policymakers to find the most cost-effective method of achieving the UK’s minimum deterrent requirements, rather than selecting a gold-plated option that significantly exceeds the requirement. Where the cost differences are great, this places a heavy burden on those proposing a system that overmatches the requirement to prove this overmatch represents VfM.

**Would the UK actually use its nuclear weapons?**

Deterrence needs to be backed by the credible threat that the *capability* to inflict disproportionately severe physical damage to any advantage an adversary could gain is matched by the *willingness* (intent) to use it if challenged. At minimum, deterrence theory demands that a potential adversary cannot plan on the UK not using its nuclear weapons. This “will they/won’t they” conundrum remains the biggest weakness in nuclear deterrence: no amount of theorizing, sabre-rattling or bluff-calling will eradicate this dimension from the calculation, which is why it is so important to minimise the risk that potential adversaries may think that the UK is bluffing. However, without a realistic acceptance that the UK could use its nuclear weapons in extremis, deterrence must fail.

This position is in line with the ICJ’s 1996 Advisory Opinion that could not reach a conclusion on the legality of the use of nuclear weapons “in an extreme circumstance of self-defence, in which [the State’s] very survival would be at stake.” However, Freedman is clearly right to describe “powerful inhibitions” against the unimaginable consequences of the use of nuclear weapons are taboo against their use and it is not unreasonable to think that taboo is even greater than that for biological or chemical Weapons of Mass Destruction (WMDs). Not only did this frustrate Eisenhower’s Secretary of State John Foster Dulles, under whose aegis the Administration fruitlessly sought an opportunity to use nuclear weapons in order to normalise their use, but it also suggests the emergence shortly after WWII of a strong international norm against the use of nuclear weapons.

For the UK, a combination of declaratory policy, actual deployment and regular, rigorous and realistic exercise policy provides the best possible signalling that the UK is ready, willing and able to use its nuclear forces if the need arose. This consistently high level of operational readiness demands the highest level of political support and financial priority; it
is much to the credit of the RAF that it maintained the V-Force\textsuperscript{132} Quick Reaction Alert (QRA) from 1 February 1962 – 30 June 1969\textsuperscript{133} and to the RN that has maintained uninterrupted the Continuous At-Sea Deterrent (CASD) patrols for more than 45 years as since 1 January 1969.\textsuperscript{134} Since the SDR98, the UK Trident SLBMs are de-targeted, and are held at “several days” notice to fire.\textsuperscript{135}

Whatever system the UK ultimately selects to replace the existing Trident force, the UK will continue to rely on similar public and rhetorical steps to demonstrate that the UK is prepared, willing and able to use its nuclear forces if the situation demands it.

**What is a credible minimum UK nuclear posture?**

In considering alternatives, the TAR took as its notional requirement the ability “to deliver at short notice a nuclear strike against a range of targets at an appropriate scale and with very high confidence” during a crisis.\textsuperscript{136} Insistence on “very high confidence” of a successful UK strike is problematic because as we have already seen, it is unnecessary to deter an aggressor state by leaving the defender with a little or no hope of preventing unacceptable loss. “Very high confidence” is therefore a gold-plated requirement overmatch, and should be replaced with the requirement that a potential aggressor has a low certainty that they will be able to prevent unacceptable loss.

Revising the requirement in this way places an altogether different complexion on the requirement for a credible UK nuclear posture. No longer does the Moscow Criterion require the UK to saturate and defeat the Soviet capital’s ABM defences; normalising the requirement in line with the thinking behind the Duff Group’s Options 3a and 3b means that nuclear systems with considerably less capability than Trident are sufficient to deter Russia (and any other potential aggressors) from attacking the UK.

A credible minimum UK nuclear deterrent system would be capable of delivering with reasonable confidence unacceptable loss on a potential adversary, defined as the destruction of ten or more cities, or delivering 30 warheads at 72 – 96 hours’ notice in a crisis. UK posture should demonstrate readiness through no-notice exercises, and other means such as declaratory statements that show political commitment to the on-going nuclear deterrent posture. The UK should also make clear that though the UK nuclear weapons remain in the TAR’s words “a political tool of last resort rather than a war fighting capability”\textsuperscript{137}, the UK would use its nuclear weapons in an explicit countervalue strategy against other nuclear weapons states (NWSs) worldwide if the situation demands it.
Finally, UK nuclear doctrine should be backed by a declaratory policy stressing the UK’s continuing commitment to negative security assurances (NSAs) for Non-Nuclear Weapons States (NNWS) that comply with International Atomic Energy Agency (IAEA) Safeguards Agreements. The UK’s policy to move NWS to legally binding NSAs for NNWS is correct, and should continue. Ultimately, if agreement is not possible, the UK should consider legally binding NSAs on a unilateral basis if necessary.
3 - Critiquing the Trident Alternatives Review

Published in July 2013, the Trident Alternatives Review (TAR) considered a range of alternatives to like-for-like replacement of CASD Trident. These included changes to the warhead and delivery system (i.e. replacing Trident with another nuclear system) and the readiness state (i.e. moving away from a continuous readiness state either with Trident or with another nuclear system).

The most useful element of the TAR is its reconsideration of the “unacceptable loss” notion at the heart of deterrence theory, by accepting that the absolute level of damage to deliver unacceptable loss will vary from adversary to adversary. In doing so, it accepts that the “Moscow Criterion” does not prescribe an absolute level of destructive capability. Further, nuclear weapons are explicitly reserved for nuclear states’ targets that cannot be held at risk by UK conventional capabilities. Crucially, this means that deterring non-P5 states’ less well-defended targets, a lower level of capability than Trident offers would still provide a sufficient threat that the deterrent effect would be achieved.

Four TAR Analytical Failings

Given that a major reason for considering alternatives to Trident is to reduce the costs, the “Costs” section of the TAR is critical. As published, four analytical failings fundamentally undermine this section of the TAR’s analysis.

Free fall costings

First, the JSF / modernised WE.177 free-fall bomb option that is referenced elsewhere in the TAR is excluded from the cost comparator Chart A; the only JSF option shown is for JSF carrying a yet-to-be developed supersonic cruise missile. It is assessed that this curious omission is because a JSF / modernised WE.177 free-fall bomb option would be available before the Vanguard-class SSBN out of service date (OSD), meaning
that two *Successor*-class SSBNs would not be required.

This is critical. As the TAR notes, “It is the need for these 2 *Successor* SSBNs that makes the cost of the alternatives more expensive overall than a 3 or 4-boat *Successor* SSBN fleet”. In other words, these two SSBNs are the key cost driver of the non-Trident alternatives. Thus, if a modernised WE.177 free-fall bomb option could be available before *Vanguard*-class OSD, the TAR implicitly accepts that this option would be much cheaper than the *Successor*-class based alternatives.

It is therefore hard to escape the conclusion that the costs of a JSF / modernised WE.177 free-fall bomb option was omitted to avoid the embarrassment of having a much cheaper alternative to *Successor*-class SSBNs being shown in the TAR. This raises serious questions about the impartiality of the rest of the TAR’s analysis. To overcome these concerns, CentreForum would welcome publication of an updated TAR Chart A including the JSF / modernised WE.177 free-fall bomb option costed on the same basis as the other options.

**Alternative warhead timelines and costs**

Second, the TAR studiously avoids detailing how long it would take AWE to produce a modernised WE.177 free-fall bomb. Instead, the TAR provides a figure of 17 years to design, develop, certify and produce a ballistic missile-based thermonuclear warhead if one were required, and 24 years for a similar process for a cruise missile.

Austere post-WWII Britain developed and constructed the infrastructure to enrich uranium, separate plutonium, design and manufacture an atomic warhead from scratch in six years (1946 – 52), and went on to develop a thermonuclear weapon in a further three years (1954 – 57). Against a backdrop where the UK has more than 60 years’ experience with the design, construction and deployment of nuclear weapons, long-standing interchange relationship with the US nuclear weapons community, has the separated fissile material, and currently spends approximately £1bn annually on the AWE, the implied TAR timelines for a free-fall weapon are not credible.

The TAR’s concession that these timescales could be shortened if it was “driven as a UK national imperative” is revealing, begging the question under what circumstances would a new warhead design be required and this fact not constitute a “national imperative”? What the TAR fails to explore however, is just how much shorter this timescale could be and how much this trade-off would cost. For example if pressing forward with a new warhead more quickly increased the cost by 50% to £12 – 15bn
but it meant that two *Successor*-class SSBNs were not required, such a new warhead option would still constitute a net saving over the non-Trident options.

Taken together with the TAR’s failure to outline how long a modernised WE.177 would take to produce, this failure to provide a sensitivity analysis over cost versus time for a new warhead means that these choices cannot be tested, significantly undermining the TAR’s value.

**Free-fall aircraft fleet requirements**

Third, the TAR’s only costed JSF option is predicated on purchasing an additional 36 F-35 JSFs dedicated to the nuclear mission at an additional capital cost of more than £5bn. The TAR adduces no evidence to explain why the UK would not or could not repeat previous RAF and RN practice of operating dual-role (i.e. aircraft capable of both nuclear and conventional missions) strike aircraft dating back to 1956. Dual-role platforms maximise VfM by effectively allowing the nuclear mission to free-ride on the capital investment of the conventional strike platform.

Taken together, failings two and three suggest that *contra* the TAR, it should be possible to bring a free-fall weapon into service before the Vanguard-class OSD. In doing so, the UK would avoid unnecessary SSBN construction. On the TAR’s own analysis, the removal of the need to build two *Successor*-SSBNs and using dual-role F-35Cs will be substantially cheaper than any Trident-based Vanguard-class replacement.

**Free-fall bomb choice**

Fourth, the TAR bases its free-fall bomb analysis on the modifying and modernising the existing UK WE.177 design rather than on the forthcoming US B61 Mod 12 (B61-12) free-fall bomb design. The inclusion of a “WE.177 updated to modern safety standards” as the free-fall comparator in the TAR indicates a high level of confidence that the UK could manufacture a modernised WE.177. As the TAR notes, the WE.177 design would need to be updated; additionally production lines for both the weapon’s nuclear and non-nuclear components would need to be recreated.

However, it is striking that the TAR omits any mention of the B61-12 programme, or the impact that the availability of the B61-12 would have on the UK’s non-Trident options. This could be the result of a lack of certainty when the TAR was conducted that the B61-12 programme would proceed. However, the impact on UK options is so great that the TAR should have included an explanation for omitting the B61-12 from its attenuated
free-fall options analysis.

Fully funded for US Fiscal Year (FY) 2015 on 17 January 2014\textsuperscript{152} the B61-12 will be the US-provided free-fall bomb for the NATO Dual Capable Aircraft (DCA) nuclear burden-sharing programme from the early 2020s. Ultimately, some 200 B61-12s are expected to be based in Europe for the NATO DCA programme.

However, \textit{contra} the TAR, it does not follow that a modernised WE.177 is the optimal choice for a future UK free-fall weapon. There are three considerations:

1. First, the B61-12 is entering production, and will not need modernisation to meet current US / NATO safety standards;

2. Second, a decision to replace Trident with a free-fall bomb is explicitly intended to maximise savings. B61-12 offers two large areas for savings:
   a. In-production non-nuclear components, which the UK could purchase\textsuperscript{153} reducing costs for both the UK and US / NATO programmes;
   b. Integration of B61-12 onto F-35A is scheduled from 2015, with the JSF’s family commonality significantly reducing the costs to integrate onto F-35C. A modernised WE.177 would need to start F-35C integration from scratch;

3. Third, it is not clear that the WE.177 series’ comparatively portly diameter of 16.5 inches\textsuperscript{154} would fit within the F-35A/C’s internal weapons bay designed around the 13-inch diameter AGM-154 Joint Standoff Weapon (JSOW).\textsuperscript{155} The F-35A/C’s bays will comfortably accommodate the 13.3-inch diameter B61-series bombs\textsuperscript{156}, so whilst it may be possible to slim the UK’s WE.177 design by 3.2 inches to fit the F-35A/C weapons bay, doing so imports significant unnecessary temporal, financial and engineering risk into the programme.\textsuperscript{157}

The B61-12 programme costs are known: a production run of approximately 480 weapons\textsuperscript{158} will cost approximately $10-12bn, or a maximum of $25m each.\textsuperscript{159} For the purposes of our analysis, it is assumed that 100 UK B61-12 bombs would be limited to a ceiling price of twice their American counterparts, or $50m per weapon for a total of £3.0bn. This is less than half the £8 – 10bn price range that the TAR suggests for a new warhead.\textsuperscript{160}

Assuming that B61-12 technical data and non-nuclear components are available to the UK via the established MDA procedures, B61-12 provides
a lower-risk, quicker and cheaper route to a future UK free-fall weapon than a national attempt to modernise and redesign the WE.177 design for internal carriage on UK F-35Cs.\textsuperscript{161}

**Summary**

The TAR’s analysis of free-fall options is fundamentally flawed. Instead, we will consider whether a dual-role F-35C carrying a B61-12-based UK free-fall bomb could meet the UK’s deterrence needs measured against the Duff Group deterrence criteria, and enter service before Vanguard-class OSD, allowing for the cancellation of the Successor-class, creating significant savings.
4 - F-35 Lightning II Joint Strike Fighter

Figure 3: F-35C Lightning II landing aboard USS Nimitz

Source: US Navy.

The UK has ordered the F-35B Lightning II (F-35C illustrated at Figure 3, above) as its principal future manned strike aircraft, replacing Panavia Tornado GR4s in Royal Air Force (RAF) service. As the only Tier 1 Partner, the UK occupies a unique position in the JSF programme, which has seen the UK invest more than $2.5bn since the JSF programme began in 1995 in return for guaranteed UK workshare and UK involvement in aircraft selection. With four aircraft delivered and 14 aircraft on order, the UK currently expects to operate a total fleet of up to 138 F-35s. The F-35 Joint Strike Fighter programme is a family of low observable (LO, "stealth") manned strike aircraft with distinct versions developed for the
US Air Force (USAF), US Navy (USN) and US Marine Corps (USMC). These comprise the USAF’s F-35A land-based variant, the USMC’s F-35B Short Take-Off / Vertical Landing (STOVL) “jump jet” variant for shipboard and improvised runway use, and the USN’s F-35C Catapult Assisted Take-Off But Arrested Landing (CATOBAR) aircraft carrier variant. Cost savings will come from the large numbers ordered, and the high degree of commonality between the three variants.

Both the RAF and the Royal Navy’s (RN) Fleet Air Arm (FAA) will operate F-35s in UK service. Unlike the USA, the UK will use a single JSF variant from both land-bases and from the new Queen Elizabeth-class aircraft carriers. This decision should reduce the UK’s through-life costs when compared to operating more than one variant, but it means that the JSF variant choice is driven by the design of the Queen Elizabeth-class carriers. The Queen Elizabeth-class carrier design itself is flexible, capable of configuration as either a conventional CATOBAR carrier with an angled flight deck, catapults and arrestor gear, or with a ramp for STOVL operations without catapults or arrestor gear. However, in STOVL configuration, Queen Elizabeth-class is limited to operating STOVL aircraft and helicopters only.

When initially ordered in July 2007, both Queen Elizabeth-class carriers were configured for STOVL operations with the UK purchasing the F-35B for the RAF and the FAA. SDSR10 opted to convert the second ship to CATOBAR configuration carriers to operate the cheaper but more capable F-35C and constructing and immediately mothballing the first ship, which was too late in-build to for easy conversion to CATOBAR configuration. This was also driven by the SDSR10 decision that the UK would only operate one of the two Queen Elizabeth-class carriers.

In an embarrassing May 2012 volte-face, the UK Ministry of Defence (MoD) concluded that converting the second carrier to operate the F-35C would prove unaffordable at a cost of £2bn, and instead it would construct both carriers in STOVL configuration. Concurrently, the UK MoD changed the JSF order back from the F-35C to the less capable but more expensive F-35B. These decisions unnecessarily increased the Queen Elizabeth-class carrier programme cost by at least £74m.

**F-35 Stealth Characteristics**

Lockheed Martin, the F-35’s manufacturer defines LO (“stealth”) capability as “the ability to evade detection by radar, infrared (IR) sensors or emission interception... [s]tealth provides greater survivability and access.” Interviewed in 2014, the USAF Chief of Staff opined that stealth
technology “is the price of admission into the fight” as the “lethal envelope of advanced air-defense (sic) systems continues to grow against [existing] aircraft.” In other words, the proliferation of radar guided and cued advanced surface-to-air missiles (SAMs) means that attacks by existing non-stealth aircraft would result in unacceptably high losses; stealth is one approach to overcoming the threat posed by such weapons.

LO comes from carefully shaping the aircraft to reduce its radar cross-section (RCS), using radar absorbing materials, and through the fusion of hostile threat data to increase tactical situational awareness (SA). To keep the RCS as low as possible for missions in high-threat areas, F-35s carry weapons, extra fuel and electronic warfare equipment internally; in previously designs, these items typically were carried on wing pylons. The use of external fuel tanks, pylons and weapons significantly increases RCS, meaning that this would only occur when the need for stealth had been removed, e.g. through the degradation or destruction of enemy air defences. Consequently, in assessing whether the UK could credibly rest its deterrence posture on a free-fall bomb carried by F-35C, this paper assumes that any mission would be conducted on internal fuel and carrying weapons internally to ensure that the lowest possible RCS – and therefore highest possible survivability – was achieved.

F-35B Development Problems

The F-35B has suffered from weight problems throughout its development, and by 2004 was 3,000 pounds overweight – fully 9.3% of the aircraft’s empty weight. Initially, all three variants had common internal weapons bays, but one of the trade-offs made in successfully reducing the F-35B’s weight by 2,700 pounds was the decision to shorten its internal weapons bays. This means that the F-35B’s weapon bays are not only too small to carry 2,000lb class UK Precision Guided Munitions (PGM), but they are also too short for internal B61-12 carriage.

Therefore, in order to have a credible free-fall option from F-35, the UK will need to use either the F-35A or F-35C. In the interests of RAF and FAA commonality, it makes sense to operate the F-35C from land bases and to convert both the new Queen Elizabeth-class carriers to CATOBAR configuration to operate it. F-35C also delivers sustained through-life savings, as the MoD estimated in SDSR 10 that replacing the complex STOVL F-35B with the simpler – but more capable – F-35C would have reduced through-life costs by approximately 25%.
Does an F-35C nuclear force require additional aircraft?

There is no reason why an F-35C nuclear force will require more than the 138 F-35 airframes the UK is already planning to buy. The attenuated TAR discussion of the free-fall option is based on acquiring an additional 36 dedicated airframes for the nuclear mission at an additional cost of £5bn. As discussed on page 34, given that the RAF’s Tornado GR1 squadrons were equipped with the WE.177 as part of their core dual-role mission set, this paper sees no case for dedicated nuclear-armed F-35Cs. All 138 planned F-35Cs would be equipped for the nuclear role, and aircrew trained for the nuclear mission as part of their normal training, in line with existing NATO DCA training.

F-35C as an RAF or FAA asset?

The major operational distinction of an F-35C force compared with an F-35B force would be the additional training requirement for CATOBAR carrier landings, leading to a strong presumption in favour of dedicated FAA squadrons. Whereas CATOBAR operations have always incurred a significant additional training requirement versus land-based operations, STOVL operations can provide the impression that large amounts of embarked time are not required, and that land-based squadrons can simply “plug in”, quickly assimilating to naval operations and life afloat.

Senior RN officers robustly dispute this sunny characterisation. They point out that whilst an Afghanistan focus for the common RAF / FAA Harrier GR7/9 force known as “Joint Force Harrier” (JFH) was understandable, JFH reflected RAF priorities. This led to sometimes-fractious inter-service debates resulting from JFH’s limited time embarked aboard the Invincible-class carriers. These limited duration embarkations meant that there was serious degradation in both aircrew experience of carrier operations, and of RN fleet expertise of how to integrate carrier aviation successfully with a naval task force. This is especially true of operations at night and/or in adverse weather conditions.

Dedicated RAF and FAA F-35C squadrons would also reflect subtle but important differences in their operational role. For example, though all UK F-35Cs will be tasked for conventional and nuclear strike, the FAA’s F-35Cs will additionally fulfil a Fleet air defence (AD) role – an entirely separate skill set to conventional and nuclear strike, which the RAF perform with the AD–optimised Eurofighter Typhoon F2/FGR4 fleet. Combined with the need for specialist naval operations skill sets, this strongly suggests that FAA should operate its own fleet of F-35Cs, with the potential for a surge capability from suitably trained RAF F-35C aircrew.
Under this paper’s proposals, the F-35C aircraft would be common, with common maintenance procedures and standard and RAF / FAA weapon fits tailored to their operational requirements. Indeed, cycling airframes between land-based and carrier-based operations is essential to evening out the greater fatigue inherent in carrier operations across the fleet. Beyond common core F-35C training, however, RAF and FAA operations would be quite distinct, reflecting their different operating environments and tasking requirements.\textsuperscript{182}

It is unclear from the SDSR10 papers how the FAA intended to train air-crew in conventional carrier landings when the decision to convert the Queen Elizabeth-class carriers to CATOBAR configuration was made. Two possible routes suggest themselves: first, copying the practice of the French Navy, to send trainees to the USN for advanced training and carrier-landing training\textsuperscript{183}; second, to acquire a carrier-capable jet trainer such as the Boeing / BAE Systems T-45C Goshawk\textsuperscript{184} and conduct the training in the UK. The lack of clarity from MoD in SDSR10 suggests that this decision had not been taken, but given the capital costs of T-45Cs and the small number of steady-state trainees, this paper assumes training would be contracted to the USN.

Given the Queen Elizabeth-class’s nominal capacity of 36 F-35Cs, it would be reasonable to project an FAA establishment of 60 airframes (48 frontline), leaving 78 airframes (62 frontline) for the RAF.\textsuperscript{185} Given the historic differences in fast-jet squadron sizes between the RAF and the FAA, these allocations would be sufficient for both the RAF and FAA to form five operational squadrons and a training unit.\textsuperscript{186}
5 - A 21st century UK nuclear force

NATO Dual-Capable Aircraft (DCA) Programme

In the post-Cold War era, approximately 180 B61s\textsuperscript{187} are the only American nuclear weapons still deployed in Europe.\textsuperscript{188} Aside from British and French national nuclear forces, NATO’s B61-equipped Dual-Capable Aircraft (DCA) provide NATO’s only nuclear burden-sharing with the USA. As tactical nuclear weapons initially designed for attacking invading Warsaw Pact armoured forces, questions have been raised about the cost\textsuperscript{189} and the military utility\textsuperscript{190} of NATO’s current DCA mix of B61 Mod 3 (B61-3) and B61 Mod 4 (B61-4) weapons\textsuperscript{191} in a post-Cold War world.\textsuperscript{192} It is important to set out why the 2012 Chicago NATO Summit agreed to continue the DCA programme.\textsuperscript{193}

A major driver for renewing the DCA programme are the security concerns of Baltic and central and eastern European “New NATO” member states.\textsuperscript{194} “New NATO” members are debarred from hosting NATO nuclear weapons themselves under the 1997 “Founding Act on Mutual Relations, Cooperation and Security between NATO and the Russian Federation”.\textsuperscript{195} Given increased Russian adventurism (e.g. in Ukraine), these states have a particular interest in NATO’s nuclear-backed Article V guarantee. Hence, B61-equipped DCA provides a tangible evidence of NATO’s nuclear guarantee, as well as a political signalling tool of intent and nuclear burden-sharing.

It is for this combination of reasons that Chicago’s 2012 NATO Summit agreed to continue the DCA programme with the enhanced B61-12.\textsuperscript{196} Integration of the new B61-12 as an unguided weapon is scheduled to begin on existing NATO DCA aircraft in 2015 for completion in 2017/18.\textsuperscript{197} In the early 2020s, the B61-12 will directly replace the current DCA mix of B61-3 and B61-4 weapons. B61-12’s precision capabilities require integration with the F-35’s digital avionics, or the creation of a bespoke aircraft to weapon interface adaptor.\textsuperscript{198}
Over the medium-term, NATO DCA faces an equipment challenge. With the exception of Germany’s Tornados, all of the DCA Lockheed Martin F-16 Fighting Falcons and Tornados are due to be retired over the next decade. The calculation is simple: if the DCA mission is to continue, their replacements must be nuclear-capable. For all DCA states bar Germany, the replacement aircraft will be the F-35A. Currently, the USAF is locked in a political battle over funding the $350m integration cost by 2018/19. US opposition to funding the F-35 modifications derives from the perception that NATO allies are not willing to share that burden.

**NATO DCA Implications for the UK**

As it is key to continuing the NATO DCA programme, B61-12 is almost certain to be integrated onto F-35A. Currently, there is no public USN requirement for integration of B61-12 onto the F-35C, but given the commonality between the F-35A and F-35C variants, previous integration of B61-12 on to F-35A should significantly ease B61-12 integration on F-35C. From a weapons integration perspective the F-35A and F-35C have more in common with each other than either has with the F-35B due to the F-35B’s smaller weapons bays. As the B61-12 cannot be carried internally on the F-35B due to these smaller bays, it is unlikely the USMC’s F-35B will be certified for the nuclear mission for fear that external carriage would compromise the aircraft’s stealth qualities.

The position of Germany also matters to the UK. If Germany eventually were to certify its Eurofighter Typhoons for the DCA mission, this would immediately open the possibility of certifying similar British, Italian and Spanish aircraft for B61-12 carriage. Coupled with F-35C nuclear certification, this could increase UK flexibility by having both of its major combat aircraft nuclear certified, providing significant redundancy in the unlikely event that one or other fleet were to be grounded.

**B61-12 storage**

It was estimated in November 2014 that that NATO DCA was equipped with approximately 180 B61s, stored in Weapon Storage and Security System (WS3) vaults at Kleine Brogel, Belgium; Büchel, Germany; Ghedi Torre, Italy; Volkel, Netherlands and Incirlik, Turkey, as shown in Figure 4. Table 1 details estimated NATO DCA B61 holdings.
Figure 4: NATO DCA bases and proposed storage facilities

Table 1: Estimated Current NATO B61 deployment

<table>
<thead>
<tr>
<th>Base</th>
<th>Estimated deployed B61s</th>
<th>WS3 storage capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Büchel, Germany</td>
<td>10 – 20</td>
<td>44</td>
</tr>
<tr>
<td>Ghedi Torre, Italy</td>
<td>10 – 20</td>
<td>44</td>
</tr>
<tr>
<td>Kleine Brogel, Belgium</td>
<td>10 – 20</td>
<td>44</td>
</tr>
<tr>
<td>Volkel, Netherlands</td>
<td>10 – 20</td>
<td>44</td>
</tr>
<tr>
<td>Total NATO DCA</td>
<td>60 – 70*</td>
<td>176</td>
</tr>
</tbody>
</table>

*Upper and lower bounds assuming that July 2009 NATO briefing figure of 180 weapons made by US Principal Deputy Under Secretary of Defense for Policy Jim Miller is correct, along with the USAFE-AFAFRICA holdings.

Table 2: Estimated Current USAFE-AFAFRICA deployment

<table>
<thead>
<tr>
<th>Base</th>
<th>Estimated deployed B61s</th>
<th>WS3 storage capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviano, Italy</td>
<td>50</td>
<td>72</td>
</tr>
<tr>
<td>Incirlik, Turkey†</td>
<td>60 – 70</td>
<td>100</td>
</tr>
<tr>
<td>Lakenheath, UK²¹</td>
<td>0</td>
<td>132</td>
</tr>
<tr>
<td>Total USAFE-AFAFRICA</td>
<td>110 – 120</td>
<td>304</td>
</tr>
</tbody>
</table>

† No Turkish AF units are currently DCA-declared or DCA-certified. These 60 – 70 B61s are notionally USAFE-AFAFRICA weapons, though there are no USAFE-AFAFRICA nuclear capable aircraft assigned to Incirlik. It is assessed that c. 20 are notionally assigned to TuAF F-16s under DCA, with the remainder assigned to non-USAFE-AFAFRICA USAF units temporarily assigned to Incirlik.
Additional B61s are based in Europe for use by USAF Europe – Air Force Africa (USAFE-AFAFRICA) units. Table 2 details estimated USAFE-AFAFRICA holdings.

There are concerns about the security on some of the allied airbases; a 2008 USAF review discovered that “most [overseas] sites require significant additional resources to meet [Department of Defense] DoD security requirements”. This assessment was underlined by peace activists gaining entry to the specially-equipped nuclear-capable hardened aircraft shelters at Belgium’s Kleine-Brogel air base (AB) and the Netherlands’ Volkel AB. Together, these security lapses led to the USAF requesting $154m for security enhancements at DCA bases in FY2015, underlining the importance the US attaches to NATO nuclear burden-sharing, especially in light of President Obama’s “pivot” to the Pacific.

Combined with continuing controversy over the DCA mission and concerns about weapon security, the Belgian, German and Dutch governments have formally asked NATO to remove the weapons from their territory. Some US commentators have expressed concern that concentrating the B61s at a single European site would lead to pressure on the sole host government to withdraw the weapons, ending European B61 deployment and with it, effective NATO nuclear burden sharing through DCA.

To address this, leading American analyst Dr Jeffrey Lewis has proposed that all DCA B61s should be centralised at two USAFE-AFAFRICA facilities at Incirlik AB, Turkey and at Aviano AB, Italy. This would leave B61-4 Type 3E training aids in place on the other operational bases allowing DCA units in Europe to use training aides to maintain operational effectiveness for the DCA mission; live weapons would only be distributed to DCA bases as part of a graduated crisis response during a transition to war (TTW).

However, both Incirlik’s distance from the active DCA bases, its proximity to war-torn Syria and an unstable Middle East together with questions about whether TuAF units would return to DCA operations club make it a sub-optimal B61-12 storage site. By contrast, RAF Lakenheath, Suffolk, is closer to the DCA operational bases for ease of transport, and further from the Middle East. Between them, Lakenheath (132) and Aviano AB, Italy (72) are already equipped with sufficient WS3 capacity to accommodate the European deployment of 200 B61-12s.

The US Department of Defense’s (DoD) January 2015 European Infrastructure Consolidation plan confirmed that Lakenheath would be host the initial USAFE-AFAFRICA deployment of 48 F-35As in 2020. Given
that the current European B61 stockpile services both NATO DCA and USAFE-AFRAFRICA requirements, the F-35A’s Lakenheath deployment provides an added strategic rationale for redeploying the B61s to Lakenheath from Belgium, Germany, the Netherlands and Turkey.

Offering to co-host NATO’s DCA B61-12 European stockpile with Italy offers two benefits to the UK. First, it demonstrates the UK’s commitment to NATO nuclear burden sharing beyond the UK’s independent nuclear deterrent, and provides the Italian government with tangible evidence that a major NATO and EU partner was taking the same risks as they were. Second, it provides a direct case of the UK helping Belgium, Germany and the Netherlands deliver an important domestic policy.

Anglicised UK B61-12 free-fall bomb on F-35C

Using the B61-4 warhead, the B61-12 will offer selectable yields ranging from 0.3kt to 50kt, with the maximum yield being approximately three times the power of the bomb that destroyed Hiroshima and half the maximum yield of the existing UK Trident warhead. However, the required yield to destroy a target is inversely related to the accuracy of the weapon: the more accurate the weapon, the lower the required yield to achieve the same level of damage.

The B61-12’s guidance kit will improve its accuracy from the circa 100m CEP of legacy B61s to between 5 – 30m CEP, which allows the B61-12’s 50kt warhead to achieve the same effect on buried or hardened point targets as the less accurate 360kt B61 Mod 7 (B61-7). In this, the B61-12 repeats the USAF experience in replacing the relatively inaccurate 9Mt yield B53 bomb with the more accurate 440kt earth-penetrating B61 Mod 11 (B61-11) in the free-fall “bunker buster” role to destroy heavily buried, hardened targets.

As the B61-7’s yield is more than triple the UK Trident warhead with the two systems having similar accuracy, the implication is that the number of types of target that are currently capable of being destroyed by UK Trident but which would be impervious to a successfully delivered UK B61-12 is limited. In reality, it may be close to zero.

UK Basing Options

Current UK F-35B deployment plans will base the aircraft at RAF Marham, Norfolk when not deployed on the Queen Elizabeth-class carriers. Coincidentally, Marham was the last operational base for the WE.177 free-fall nuclear bomb, and was equipped with 24 US-designed WS3 nuclear storage vaults in each of Marham’s hardened aircraft shelters (HAS).
Though the vaults were decommissioned in 1998 with the retirement of the WE.177 free-fall bomb, the HASs have remained in continuous service, and it has been suggested that the WS3s could be reactivated relatively easily.\textsuperscript{238}

Given the limited weapon storage capacity at the AWE, the Special Storage Areas (SSAs) – nuclear weapons dumps – at RAF Honington, Suffolk and RAF Marham, Norfolk have both been used for nuclear weapon storage after the withdrawal of WE.177 for periods since 2000.\textsuperscript{239} This relatively recent use provides confidence that both SSAs are – or could be made – serviceable at limited cost.

There are no declared SSAs at HMNB Portsmouth, meaning that operations aboard the \textit{Queen Elizabeth}-class carriers would require the delivery of weapons by convoy from Marham prior to deployment. For training purposes, live weapons would rarely be flown; in common with the existing DCA programme, routine flight training would be conducted with inert training dummies.

Retiring Trident would also result in the removal of the \textit{Vanguard}-class SSBNs from HMNB Clyde (Faslane) and the closure of the Trident warhead storage area at RN Armament Depot (RNAD) Coulport. Unless there were subsequent developments to equip Lossiemouth-based Typhoons with B61-12, the effect of this proposal would be to remove nuclear weapons from Scotland.
**6 - A UK 21st century free-fall nuclear force**

What would a UK free-fall option mean operationally? It is clear that a free-fall system would be less capable than Trident because it would:
- Be more vulnerable than the practically invulnerable *Vanguard*-class SSBNs;
- Be shorter-ranged;
- Have lower maximum yield than Trident;\(^{240}\) and
- Have longer deployment timelines.

Vulnerability and range provide the keys to determining whether a UK free-fall system provides a credible deterrent: unless a potential adversary can exclude a successful attack, deterrence will be achieved. By contrast, reduced accuracy and lower yield can be mitigated / overcome by using more warheads. We will consider vulnerability and range in turn.

**Vulnerability**

During the Cold War, a key rationale of the CASD posture was that without CASD the UK’s nuclear force was vulnerable to a surprise attack by the USSR-led Warsaw Pact. The credible minimum independent free-fall nuclear deterrent proposed in this paper would by its nature be more vulnerable than the effectively invulnerable SSBNs armed with uninterceptable warheads. However, the question that needs to be answered is not “is the free-fall option is more vulnerable than Trident?” Rather the correct question is “does the increased vulnerability of the free fall option preclude its use as a credible deterrent?”

Vulnerability takes two forms: first, the vulnerability of the bases and the aircraft to a surprise attack; second, vulnerability in the strike phase of a nuclear mission the aircraft and their weapons will be destroyed (“hard kill”), or that the aircraft will not complete their mission (“mission kill”). We will consider both vulnerabilities in turn.
Surprise Attack / “Bolt from the Blue”

To achieve certainty that there could be no successful UK nuclear response, an adversary would need to ensure the near simultaneous destruction of all of the UK’s delivery platforms and/or all of the UK’s nuclear weapon stockpile. Unlike the TAR that is predicated on procuring an additional 36 nuclear-dedicated F-35s, this proposal sees all 138 UK F-35Cs having free-fall nuclear capability. In the narrow case that only F-35C being certified for the nuclear mission, this means at minimum the destruction of 138 F-35Cs and the sinking or disabling of one or both Queen Elizabeth-class aircraft carriers.241

Even in the depths of the Cold War, there was never an expectation of a true “Bolt from the Blue” attack in the sense of an immediate transition from normal levels of international tension to nuclear war. As now declassified USAF Strategic Air Command (SAC) history of the 1962 Cuban Missile Crisis demonstrates, US forces – with SAC in the vanguard – undertook a graduated increase in military preparedness in the period 20 – 22 October 1962.242 This culminated in the first ever dispersal of the Boeing B-47 medium bomber force to 32 US bases243, and the famous continuous CHROME DOME airborne nuclear alert which ultimately saw 1-in-8 of the entire available B-52 force continuously, airborne armed and ready to attack Soviet targets.244 Further SAC B-52s and the dispersed B-47 medium bomber force held ground-alert across the United States. During the same period, RAF Bomber Command’s V-Force held up to 120 armed aircraft245 at Readiness State 15 – armed and fuelled aircraft at less than 15 minutes’ notice to launch. Ultimately, throughout the afternoon of 27 October 1962 the V-Force moved to Readiness State 05, with crews manning their cockpits at less than five minutes to launch.246

Prime Minister Harold Macmillan’s political requirement was that the RAF make no overt signs of V-Force or Bomber Command mobilisation, meaning that no order to disperse the V-Force was possible, even though it would have increased the V-Force’s survivability.247

Even the event of a future Cold War, staged escalation over time remains the most likely model.248 Resultantly, it is assessed that there will be at least 24 hours of strategic warning during which the UK would disperse its nuclear forces away from RAF Marham.249 During this period of strategic warning, nuclear-armed F-35Cs would disperse to military bases around the UK to pre-prepared Operational Readiness Platforms (ORPs), concrete hardstandings adjacent to the runway at bases around the UK, allowing nuclear QRA aircraft to launch within the available warning time.250
Despite the post-Cold War down-sizing of the UK defence estate, Figure 5 shows 18 potential UK dispersal bases in addition to the Queen Elizabeth-class aircraft carriers that meet the criteria of at least one MoD-controlled 6000ft runway with existing MoD accommodation and no public disposal plans. This comprises 13 active RAF bases, three British Army barracks on former RAF stations with operational runways (Kinloss Barracks; the former RAF Leuchars; Wattisham Airfield), and two RN FAA bases (HMS Seahawk, RN Air Station (RNAS) Culdrose; HMS Heron, RNAS Yeovilton). If MoD estate disposal plans changed, RAF Wyton, Cambridgeshire could be added to the list of dispersal airfields; the January 2015 announcement that the USAFE-AFAFRICA will be closing RAF Mildenhall, Suffolk offers the same opportunity.

In the worst case, the UK would need to rely on early warning on the RAF-manned Ballistic Missile Early Warning System (BMEWS) at RAF Fylingdales, North Yorkshire. BMEWS alone would provide approximately 10 minutes’ warning of an attack by a ballistic missile fired from the Moscow area, and more than 4 minutes 12 seconds for a ballistic missile fired from Russia’s Kaliningrad exclave.

During the 1960s V-Force QRA era, the RAF consistently demonstrated the ability to launch two to four aircraft from the ORPs at each dispersed operating base in under 2 minutes 30 seconds. Using the 18 airfields shown in Figure 5 today, this would translate into 72 nuclear-armed F-35Cs and their accompanying Airbus Voyager KC2 / KC3 tankers safely airborne before a surprise attack could destroy them on the ground. Demonstrable capability requires practice: in common with the V-Force, RAF and land-based RN FAA Squadrons would undertake short-notice dispersion training as part of their normal training cycle.

Additionally, the UK’s overseas bases and civil airfields in the UK’s overseas territories provide significant flexibility in both dispersal and in providing credible Forward Operating Bases (FOBs) to credibly threaten states of concern. Figure 6 shows that land-based operations with Air-to-Air Refuelling (AAR) support from RAF Voyager KC2 / KC3 tankers covers all of Africa, Europe, the Middle East and South America, along with the Indian subcontinent and most of former Soviet Central Asia. Importantly, many areas are held at risk from more than one British base, making defence more complex by requiring a potential adversary to prepare and defend against simultaneous attacks on more than one attack axis.
Figure 5: Potential UK F-35C dispersal land bases

Decode: EGDR, RNAS Culdrose (HMS Seahawk), Cornwall; EGHQ, RAF St Mawgan, Cornwall; EGDY, RNAS Yeovilton (HMS Heron) Somerset; EGDM, Boscombe Down, Wiltshire; EGVN, RAF Brize Norton, Oxfordshire; EGUW, Wattisham Airfield, Suffolk; EGXH, RAF Honington, Suffolk; EGXT, RAF Wittering, Cambridgeshire; EGYM, RAF Marham, Norfolk; EGYD, RAF Cranwell, Lincolnshire; EGOV, RAF Valley, Anglesey; EGXC, RAF Conningsby, Lincolnshire; EGXW, RAF Waddington; EGXP, RAF Scampton, Lincolnshire; EGXE, RAF Leeming, North Yorkshire; EGQL, former RAF Leuchars, Fife; EGQK, Kinloss Barracks, Moray; EGQS, RAF Lossiemouth, Moray.

Source: CentreForum analysis. Map generated by the Great Circle Mapper (www.gcmap.com) - copyright © Karl L. Swartz.
Figure 6: UK global land basing options

Notes:  
(i) Bases shown are: RAF Lossiemouth, Moray, Scotland (EGQS); RAF Gibraltar (LXGB); RAF Akrotiri, Cyprus (LCRA); Permanent Joint Operating Base (PJOT) Diego Garcia, British Indian Ocean Territory (BIOT) (FJDG); RAF Mount Pleasant, Falkland Islands (EGYP); Providenciales Airport, Turks and Caicos Islands (MBPV); Bermuda International Airport, Bermuda (TXKF); Wideawake Airfield, Ascension Island (FHAW). St Helena airport opening in 2016 is the unnamed airport marked SE of Ascension Island.

(ii) For land-based F-35C operations with in-flight refuelling, a 2500nm radius of action is shown.

(iii) For clarity, other UK bases are not shown, as their radiuses of action would be contained within the radiuses shown for RAF Lossiemouth, RAF Gibraltar and RAF Akrotiri.

Source: CentreForum analysis. Map generated by the Great Circle Mapper (www.gcmap.com) - copyright © Karl L. Swartz.

In order to maximise their ability to support extended-range attack, real-time electronic intelligence (ELINT) gathering, tanking and transport missions, CentreForum’s proposed package funds the conversion of the RAF’s Voyager KC2 / KC3 fleet to provide “flying boom” refuelling with the Airbus Air Refuelling Boom System (ARBS) and to receive fuel themselves with a Universal Air Refuelling Receptacle System Installation (UARRSI) receiver.

SAC pioneered “Flying boom” refuelling in the 1950s, and it provides much faster fuel transfer rates, making it the preferred option for large aircraft (e.g. the RAF’s E-3D Sentry Airborne Warning and Control System (AWACS)) than the RAF’s standard hose and drogue AAR system.258 Air-
bus’s ARBS and UARSI are systems already in-service on the Royal Australian Air Force (RAAF) A330-based KC-30A tanker aircraft which are closely related to the RAF’s Voyager KC2 / KC3s. This modification to the RAF’s Voyager tankers confers a number of operational advantages to nuclear strike missions. It will allow the Voyagers to:

1. support a larger nuclear strike F-35Cs at 2500nm operational radius from UK land bases than if the tankers cannot refuel each other;
2. fly B61-12 weapons non-stop from the UK to distant sovereign UK land bases (e.g., PJOB Diego Garcia) in international airspace from UK bases;
3. act as a tanker-transport from the UK to distant sovereign UK land bases (e.g., PJOB Diego Garcia) accompanying the F-35Cs and other force enablers whilst carry their ground and spare aircrew; and
4. maximise RC-135W RIVET JOINT real-time ELINT on-station time in support of UK-only nuclear strike missions, as RIVET JOINT can only use flying boom refuelling.

Modifying the Voyagers in this way will significantly improve the UK’s conventional capabilities and operational flexibility, by allowing the RAF to in-flight refuel its C-17A Globemaster III strategic transports for the first time. Like RIVET JOINT and a large number of EU allies’ current and future aircraft – specifically F-16s and F-35As – C-17A Globemaster III can only use flying boom refuelling, meaning that this Voyager modification makes a significant contribution to conventional UK, NATO and European power-projection. Finally, UK boom-equipped tankers would provide a welcome capability enhancement to the UK E-3D Sentry AWACS force for UK and EU operations.

Sovereign operations from land bases

Historically, it is not uncommon to refuse overflight rights; this has included refusals from close allies. A notable example occurred in 1986 when France, Italy and Spain refused overflight rights to UK-based USAF aircraft participating in the Operation ELDORADO CANYON attacks on Gaddafi’s Libya. In this case, NATO allies’ refusals of overflight rights forced a detour around the Iberian Peninsula and through the Straits of Gibraltar, adding more than 2,600nm to the round-trip distance and almost doubling the mission duration. This significantly increased the AAR requirement and the operation’s complexity; under other circumstances, the denial of overflight rights could have made the land-based component of the operation impossible.
Therefore, truly sovereign operations either need to be able to route through international airspace from UK bases, or be prepared to fight their way through third-country airspace to target without requiring overflight clearance. Though the latter should never be definitively ruled out, it is clearly preferable to operate without needing to trespass through third countries’ airspace.

**Carrier Basing**

Being mobile, the *Queen Elizabeth*-class carriers provide further survivability to a UK nuclear strike force by reducing a potential adversary’s ability to deliver a “bolt from the blue” surprise attack, as well as increased operational flexibility to UK deterrence by complicating a potential adversary’s defensive problem in making an assessment of, and defending, likely attack routes. Carrier mobility means that an adversary has to continuous track the aircraft carrier’s position in order to engage it. This is a non-trivial task: not only are the carrier’s own aircraft intent on shepherding away potential adversary aircraft, the carrier operates with an escorting group of frigates, destroyers and submarines to ward off airborne, surface and subsurface threats.

Moreover, once found in the vast oceanic spaces, an adversary needs to maintain persistent surveillance of the carrier group. Losing contact with the UK carrier group for six hours when steaming at 25 knots forces a potential adversary to search an area of nearly 71,000 nm²; after 24 hours, this search area grows to more than 1.1 million nm². Hence, being able to defeat persistent adversary surveillance is key to increasing the survivability of the carrier group, and is a key reason why CentreForum’s costed proposal includes the capital cost of E-2D Advanced Hawkeye Airborne Early Warning and Control (AEW&C) aircraft, and land-based MPA / MMA to support the carrier group. These purchases obviously also significantly improve both the survivability and operational utility of the UK carrier group in conventional power-projection, too.

To ensure that at least one carrier is always available, the UK should implement the decision announced by Prime Minister David Cameron at the 2014 NATO Summit that both *Queen Elizabeth*-class carriers would be brought into service. This paper’s proposal makes allowance for the capital costs of doing so and equipping them to operate the F-35C.

Finally, land-based and carrier-based operations are not mutually exclusive; indeed, the reverse is true. The UK’s efforts are likely to be most effective when land-based and carrier aviation complement one another. This additional flexibility takes three forms:
1. Possibility of extended range carrier operations using land-based RAF AAR tankers;\(^{269}\)

2. Launching strikes from the carriers and recovering to a UK land base (or vice-versa), and so maximising tactical surprise by disguising the axis of attack;

3. For some target sets, carrier strikes can be coordinated with a land-based attack to saturate the defences on multiple attack axes.

All three complicate a potential adversary’s defensive picture, making it much more difficult to exclude the possibility of a successful UK attack, thereby increasing deterrence.

**Attack phase vulnerability**

Once safely airborne, the F-35Cs have to reach the launch point for their B61-12s in order to conclude a successful nuclear attack. A potential aggressor’s failure to destroy all of the aircraft and their weapons, or to force the crews to abort, will result in a successful nuclear strike causing widespread damage against the chosen target(s).

The key to the F-35C’s survival in the attack phase of the mission is the combination of its stealth characteristics, and the B61-12’s approximately a 40km standoff from medium level.\(^{270}\) The F-35C’s low RCS allows much deeper undetected penetration of hostile airspace than current generation combat aircraft. Open source information suggests that the difference in detection range against the Russian 92N2E GRAVESTONE fire control radar for Russia’s most advanced SA-21 GROWLER SAM is c. 200nm for current aircraft, falling to c. 25nm for F-35.\(^{271}\) As a radar-guided weapon, if the SA-21 battery cannot acquire and track the target, then its missiles cannot shoot it down.\(^{272}\)

However, survivability is not solely about stealth; it is also about training and tactics, and the manner in which the aircraft are employed. Large numbers of F-35Cs attacking simultaneously have a greater cumulative effect, as the defender risks being swamped with actual and electronic warfare (EW) false targets.\(^{273}\) CentreForum modelling suggests that F-35Cs attacking targets protected by a co-located SA-21 GROWLER brigade\(^{274}\) should remain undetected up to the point of B61-12 release. The kinematics of the engagement suggest that there are a number of alternatives for the F-35C to egress safely.

Taken together, stealth, EW and tactics significantly increases the defensive problem of a potential adversary, decreasing their certainty of intercepting all of the UK’s B61-12s. In the case of 80 B61-12s being launched
simultaneously at a city-scale target from 80 F-35Cs at a range of approximately 43km\textsuperscript{275}, a defender would be presented with 160 valid targets (along with numerous EW false targets) simultaneously, and without prior warning.

Weapon time of flight (TOF) to target would approximately 120 seconds\textsuperscript{276}, in this time the defenders would have to track, prioritise and engage the targets. Assuming that no false targets were engaged, attacking each target with two missiles requires 320 available missiles, 83\% of an SA-21 GROWLER brigade’s inventory of 384 missiles. Even then, if each B61-12 were targeted with two high (85\%) probability of kill (P\textsubscript{k}) missiles each, statistically at least one and probably two bombs would penetrate the defences.\textsuperscript{277} At 50kt per warhead, this implies widespread destruction, as discussed on pages 58-60 below.

Moreover, false targets laid into the hostile integrated air defence system (IADS) by electronic warfare further exacerbates the defender’s problems. If each real target is matched by only one false target, the 320 apparent targets would exceed the SA-21 brigade’s ability to attack each target with two SAMs, increasing some warheads’ likelihood of surviving from 2.25\% to 15\%. A successful EW attack that quadrupled the number of targets ‘seen’ by the IADS from 160 to 640 would swamp even an SA-21 brigade’s ability to respond, resulting in far more of the B61-12s reaching target.

**Improving potential adversary air defences**

A free-fall nuclear force – even an LO one with an effective stand-off range of more than 40km – is vulnerable to improvements in potential adversary’s air defences. As we have seen, stealth is the raison d’être of the JSF programme, and the TAR notes that the “vulnerability of JSF is largely dependent on the vulnerability of the aircraft carrier / FOB where it is based. The stealth of the JSF aircraft itself enables it to penetrate even sophisticated defences.”\textsuperscript{278} As the TAR rightly concedes, “this level of effectiveness may reduce as counter-stealth technology improves”.\textsuperscript{279}

However, nuclear deterrence calculations are different for both sides to calculations for conventional strike missions. For the UK, any nuclear mission is likely to incur significant losses, and our declaratory policy needs to accept that significant losses are inevitable; indeed, expected. High levels of losses are to be expected from what is by definition a mission that would only be ordered if there were an existential threat to the UK’s survival.
This correlates with the oral history testimony from RAF V-Force crews in the 1962 Cuban Missile Crisis, who understood that an attack on the Soviet Union was “a mission from which we were not coming back to the UK, even if there had been anything to come back to after a nuclear exchange”. Thus, 75% attrition could be acceptable for a one-off nuclear mission whereas a 3% per wave loss rate would be crippling in a sustained conventional conflict.

**Use of supporting Air Assets (COMAO)**

This vulnerability assessment is based on the worst-case scenario that UK forces would encounter on a nuclear mission – a single aircraft, with minimal warning time and no supporting aircraft. In reality, faced with an existential threat, a UK nuclear strike scenarios would be conducted in the same manner as modern conventional air strikes using the complementary capabilities of different types of aircraft within a force package: a so-called Composite Air Operation (COMAO).

The use of AAR tankers to extend strike range provides a simple example of this sort of support. COMAOs takes this further, encompassing a wider range of capabilities. In the “UK alone” scenario, this could include airborne early warning (AEW) through from RAF’s E-3D Sentry AWACS and/or the FAA E-2D AEW&C budgeted for in this proposal. AEW would be partnered by real-time electronic surveillance RC-135W RIVET JOINT aircraft via high-fidelity datalinks, fighter escort to intercept adversary aircraft, electronic warfare from non-nuclear rolled F-35Cs, and strike support from RAF Typhoons launching conventional Storm Shadow air-launched cruise missiles (ALCMs) and BGM-109 Tomahawk Land Attack Cruise Missiles (TLAM) submarine-launched cruise missiles (SLCMs), e.g. against known radar sites just ahead of the strike. Finally, the land-based MPA / MMA budgeted in this proposal would support the fleet and provide search and rescue for overwater sorties.

Involving each of these force elements significantly increases the chances of the F-35Cs successfully achieving their nuclear mission, and minimises a potential adversary’s expectation that they could expect to achieve hard or mission kills on the whole of the UK nuclear strike force, ensuring that deterrence is maintained. As such, COMAO tactics leverages the UK’s existing investment in our conventional forces, allowing the nuclear mission to free ride on them. If this model it meets the deterrence requirement threshold – and we are confident that this proposal does – such an approach will always offer superior VfM to procuring the expensive single-role SSBN / Trident system.
Range

The unrefuelled operational radius of an F-35C in LO operations using only internal fuel and weapons is 615nm. Multiple in-flight refuellings increases the radius of action of land-based F-35Cs to the aircrew fatigue limit, which based on current USAF operational practice in operations over Afghanistan is approximately 12 hours. For our purposes, this translates into a land-based radius of action of 2500nm.

For organic carrier-based operations without land-based AAR support, F-35Cs will initially rely on buddy-buddy refuelling from other F-35Cs. This is estimated to increase the F-35C radius of action from the Queen Elizabeth-class aircraft carriers to 1000nm. However, the increased range is dependent on the planning assumptions of the required size of the strike force, any escorts and therefore the number of F-35Cs available for buddy-buddy refuelling. On this basis, for comparative purposes we have limited the radius of action for carrier-launched F-35Cs with buddy-buddy refuelling to 1000nm.

As part of the FAA enhancement package to maximise the effectiveness of the carrier-borne element of the deterrent, this paper not only funds the conversion of the Queen Elizabeth-class carriers to CATOBAR operation, but it also funds the procurement of C-2A Greyhound carrier on-board delivery (COD) aircraft to maximise combat efficiency of the carrier group through providing a logistics link to shore bases. Analysis suggests that in UK service C-2As modified as single-point AAR tankers could sustainably ease the burden on F-35Cs’ buddy-buddy refuelling. Conservatively, use of four C-2As in the tanker role could increase the carrier-only F-35C strike radius beyond 1250nm. However, CentreForum’s analysis has not found a target set that requires this capability.

B61-12 Yield

Some interviewees have expressed the concern that a 50kt warhead is too small to provide an effective deterrent. Figure 7 illustrates the damage caused by a single 50kt warhead detonated 3900ft above CentreForum’s Westminster office. The burst height maximises the area subject to 5-psi overpressure that is sufficient to destroy or severely damage conventional, non-hardened buildings.
Modelling estimates that a single 50kt warhead detonated over Westminster during the working day would result in more than 160,000 fatalities – approximately the population of greater Swindon – and cause nearly 650,000 injuries. Non-hardened buildings at a radius of 1.8 miles will be destroyed or seriously damaged by the 5-psi blast wave. This devastated zone stretches from Kensington’s Natural History Museum in the west to Euston Station in the north, to the Shard at London Bridge in the east, and to Wandsworth Road railway station in the south. It is important to note that fatalities will be higher and damage greater against targets with higher population densities and/or lower building structural quality than central London.

A potential aggressor will be aware of the damage potential of a successfully delivered 50kt warhead. Less than very confidence of achieving 100% hard or mission kills against at least 36 (and likely considerably
more than 50) F-35C aircraft carrying one or two B61-12s flying a number of different routes, and utilising EW, means that a potential adversary will be deterred.

**Accuracy**

The B61-12 programme adds a Joint Direct Attack Munition (JDAM) derived guidance kit and updated safety devices to the existing B61-4 warhead, making the B61-12 the world’s first precision guided thermo-nuclear weapon. The first guided test drop of the B61-12 is scheduled for 2015 with production scheduled from 2019.

As described above on page 35, the B61-12 utilises JDAM-derived GPS-guidance components to increase accuracy over previous free-fall nuclear weapons. Consequently, with a 5 – 30m CEP, B61-12 should be significantly more accurate than the publicly available data suggests Trident warheads are, allowing a smaller warhead to achieve the same level of damage as larger, less accurate warheads. The principal benefit is that the smaller warhead has lower secondary and collateral damage from direct physical and radiological effects, as well as from fallout and rainout.

Further, foreseeable anti-aircraft systems will continue to rely on radar for warning and targeting, and therefore successful attacks on the search and fire-control radars will blind the system, rendering the weapons themselves largely useless. As a UK nuclear strike would only be ordered if there was an existential threat to the UK, UK declaratory policy should clearly state that it would take whatever steps were required in order to get its strike aircraft to target, up to and including the use of nuclear weapons to destroy / disable an opponent’s air defence system en route. It is therefore extremely unlikely that a non-P5 adversary will be able to provide a high level of assurance that no UK F-35Cs would successfully complete their nuclear missions against their primary targets now or beyond 2040, maintaining deterrence.

**Deployment timelines**

How soon could a new UK free-fall force enter operational service? Given the lack of clarity for the timelines to convert the Queen Elizabeth-class carriers to CATOBAR configuration, it is likely that an initial nuclear capability would be achieved from land bases before carrier operations were added by the mid-2020s. With the US B61-12 programme delivering weapons in the 2019 – 24 timeframe, an Initial Operating Capability (IOC) of an anglicised B61-12 in the early- to mid-2020s from land bases before transitioning to carrier operations appears feasible.
It would be a matter for the Government whether to continue SSBN patrols until the carrier group achieved nuclear IOC or to end SSBN patrols when land-based aircraft had achieved nuclear IOC. Unlike the Successor-class SSBN, the timelines are flexible enough to allow either option. A 2024 carrier nuclear IOC would match the scheduled retirement dates of the existing Vanguard-class SSBNs, and would remove the need for all four SSBNs to complete the life-extension programme.\(^{303}\) However, it is unclear how much of cost of the life-extension programme will be saved, so in line with our conservative assumptions, we are not assuming that this will result in any savings. Realistically, this is likely to provide additional savings.

**UK nuclear posture**

If the UK were to adopt the B61-12 / F-35C combination as the credible minimum independent nuclear deterrent, what nuclear posture the UK should adopt? Specifically, should the nuclear force be:

1. **fielded**, with live weapons dispersed to operational bases and aboard the Queen Elizabeth-class aircraft carriers, and on-going training by aircrews and ground crews;
2. **semi-recessed**, with a stockpile of weapons held centrally, but limited training of aircrews and ground crews; or
3. **recessed** with the capability to assemble the weapons at 18 – 24 months’ notice and training for aircrews and ground crews postponed until weapon assembly was authorised?

Without detailed costings of the various options, it is hard to make definitive posture recommendations. However, two points can be made. First, as with the existing UK Trident warhead, an anglicised B61-12 would share key non-nuclear elements with its US counterpart, and the UK programme is likely to benefit significantly from being able to purchase these components from a live production line.\(^{304}\) The UK’s experience with being the sole customer for ageing UGM-27 Polaris components after the USN retired Polaris demonstrates that this is an expensive and unattractive option.\(^{305}\)

As such, it is likely to be cheaper to produce an anglicised B61-12 buying the non-nuclear components from active US production lines, rather than producing the bombs at a later stage and having to incur additional cost to get them restarted. Moreover, in purchasing 100 B61-12s, the UK would be increasing total production by 21%, which should modestly reduce the unit costs for both the US and the UK. Consequently, a fully recessed option is unlikely to maximise VfM and should be rejected.
Second, unless there were major savings to be made from a semi-recessed posture, two recent reports into United States’ Strategic Command (USSTRATCOM) demonstrate the challenges in maintaining operational standards amongst the nuclear forces. In the wake of both the 2007 inadvertent, unauthorised – and undetected – movement of nuclear-armed AGM-129 Advanced Cruise Missiles from Minot AFB to Barksdale AFB, a USAF blue-ribbon panel conducted a review into nuclear weapons policies and procedures, concluding that effectively maintaining dual-role capability is challenging and requires active management. Following the 2014 cheating scandals amongst USAF ICBM crews and USN nuclear propulsion trainees, the US DoD commissioned an independent review into their nuclear forces. In a strikingly transparent report, the DoD review panel reiterates the importance of the overt, top-level support and prioritisation of the nuclear mission, the morale and efficiency benefits of dual conventional/nuclear roles when well executed, and restoring the balance between mission effectiveness and inspections to certify mission effectiveness.

Taken together, these considerations point towards a well-resourced, well-exercised fielded posture with a focus on operational excellence as the best mixture for maximising operational efficiency. CentreForum therefore recommended that the UK retains a fully fielded nuclear posture.
7 - Three Case Studies

In order to test the utility of the adoption of a UK free fall nuclear delivery strategy more robustly in this respect we will consider its application against three cases that reflect the general trends identified above: Middle Eastern dictatorships; Democratic People’s Republic of Korea (DPRK, North Korea), distant foe; Resurgent Russia.

There is no publicly available evidence that any of these countries have the intent to attack the UK now, or at any point in the future. These scenarios are therefore illustrative only.

Case One: Middle Eastern / South Asian Nuclear Threat

Amid a series of unlikely scenarios, an emergent nuclear threat from the Middle East or South Asia following a fundamentalist / extremist takeover of the government of a nuclear-armed or nuclear threshold state is arguably the least unlikely scenario a UK deterrent would have to counter. It should be noted that in the unlikely event that such a takeover occurred, however, it is far from clear that the UK would be the sole – or even the principal – target, making the “UK-alone” scenario even less likely.

Israel\textsuperscript{314} and Pakistan\textsuperscript{315} have indigenous nuclear capability, Iran has much of the nuclear infrastructure required to produce a crude nuclear device at short notice, and Saudi Arabia is widely believed to have funded the Pakistani nuclear programme on the basis that Pakistan would supply completed weapons to Saudi Arabia on demand.\textsuperscript{316} All of these countries have ballistic missiles, some of which are theoretically capable of reaching the UK or the UK’s overseas bases.\textsuperscript{317}

Figure 7 shows nuclear and WMD associated sites in the broader Middle East and South Asia. All are within 2500nm of the UK sovereign base at RAF Akrotiri, Cyprus, with Pakistani, Saudi Arabian and many Iranian WMD-associated targets within range of Permanent Joint Operating Base (PJOB) Diego Garcia, British Indian Ocean Territory (BIOT). The importance of sovereign basing is discussed above on pages 53-54.
In addition, all sites can be covered from *Queen Elizabeth*-class carriers operating in international waters, demonstrating that coordinated attacks from land and carrier-based aircraft can offer different attack axes against the same targets, further complicating defensive arrangements. From this, we can conclude that the UK is well placed to conduct successful attacks on against a range of countries in the Middle East and South Asia from sovereign UK land bases and carrier operations thereby ensuring deterrence. As regional air defences improve, the cost of hitting all of the possible targets increases, but it is assessed as unlikely that these countries would – especially in the aftermath of an extremist takeover – have a high level of confidence that their air defences would achieve hard or mission kills on 100% of a UK attacking force. As a result, deterrence will be maintained.
Figure 8: Target coverage of a selection of known WMD-associated sites in the broader Middle East / southwest Asia from RAF Akrotiri, Cyprus, and PJOB Diego Garcia and Queen Elizabeth-class carriers operating in international waters

Notes: (i) Bases shown are RAF Akrotiri, Cyprus (LCRA) and PJOB Diego Garcia, BIOT (FJDG).
(ii) For land-based F-35C operations with in-flight refuelling, a 2500nm radius of action is shown.
(iii) For carrier-based operations, F-35C with buddy-buddy in-flight refuelling and a 1000nm radius of action is shown.
(iv) A selection of Middle Eastern and South Asian WMD associated sites are marked in red.318

Source: CentreForum analysis. Map generated by the Great Circle Mapper (www.gcmap.com) - copyright © Karl L. Swartz.
Case Two: North Korea, distant foe

In the very unlikely event that North Korea attempted to nuclear blackmail the UK and no other country, the UK would not be able to respond with land-based assets from UK sovereign bases. Of course, the notion that the UK alone would be the subject of nuclear blackmail from the DPRK is vanishingly small, so any UK nuclear response would likely be as part of a US-led coalition, benefitting from allied basing in Japan, South Korea the north-west Pacific.

Nonetheless, in the limiting case that the UK had to operate wholly alone, with sufficient notice it could deploy one or both Queen Elizabeth-class carriers to the northwest Pacific. With the F-35C’s unrefuelled operating radius of 615nm there is considerable flexibility in positioning of the aircraft carriers in international waters whilst covering DPRK leadership and WMD-associated targets, allowing autonomous indigenous UK strikes from the carrier decks. Figure 9 shows the flexibility of the 615nm radius of action from the carriers operating in international waters around the DPRK. Use of buddy-buddy and/or C-2A Greyhound refuelling to extend carrier-based F-35C range beyond 1000nm provides additional flexibility in carrier positioning and aircraft routing.

Figure 9: North Korean leadership and WMD-associated targets held at risk from F-35C operating unrefuelled from Queen-Elizabeth class aircraft carriers in international waters.

Notes: (i) F-35C 615nm unrefuelled radius of action is shown.
(ii) A selection of DPRK nuclear, WMD and leadership-associated sites are marked in red.

Source: CentreForum analysis. Map generated by the Great Circle Mapper (www.gcmap.com) – copyright © Karl L. Swartz
Case Three: Resurgent Russia

The hardest case that the UK deterrent could face is that of a resurgent Russia. Under this scenario, Russia attempts nuclear coercion against the UK after the US has explicitly withdrawn the NATO Article V nuclear guarantee to the UK, forcing the UK to rely solely on the UK’s deterrent. It must be stressed that such scenario is vanishingly unlikely. Any such US statement would signal the immediate demise of NATO, plunging Europe into a politico-military crisis.

However, should such a scenario occur, Russia poses a defensive strength problem to the F-35C / B61-12 combination, not a range problem. Figure 10 shows that 2500nm radius of action from RAF Lossiemouth, Moray and RAF Marham covers targets across European Russia; Figure 11 shows that many of the same targets are within range of RAF Akrotiri, Cyprus.

In the Russian case, it is probable that the quality and quantity of the defences around Moscow mean that the F-35C free-fall bombers could not be certain of breaching the defences. However, as the TAR notes in dismissing the “Moscow Criterion”, deterrence requires unacceptable loss, not destroying Moscow in toto.

In contrast to Moscow, St. Petersburg is coastal, and missile defences ashore would be unlikely to guarantee the destruction of all the F-35Cs before the aircraft had released their weapons. CentreForum analysis suggests that even without COMAO support F-35Cs against the most advanced SAMs supported by an IADS results in a high level of confidence that one and probably two B61-12 warheads would penetrate the defences. This failure to guarantee 100% physical or mission kills means that Russia cannot be certain that St. Petersburg would be immune from a UK attack.

In reality, three considerations significantly increase the likelihood of the success of a UK nuclear strike on targets in the Russian Federation.
Figure 10: 2500nm operational radius from RAF Lossiemouth, Moray, UK

Notes:  
(i) F-35C 2500nm multiple refuelling radius of action is shown.  
(ii) ULLI – St Petersburg; UUDD – Moscow

First, any UK strike would be by definition the highest priority UK military mission, and therefore would have the full range of UK sovereign enabling assets, including:

- Electronic computer network attack ("cyber warfare") against Russian military targets, notably the Russian IADS;
- Conventionally-armed cruise-missile attacks on air defence sites both by TLAMs from RN SSNs and Storm Shadow ALCMs;
- Mutual EW support from other F-35Cs;
- Real-time electronic intelligence from RC-135W RIVET JOINT,
- Diversionary conventional air attacks.

Second, any UK nuclear strike will only ever take place in the case of a clear threat to national survival. Consequently, it is unlikely that the UK would be concerned about violating neutral airspace en route to Russian targets. However, in order to underline the conservative nature of the
modelling of an attack on St. Petersburg, we have assumed that the RAF will only operate in international or Russian airspace; even with this very restrictive planning constraint, we have a high level of confidence that an attack on St. Petersburg would successfully penetrate the defensive screen. With this unrealistic planning constraint removed, the (already high) level of confidence increases.

Third, Russia’s scale offers a wide dispersion of countervalue targets in European and Asian Russia. Large numbers of these targets can be held at risk from a combination of RAF land bases and from the Queen Elizabeth-class carriers operating in the Baltic, Black and White Seas, making the defensive task formidable against multiple simultaneous conventional and nuclear attacks. The assessed inability of Russia to ensure that the UK could not inflict unacceptable loss means that deterrence would be achieved.

Thus, even in the limiting case of a resurgent Russia attempting nuclear blackmail after the USA had announced that the UK was not covered by the NATO Article V guarantee, the F-35C / B61-12 combination’s ability to pose a credible threat to St. Petersburg and regional Russian cities meets the Duff Group’s Option 3a and 3b deterrence requirements.
8 - Broader policy considerations

UK Submarine industrial base

Britain’s submarine building industry is a monopsony; that is, it is a situation in which there are monopoly suppliers (BAE Systems at Barrow for submarines; Rolls-Royce at Derby for nuclear power plants) and a single customer (Royal Navy). This is not unique in defence procurement – BAE Systems is also the default supplier for surface ships – but the intensity of the relationship is unusual as there is not even a theoretical international competitor for the construction of UK nuclear submarines.

Moreover, whereas a number of different frigate designs could be substituted one for another with relatively small changes in capability, the difference in capability between nuclear-powered conventionally armed submarines (SSNs) and their conventional equivalents (SSKs) is far greater. This is reflected in transit speeds, submerged duration, deployment periods and platform size; nuclear-powered submarines offer high sustained speeds, submerged duration limited only by crew rations, longer deployment periods and larger platforms than their diesel-powered equivalents. Whilst Air-Independent Propulsion (AIP) technologies have somewhat narrowed the submerged duration gap, trading UK SSNs for commercially available SSKs would effectively represent a decision to move from a global to a regional role for the RN. Consequently, for as long as the UK intends to retain a global role, nuclear-powered submarines will have a key role to play in RN conventional global power projection.

The small number of submarines in the UK fleet means that there is careful planning to ensure that BAE Systems at Barrow and Rolls-Royce at Derby both have a continuous stream of work in order to protect the skills and industrial base. The Astute-class SSN was built after a decade-long gap, and resulted in overruns and delays that were the direct result of lost skills arising from the hiatus in submarine design and construction. Consequently, there is a strong presumption in favour of maintaining a throughput of submarine design and build work to ensure that the UK is in a position to replace the Astute-class SSNs in the 2030s.
However, it would be an extreme case of “the tail wagging the dog” if the need to keep Barrow and Derby in business to build a post-Astute SSN became the key driver for committing to the £109bn through-life cost for Successor-class SSBNs and Trident operations beyond 2042. It would be much cheaper for the UK to extend the Astute-class production run beyond the existing seven boats to 12, with the final five leveraging the investments made in the PWR-3 nuclear propulsion system developed for Successor-class.

**Exporting Astute**

The UK should also market these evolved Astute-class SSNs to Australia\(^3\) and Canada\(^3\) which both have submarine replacement programmes in the 2020s and for which an evolved Astute could provide an effective solution. In both cases, the twin aims are to support traditional alliance partners and the UK nuclear submarine industrial base, meaning that export submarines would be priced at the marginal cost of UK production, and the UK would agree to decommission and dispose of export submarines in the UK at the end of their service lives as part of the UK submarine decommissioning programme. An Australian desire to assemble Astute SSNs in South Australia from UK-supplied components should, where possible, be met.

Initial crew training for both the Royal Australian Navy (RAN) and the Royal Canadian Navy (RCN) could be conducted in existing UK Astute training facilities at HMNB Clyde, Faslane, with the three Commonwealth navies reaping the savings of commonality benefits through-life.\(^3\) Given the well-documented problems with their existing SSKs,\(^3\) thought should be given to lending both the RAN and RCN one or more Astute-class SSNs for familiarisation training and operations whilst their submarines are constructed.

**Would the savings stay in MoD?**

For many in the UK defence and foreign policy community, the key argument against non-Trident options is scepticism (or worse) that the savings would stay in the MoD. If the savings from cancelling the Successor-class and replacing Trident from 2021/24 with a cheaper B61-12 based free-fall system were simply reclaimed by HM Treasury, then there is little or no incentive for the MoD to forgo Trident’s high-end capabilities.\(^3\) Reflecting years of adversarial relations between MoD and HM Treasury, there appears to be cynicism and deep distrust on both sides of the debate.\(^3\)
However, appearances can be deceptive. First, any such a decision is political, and if a political agreement were made to keep the savings in MoD, then this will occur. In effect, what is required is a grand bargain between MoD and HM Treasury to ensure that if Successor-class scrapping leads to savings, then these savings should remain in the MoD budget. Given the nature of the deal, the MoD would in any event be procuring new equipment with the saved funds, and signing these contracts at the same time as cancelling the Successor-class SSBNs with appropriate penalty clauses would give MoD and industry significant confidence that HM Treasury would not reclaim the savings at a later date.

Second, keeping the savings in the MoD is current HM Treasury policy. During the SDSR10 process, Chancellor George Osborne said he had made it “absolutely clear” the Trident costs were a part of the core defence budget, rather than additional, special funding. This reflects long-standing policy, demonstrated by the position taken by then-Defence Secretary Francis Pym in 1980, when he noted in a Parliamentary debate on Trident I C4 replacing Polaris A3TK that, “Just as Polaris was fitted into the ordinary routine budget, so will Trident I be.”

In other words, the received Whitehall wisdom that Trident’s geopolitical rather than military role means that there is additional ring-fenced funding for it is simply wrong. The record shows that HM Treasury has viewed the UK nuclear weapons programme as just another military procurement programme since at least the mid-1960s. However, the corollary of this is that if MoD decides that a nuclear free-fall weapon and significantly improved conventional forces are the best method of delivering Departmental priorities, then they should be left to do so, with the funds saved staying in the MoD.
9 - Costs

A conservative cost for a UK free-fall bomb capability based on the F-35C / B61-12 combination, and operating from land bases and the Queen Elizabeth-class aircraft carriers is indicatively £16.7bn, as detailed in Table 3. This includes the cost of converting both of the Queen Elizabeth-class carriers to catapult launch and arrested landing configuration, significantly increasing their operational flexibility and their conventional power-projection capabilities.

Further conventional enhancements paid for by the needs of the nuclear mission come from the purchase of E-2D Advanced Hawkeye AEW&C, C-2A Greyhound COD transports, land-based MPA / MMA, and five new evolved Astute-class SSNs to ensure the long-term viability of the UK submarine industrial base.

Table 3

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (£bn*)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 UK B61-12 derived nuclear weapons @ ceiling price of US$60m / weapon</td>
<td>3.0</td>
<td>This ceiling price is twice the maximum unit price of US B61-12 production.</td>
</tr>
<tr>
<td>CATOBAR conversion of two Queen Elizabeth-class aircraft carriers</td>
<td>4.2</td>
<td>£2.0bn estimate for one carrier conversion in 2012 deflated to £2.1bn in 2014. Significant enhancement to Queen Elizabeth-class conventional capabilities.</td>
</tr>
<tr>
<td>F-35B to F-35C conversion</td>
<td>-1.2</td>
<td>At $156.8m F-35B is $14.2m more expensive per aircraft, than the F-35C. Saving computed over 138 aircraft buy.</td>
</tr>
<tr>
<td>F-35C nuclear avionics conversion</td>
<td>0.2</td>
<td>Assumes $350m cost of conversion of F-35C as F-35A and no cost-sharing</td>
</tr>
<tr>
<td><strong>Purchase of Astute-class boats 8 – 12</strong></td>
<td>≤5.0</td>
<td>Assumes maximum cost of £1.0bn per SSN. Savings to come from ordering all five at a faster production drumbeat. Does not assume any further savings from increased production to meet export orders.</td>
</tr>
<tr>
<td><strong>Purchase of Type 26 frigate hulls 14 – 17</strong></td>
<td>2.0</td>
<td>Assumes that Type 26 meets its target unit cost of £0.5bn.</td>
</tr>
<tr>
<td><strong>E-2D Advanced Hawkeye AEW x 6</strong></td>
<td>0.9</td>
<td>Assumes no savings from Crowsnest cancellation.</td>
</tr>
<tr>
<td><strong>C-2A Greyhound Carrier On-board Delivery (COD) x 4</strong></td>
<td>0.2</td>
<td>Includes conversion to single-point AAR tankers.</td>
</tr>
<tr>
<td><strong>Long-range Maritime Patrol Aircraft (MPA) x 8</strong></td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td><strong>Conversion of Voyager KC2/KC3 to include centreline refuelling boom and to receive fuel in-flight</strong></td>
<td>0.7</td>
<td>Cost limit of £50m per airframe</td>
</tr>
<tr>
<td><strong>UK nuclear infrastructure (C2, physical)</strong></td>
<td>≤1.0</td>
<td>This centres on the reactivation of nuclear C2 and associated storage facilities at RAF Marham, Norfolk.</td>
</tr>
<tr>
<td><strong>Maximum cost of free-fall option</strong></td>
<td>≤16.7</td>
<td></td>
</tr>
<tr>
<td><strong>Range of likely like-for-like costs Successor-class costs</strong></td>
<td>24.8 – 33.1</td>
<td>2005 prices discounted to 2014 prices inflated by Astute experience (30.4%)</td>
</tr>
<tr>
<td><strong>a/w spent by 2016</strong></td>
<td>3.3</td>
<td>December 2014 update to Parliament</td>
</tr>
<tr>
<td><strong>Gross savings from Successor cancellation</strong></td>
<td>21.5 – 29.8</td>
<td></td>
</tr>
<tr>
<td><strong>Net savings from free-fall option</strong></td>
<td>4.8 – 13.1</td>
<td></td>
</tr>
</tbody>
</table>

* In 2014 pounds using HM Treasury deflators. Rounded up to the nearest single decimal place. Amounts may not add to 100% due to rounding.  

* Estimated Type 26 unit cost in 2014 pounds.  

† Given the need to modify the F-35A for NATO nuclear-sharing, cost sharing is likely. As a result, this is likely to be a significant over-estimate of the conversion cost.  

‡ Based on 2013 E-2D Advanced Hawkeye Aircraft (E-2D AHE) Selected Acquisition Report PAUC, 16 April 2014. Crowsnest is a surveillance radar system to be carried aboard RN Merlin HM2 helicopters to provide airborne early warning. Main Gate is expected in 2015, and Crowsnest is expected to cost between £230 – 500m. As it is not clear what savings would accrue from cancellation, none are assumed for these current purposes.  

Ω Costings based on Boeing P-8A Poseidon.  

GBP 1 = USD 1.68 (10 Jun 2014)
These estimates are deliberately conservative. This model assumes that:

1. the UK alone will bear the full cost of modifying the F-35A for B61-12 carriage to the F-35C, despite the fact that considerable amounts of the work for F-35A should be able to be read across given the similarities of the design, and the fact that the total costs of F-35A nuclear conversion would likely be shared by the USAF and NATO;

2. no savings are realised from cancelling the Crowsnest radar system when it is replaced with E-2D Advanced Hawkeye;

3. no savings are realised from cancelling the planned overhauls of the Vanguard-class SSBNs; and

4. no savings are realised from closing RNAD Coulport.

Similarly, to account for the cost of starting UK production of an anglicised B61-12 bomb, UK production is assumed to be up twice the cost of US produced B61-12s, pricing 100 warheads at £3.0bn. It is not known how much it would cost to provide nuclear command and control (C2) for a free-fall force, but interviewees suggested that allocating £1bn for C2 plus rehabilitation of the WS3 and SSA facilities at Marham and the Honington SSA “should be ample”.

Switching to the CATOBAR F-35C from the STOVL F-35B offers superior VfM in three ways. First, as the US Government Accountability Office showed in 2014, at $142.6m per aircraft the F-35C is 9.1% cheaper than the F-35B. On a 138 aircraft buy, this change saves £1.2bn. Second the F-35C is simpler and cheaper to run; the MoD in SDSR10 estimated that F-35C through-life costs are approximately 25% lower than the F-35B. Third, the F-35C is more capable, offering a 31% improvement in operational radius and 9% increase in payload at maximum fuel over the F-35B, significantly increasing its utility in the conventional role.

Given that B61-12 programme is proceeding and will be fielded from 2020, it is hard to envisage that if the TAR were repeated it would reach the same conclusions. As the TAR demonstrates, minus the interim two boat SSBN requirement, JSF with a new supersonic cruise missile is already cheaper than three or four SSBNs; removing the costs of the missile and warhead makes the free-fall B61-12 option cheaper still. Crucially, as the UK is procuring F-35s, dual-capable operation effectively allows the nuclear deterrence mission to free-ride on the conventional mission, rather than requiring a very expensive single-role platform which itself is heavily reliant on other enabling assets.

Therefore, not only would this change in policy significantly enhance the UK’s conventional strike capability, recycling the savings of £4.8 – 13.1bn
into the MoD procurement budget would allow for the recapitalisation of the UK’s conventional forces over the next 15 years.

**Free-fall’s disarmament impact**

Unlike the Liberal Democrats “Trident Lite” proposal, the free-fall option represents a genuine and significant step down in nuclear capability whilst making future disarmament and verification much easier. In retaining a functional nuclear weapons system, not only does it provide a deterrent capability, but it also provides something to barter away in future disarmament negotiations. Free-fall weapons also offer the possibility of international verification procedures without compromising the overall nuclear mission; fundamentally, it is much easier to use the existing inspection regimes than creating new, intrusive on-demand inspection regimes at HMNB Clyde, Faslane / RNAD Coulport to demonstrate the UK SSBN’s warload at the time of sailing, interrupting sensitive SSN operations.

Moreover, the free-fall option achieves this whilst maintaining the AWE infrastructure, the UK submarine industrial base and the fissile material stocks. This combination of expertise and material provides the UK with the ability to return to Trident if there is a significant and permanent worsening of international relations in the form of a new Cold War.

As such, a free-fall option carried by F-35C achieves all of the things that the Liberal Democrats’ “Trident Lite” policy claims, but fails, to achieve. It is a genuine reduction in the UK’s nuclear capacity without being unilateral disarmament; it considerably enhances the UK’s conventional power projection capabilities, whilst also providing very substantial savings to modernise our conventional forces and simplifying international verification of our nuclear forces in future.
10 - Recommendations

The UK faces a series of increasingly unpalatable choices over the next decade over about how to afford a stabilising global conventional role delivered in concert with our American, Commonwealth, and NATO allies, as well as our European partners.

In delivering the optimal UK outcome given the continuing austerity dictated by the national fiscal circumstances, it is hard to argue that the Conservatives’ like-for-like Trident replacement or the Liberal Democrat’s “Trident Lite” proposals are credible. Both are predicated on an extremely expensive single-role asset dedicated to a mission that was conceived when there was a credible conventional and nuclear threat to the UK. As SDSR10 acknowledges, “No state currently has both the intent and the capability to threaten the independence or integrity of the UK.”

Instead, CentreForum recommends fielding a free-fall nuclear capability using an anglicised B61-12 free-fall thermonuclear bomb from the UK’s forthcoming F-35 force. In addition to the providing the nuclear force, the capital cost of the nuclear force significantly enhances the UK’s conventional power projection capabilities by:

- converting the UK JSF order to the longer-ranged, more capable, less complex and less expensive to buy and operate F-35C;
- converting the Queen Elizabeth-class aircraft carriers to conventional take-off but arrested landing configuration to operate F-35C;
- adding six E-2D Advanced Hawkeye AEW and four C-2 Greyhound COD aircraft to operate from the Queen Elizabeth-class;
- reinstating a UK MPA / MMA capability through at least eight P-8 class MPA / MMA;
- enhancing the RN’s submarine capability through purchasing an additional five Astute-class SSNs;
- enhancing the RN’s surface fleet with four additional Type 26 frigates;
Retiring Trident

- converting the RAF’s Voyager in-flight refuelling tanker transports to receive and supply fuel in-flight using the flying boom refuelling method;
- providing UK sovereign in-flight refuelling capability for RC-135W RIVET JOINT and C-17A Globemaster III aircraft for the first time, allowing sovereign global operations;

Additionally, these investments:
- promote interoperability with our immediate European NATO allies;
- mark a clear step down the nuclear ladder by retiring the UK’s ballistic missile force; and
- provides greater flexibility over the UK’s nuclear posture and simpler verification of disarmament.

Finally, in addition to all of the above benefits, these recommendations provide a capital fund of £4.8 – £13.1bn to modernise the UK’s conventional forces between 2016 and 2032.

This proportionate proposal ensures that the UK can continue to hold states of concern at risk of nuclear retaliation, whilst providing the capital to invest in the conventional forces to ensure that the UK can continue to play a worldwide conventional role.

Recommendations
- Scrap the Successor-class SSBN producing gross capital savings of between £21.5 – 29.8bn;
- Procure 100 anglicised B61-12 free-fall nuclear weapons;
- Offer to share the hosting of NATO’s forthcoming B61-12 free-fall nuclear weapons at RAF Lakenheath, Suffolk with Italian AF Base Aviano as part of NATO nuclear burden-sharing;
- Share the costs of modifying F-35C to allow for the nuclear mission with the USA and NATO’s F-35A operating NATO DCA states;
- Retrofit the Queen Elizabeth-class aircraft carriers with conventional take-off and arrested landing equipment;
- Convert UK F-35 orders from F-35B STOVL variant to F-35C CATOBAR carrier variant.
- Field anglicised B61-12 with the lead RAF F-35C squadron from land-bases from 2021;
- Field anglicised B61-12 with the lead RN F-35C squadron from the Queen Elizabeth-carriers from the mid-2020s.
Retiring Trident

- Field an additional five Astute-class SSNs in order to safeguard the submarine industrial base;
- Field an additional four Type 26 frigates to support the carrier group;
- Field six E-2D Advanced Hawkeye AEW&C aircraft to protect the UK carrier group;
- Field four C-2A Greyhound carrier capable transport aircraft to maximise UK carrier group operational flexibility;
- Convert the 14 RAF Voyager in-flight refuelling tankers to receive and to supply fuel via the high speed flying boom refuelling method;
- Field eight long-range P-8 class MPA / MMA for UK and carrier group protection missions;
- Retire the Vanguard-class SSBNs by 2024;
- Roll the net capital savings of between £4.8 – 13.1bn from the Successor programme into the re-equipping the UK’s conventional forces.
Appendix 1

Germany and NATO DCA

Germany presents a special case amongst the DCA states, as it is the only one not intending to purchase the F-35. When Germany retires its Panavia Tornados, the obvious DCA replacement option would be the Eurofighter Typhoon, although Typhoon is not currently certified to carry either B61 or any other nuclear weapon.\(^{347}\) In the medium term, Germany appears to be extending the life of a small number of Tornados to serve the DCA mission beyond 2025 “in reduced numbers.”\(^{348}\)

At some point the cost of sustaining, crewing and operating a small fleet of Tornados dedicated to the DCA mission will be more expensive than modifying the Typhoon to perform it.\(^{349}\) When this crossover point occurs is unclear, as the Luftwaffe’s low airframe utilization rates make it unlikely that additional airframes would be required to conduct the DCA mission.\(^{350}\)

However, with some commentators suggesting German reticence in adapting Typhoon to a nuclear role stems from a latent anti-nuclear position rather than technical or financial constraints, the message of German support for and commitment to DCA is decidedly mixed.\(^{351}\) This suggests three aspects to Germany’s DCA policy:

1. First, ambivalence: Tornado is a comparatively old design and is less combat effective in most scenarios than the modern Typhoon, suggesting that Berlin is only interested in doing the absolute minimum required to stay in the DCA “club”.

2. Second, that Berlin sees the DCA mission as a primarily political, rather than military, mission. If Berlin saw it in military terms, then it would use the most effective combat aircraft it has available, Typhoon; Berlin would also ensure that the Tornados have the avionics integration to allow the B61-12 to operate in precision-guided mode. It is not clear that the required adaptor / integration has been funded.

3. Third, that Berlin’s ambivalence could be sustained for an extended period, as 85 Luftwaffe Tornados are currently undergoing an extensive update.\(^{352}\) This is far more than the 46 required for DCA nuclear operations, underscoring German ambivalence over the DCA programme.\(^{353}\) Because of the current Tornado update, CentreForum assesses that Berlin can – and likely will – ignore the DCA issue until the mid-2020s, especially if the DCA B61 weapons themselves are removed from Germany.
# Appendix 2

Potential states of concern ballistic missiles theoretically capable of reaching the UK or UK basing territories.

<table>
<thead>
<tr>
<th>State</th>
<th>Designation</th>
<th>Type</th>
<th>Length (m)</th>
<th>Diameter (m)</th>
<th>Payload (kg)</th>
<th>Range (km)</th>
<th>CEP (m)</th>
<th>Propellant</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>BM-25 Musudan</td>
<td>IRBM</td>
<td>2000</td>
<td>3500</td>
<td>Solid</td>
<td>Operational</td>
<td>Theoretical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>Sejjil</td>
<td>IRBM</td>
<td>18</td>
<td>1.25</td>
<td>750</td>
<td>3000</td>
<td>Solid</td>
<td>Operational?</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>Shahab-5</td>
<td>ICBM</td>
<td>36</td>
<td></td>
<td>4000+</td>
<td>6000+</td>
<td>Solid</td>
<td>Theoretical</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>Shahab-6</td>
<td>ICBM</td>
<td>37</td>
<td></td>
<td>6000+</td>
<td></td>
<td>Solid/Liquid</td>
<td>Theoretical</td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>Jericho-2</td>
<td>MRBM</td>
<td>14.0</td>
<td>1.56</td>
<td>1,000</td>
<td>1500 – 3500</td>
<td>Solid</td>
<td>Operational</td>
<td></td>
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<tr>
<td>Israel</td>
<td>Jericho-3</td>
<td>IRBM</td>
<td>15.5</td>
<td>1.56</td>
<td>750</td>
<td>4800 – 6500</td>
<td>Solid</td>
<td>Development</td>
<td></td>
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<tr>
<td>North Korea</td>
<td>Taepodong-2</td>
<td>ICBM</td>
<td>29.00</td>
<td>2.40/1.25/0.88*</td>
<td>100 – 500</td>
<td>6000 – 9000</td>
<td>2000 – 5000</td>
<td>Solid</td>
<td>Operational</td>
</tr>
<tr>
<td>North Korea</td>
<td>Taepodong-3</td>
<td>ICBM</td>
<td>30.00</td>
<td>2.40/1.50/1.25*</td>
<td>1000</td>
<td>10000+</td>
<td>Liquid</td>
<td>Operational</td>
<td></td>
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<td>Shaheen-2</td>
<td>MRBM</td>
<td>17.2</td>
<td>1.40</td>
<td>700</td>
<td>2500</td>
<td>350</td>
<td>Solid</td>
<td>Operational</td>
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<tr>
<td>Pakistan</td>
<td>Shaheen-3</td>
<td>ICBM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Solid</td>
<td>Development</td>
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<tr>
<td>Saudi Arabia</td>
<td>DF-21</td>
<td>MRBM</td>
<td>12.3</td>
<td>1.40</td>
<td>600</td>
<td>2500</td>
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<td>Assessed</td>
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<td>IRBM</td>
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<td>2.25</td>
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<td>Type</td>
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<td>Diameter (m)</td>
<td>Payload (kg)</td>
<td>Range (km)</td>
<td>CEP (m)</td>
<td>Propellant Status</td>
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<td>3500</td>
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<td>Sejjil</td>
<td>IRBM</td>
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<td>1.25</td>
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<td>3000</td>
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<td>4000+</td>
<td>Liquid</td>
<td>Theoretical</td>
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<td>Solid / Liquid</td>
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<td>1.56</td>
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<td>15.5</td>
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<td>750</td>
<td>4800 – 6500</td>
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<td>2.40 / 1.25 / 0.88*</td>
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<td>3000 – 4500?</td>
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<td>IRBM</td>
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<td>2.25</td>
<td>2150</td>
<td>2800</td>
<td>2000</td>
<td>Liquid</td>
<td>Operational</td>
</tr>
</tbody>
</table>

* 1st Stage / 2nd Stage / 3rd Stage diameters

Source: James Martin Centre for Non-Proliferation Studies, Middlebury Institute for International Affairs at Monterey, via Nuclear Threat Initiative, NTI.org

Note: (i) A margin of appreciation has been added to take a reasonable worst case allowing for enhanced range when launched from substantially above sea level.

(ii) The principal targets used were RAF Akrotiri, Cyprus and PJOB Diego Garcia, BIOT.
Appendix 3

Worked example for F-35C/B61-12 attacking a target against a target defended by a co-located S-400 Triumphf (SA-21 GROWLER) brigade

Assumptions:
- Target is coastal, and approach is made over the sea., meaning that no terrain masking is available once over the radar horizon;
- 92N2E GRAVESTONE (fire control) radar mounted on a 40V6M semi-mobile mast (Height = 23.8m/78.1ft);
- Radar has an unobstructed field of view;
- F-35C ingress at 1026 knots (M1.6, 528m/s) around 44kft;
- Forward hemisphere F-35C RCS 0.0015m²; implied GRAVESTONE ingress detection range without ECM is 46.3km;
- Time between detection and weapon release is 5.6 seconds;
- Weapon release at 45kft, 43.4km from target, speed M1.6 (528m/s), attitude 45 degrees nose up;
- One or two B61-12s are released simultaneously. If two weapons are carried, they will be targeting different Designated Points of Impact (DPI).

Engagement
- Weapon ballistic range before aerodynamic lift and drag: 43.4km; TOF c. 120 seconds, apogee 68,300ft.
- We assume that the opening of the bomb-bay doors and the change in aspect increased will make the F-35C detectable at the point that the bombs are dropped.
- F-35C immediately initiates max-rate (7.5g) descending 180 degree turn to low level at constant maximum Mach number (M_{Ne}). For modelling purposes, we assume that M_{Ne} at sea level (M1.06, 700 knots) is maintained through the descent. In reality, as the M_{Ne} varies with altitude, the descent may be a little faster than we have modelled.
- At an instantaneous rate of turn of 15 degrees per second, the aircraft will continue towards the target for six seconds post release, making the point of closest approach is 38.5km. This also assumes that the M1.6 is maintained through the first half of the turn (taking the aircraft closer to the target) and the slower speed for the recovery. As a result, the results are slightly biased in favour of the defender.
Further analysis may show that it is more aerodynamically efficient – and may be faster – to pitch the nose of the aircraft down through 155 degrees and begin the recovery inverted, rolling upright during the descent to the egress altitude.

Appendix 3 Figure 1: Russian X-band engagement radar detection range

Source: http://www.ausairpower.net/APA-Engagement-Fire-Control.html

Outcome:

- F-35C will be detected shortly before weapon release, but GROWLER cannot shoot the aircraft down before the weapons are released.
- Assuming a 5-second reaction time from detection to missile firing, the first missiles will be launched 0.6 seconds before the weapons are released.
- The pitch up from level flight to 45 degrees nose-up at 45 kft is only long enough to allow the weapon release on that vector; the aircraft will begin to bleed energy rapidly (which is helpful as it will allow it to turn more tightly and egress sooner);
- F-35C tail aspect detectable to 40nm (74.1km); radar horizon at 50ft AGL = 36.2km covers egress sooner than signature reduction at $M_{\text{NE}}$ (M1.06 / 360 m/s)
Will the SA-21 shoot down the F-35C?

- The sheer kinematic capability of the SA-21’s missile families is striking: the ultra-long range 40N6E and long range 48N6E3 missiles have a top speed above M7.0; the medium range 9M96E2 averages 1000m/s through flight. As this missiles are optimised for a 20G+ endgame with active radar homing and large (possibly directional) warheads, it is assessed that endgame kinematic defeat is unlikely to succeed.

- As a result, successful defeat of SA-21 series missiles is most likely through breaking radar lock through low-level egress below the GRAVESTONE radar horizon, or by moving beyond the F-35C tail aspect detection range (40nm / 74.1km). In most cases, however, the radar horizon at low level (e.g. 100ft above ground level = 42.9km) covers egress sooner than signature reduction, even allowing for the lower MNE at low level (M1.06 vs M1.6).

- Simulations therefore suggest that there are a number of plausible escape options for F-35Cs either by a high speed egress at medium or low level.

- SA-21 missiles are radar-guided by the GRAVESTONE radar for the initial period of the engagement, updating the missile via datalink before the missiles move to their on-board radar (“go active”) for the final element of the engagement.

- Radar performance is directly correlated to power and antenna size, radars on missiles will perforce be smaller than their ground based counterparts. It is unknown when the missiles will go active, and how their on board radar will cope with the F-35C’s reduced RCS.

- The physics means that the reduced RCS even in the rear hemisphere aspect will significantly degrade active seeker performance, making active radar attacks possible only when the handoff from the GRAVESTONE to the missile occurs over very short ranges; for planning purposes, we use a (conservative) assumption of 10km. Thus scenarios that produce a loss of radar connectivity to the GRAVESTONE greater than 10km are assessed as likely to also mean that the missile’s radar is unlikely to capture and hold lock against an LO target and complete the intercept.

- In our simulations, based on a 5 second detection to missile launch reaction time, and a missile average speed of 1000m/s, miss distances of ≥5km were generated when:
- B61-12 launched at 45kft, egress height of 100ft, initial nose down angle of 55 – 75 degrees, egress speed 700 knots;
- B61-12 launched at 45kft, level turn, egress height of 45kft, egress speed 1026 knots.

Assessment:
- There are a range of credible attack profiles that utilise the F-35C’s stealth characteristics to delay detection until shortly before weapon release, allowing egress at medium or low level.
- The B61-12 RCS is unknown, and thus it is unknown how easy it would be to intercept by the defences. For heavily defended targets, the obvious riposte is to significantly increase the number of B61-12s simultaneously in flight – 80 bombs plus 40 receding aircraft targets on a range of attack profiles and egress headings would make the defenders’ task considerably more complicated.
- If priority were (correctly) given to the incoming bombs over shooting down the departing aircraft, then two 48N6E or 9M96E2 missiles should be fired against each incoming bomb. Assuming an 85% probability of kill (Pk) per missile, each double targeted bomb has a 2.25% chance of survival. If 160 SAMs are launched, this implies a near-certainty than one and high probably that two B61-12s would reach the target.
- 85% Pk is a reasonable worst-case scenario for the attackers, and it assumes that the system is working optimally, and that there are in fact sufficient missiles available to double-target each bomb. If this is not the case, or if the Pk falls because of, e.g., difficulties in tracking the low RCS, then the number of weapons reaching the target rises rapidly. For instance, if all 80 were targeted by a single missile with an 85% Pk, then 12 of the 80 B61-12s would make it to the target.
- Very low-level approach (<10m) could come under the minimum engagement height of the SA-21’s missiles, but requires c. 98 – 100 seconds (ingress / release / turn / egress) inside the radar horizon to 13km from SA-21. Whilst this shortens TOF, being exposed for that length of time within the threat zone likely offsets the improvements in weapon survivability due to shorter TOF.
**Methodological Note**

This paper builds upon the March 2012 CentreForum paper “Dropping the Bomb: A post-Trident future”, and reflects the considerable amount of policy development and official documentation over the last two years. In particular, this includes:

- British-American Security Information Council (BASIC) Trident Commission Report;
- Liberal Democrat policy adopted at Glasgow Conference, September 2013; and
- Confirmation of further spending cuts to come in the 2015 – 2020 Parliament.

This paper has also drawn on desk research, structured and semi-structured interviews with current and former officers and senior officials, policy analysts, diplomats, industry figures and academics in the UK, the United States of America and from across the EU. Special mention should be made of the contribution of discussions made possible by the Friedrich Naumann Foundation for Freedom’s Dahrendorf Taskforce on the Future of Europe, coordinated by Julie Cantalou and funded by the European Parliament through the European Liberal Forum (ELF).

This paper has been peer-reviewed by Paul Ingram, Executive Director, BASIC; Dr. Jeffrey Lewis, Adjunct Professor and Director of East Asia Non-Proliferation Program, Centre for Non-Proliferation Studies, Middlebury Institute for International Studies at Monterey, Monterey, California; Air Commodore Garry Porter RAF (Ret’d), formerly Assistant Director Transformation, NATO Joint Air Power Competence Centre and Station Commander RAF Kinloss; Dr. Nick Ritchie, Lecturer in International Security, Department of Politics, University of York. Their feedback has been invaluable, though this paper solely reflects the author’s views.

Errors and omissions are solely the author’s responsibility.
Notes


2. Based on the widely accepted £97bn though-life cost figure “In the firing line: an investigation into the hidden cost of the supercarrier project and replacing Trident”, page 11, Greenpeace, September 2009, inflated to 2014 pounds.


5. HMS Prince of Wales was initially slated to be put into mothballs or sold, but David Cameron announced in September 2014 that both UK carriers would be brought into service. See “David Cameron: HMS Prince of Wales will not be sold”, Independent, 5 September 2014.


7. CentreForum analysis detailed in Table 3.

8. Currently, Belgium, Italy, The Netherlands and Turkey are DCA states intending to operate F-35A.

9. “Carrier Strike: The 2012 reversion decision”, National Audit Office, HC 63 Session 2013-14, 10 May 2013, paragraph 1.9, page 12 provides a figure of £2.0bn in 2012, which was deflated to £2.1bn per ship in 2014.


12. Lot 5 Boeing P-8 Poseidon acquisition cost is quoted as $150m per aircraft per Captain Scott Dillon US Navy at Farnborough 2014. See “Boeing P-8 May Have Inside Track in UK, Eventually”, Chris Pocock, AlNonline, 18 July 2014.


16. The purported Russian annexation of Crimea is widely held to be a violation of international law’s restrictive approach to remedial secession, under which annexation can only be considered as a remedy against oppression and violation of human rights of a minority population; there was no evidence that the Ukrainian government has denied internal self-determination to the Crimea, and therefore that remedial secession was the appropriate response. The “referendum” conducted under Russian military occupation has no legal standing. See “What do Russian Lawyers Say about Crimea?”, Anton Moiseienko, Opinio Juris, 24 September 2014; “Ukraine Insta-Symposium: Crimea, Ukraine and Russia: Self-Determination, Intervention and International Law”, Kristin Hausler and Robert McCorquodale, Opinio Juris, 10 March 2014.


21. SDSR10 paragraph 3.2, page 37 notes that “no state currently has both the intent and the capability to threaten the independence or integrity of the UK.”

CentreForum does not accept that ISIL is a state, and therefore abjures their favoured nomenclature of “Islamic State”.


The first American warhead design passed to the UK was the W-28, which was anglicized as RED SNOW, and was first used in the YELLOW SUN Mark 2 thermonuclear free-fall weapon. See “Nuclear Diplomacy and the Special Relationship”, page 92.


NPT Article I states that, “Each nuclear-weapons State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapons State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.” As both the UK and the US are recognised by the NPT as nuclear-weapons states, the NPT’s additional limitations on design and manufacturing assistance to non-nuclear-weapons states do not apply to the MDA, allowing the transfer of non-nuclear components of nuclear weapons.


CentreForum analysis of HM Treasury Budget 2014.


“Dropping the Bomb”, pages 48 – 49. 2032 assumes that there will be four SSBNs procured and “late 2020s” covers the Liberal Democrat position of two or three SSBNs being procured. Notably, as most of the cost in the early years is for design and engineering, the limited construction savings from procuring less than four SSBNs accrue at the end of the programme.

Formally, the Trident II D5 Life Extension (LE) missile will serve until 2042. However, Trident II DSLE Submarine Launched Ballistic Missiles (SLBM) are expected to serve beyond 2050.


“After years of military cuts, can Britain still defend itself?”, Con Coughlin, Daily Telegraph, 2 February 2015.


Transcribed from image of the “National Policy Forum”. Any errors are solely the author’s responsibility.

Transcribed from image of the “National Policy Forum”. Any errors are solely the author’s responsibility.


The number of SSBNs the Liberal Democrats are proposing to procure remains unclear at the time of writing.

Notably, both of these steps could be taken today, extending the life of the current Vanguard-class SSBNs, but it is noteworthy that the Liberal Democrats have not proposed this.

46 The length that CASD could be sustained for would depend on the number of SSBNs procured. For an excellent analysis of the choices, see “A Disturbance in the Force”, Hugh Chalmers, RUSI, 31 January 2014, pages 7 – 8.

47 This is either both of two SSBNs or two of the three SSBNs.

48 Whilst the warheads themselves are independently targetable, they needs to fall within an ellipse known as the “MIRV footprint”. The size of the Trident II D5 footprint is not public, but it is known that the ellipse is lengthened for longer-range launches. “The Future of the British Bomb”, John Ainslie, WMD Awareness Programme, 2006, pages 79 – 80.

49 Trident II D5 is very accurate, but absolute accuracy varies based on range, weather conditions and the re-entry profile flown by the warheads. See “The Future of the British Bomb”, pages 79 – 80. Though the US Mark 5 Re-entry Vehicle (RV) with the US 475kt W-88 warhead is not used by the UK in the hard-target counterforce role, it is noteworthy that the Mk. 5 has a stable nosetip design to reduce accuracy degradation when passing through snow or rain in contrast to the Mark 4 in UK service. See “From Polaris to Trident: the Development of US Fleet Ballistic Missile Technology”, Graham Spinardi, Cambridge University Press, Cambridge, 1998, page 153.

50 Weapon accuracy is measured in “Circular Error Probable” (CEP). This is a circle into which 50% of functional drops will fall, and is usually measured in meters. When a weapon suffers a technical malfunction after release, it is not recorded in the CEP calculation.


54 Stewart Hosie MP (Dundee East), Angus MacNeil MP (Na h-Eileanan an Iar / Western Isles), Angus Robertson MP (Moray), Michael Weir MP (Angus), Pete Wishart MP (Perth and North Perthshire), Eilidh Whiteford MP (Banff and Buchan).

55 “Nicola Sturgeon sets out her conditions for an SNP deal with Labour”, George Eaton, New Statesman, 15 November 2014.

56 “Nicola Sturgeon sets out her conditions for an SNP deal with Labour”, George Eaton, New Statesman, 15 November 2014.


58 “Relocation, Relocation, Relocation”, page 12.

59 Jonathan Edwards MP (Carmarthen East and Dinefwr), Elfyn Llwyd MP (Dwyfor Meirionnydd), Hywel Williams MP (Arfon).

60 Target seats are Ynys Môn (Anglesey) and Ceredigion.


62 “Plaid Cymru on Trident”, Democracy Live, BBC, 4 July 2012.

63 Douglas Carswell MP (Clacton), elected on 9 October 2014, and Mark Reckless MP (Rochester and Strood), elected on 20 November 2014.

64 “Ukip is making British politics more European”, Peter Kellner, YouGov, 24 November 2014.


67 Dr Caroline Lucas MP (Brighton Pavilion).

68 Green Party is targeting Norwich South (Liberal Democrats), Bristol West (Liberal Democrats), St. Ives (Liberal Democrats), Sheffield Central (Labour), Liverpool Riverside (Labour), Oxford East (Labour), Solihull (Liberal Democrats), Reading East (Conservative), York Central (Labour), Holborn and St Pancras (Labour), Cambridge (Liberal Democrats). See “Confident Greens eye 12 seats in England”, Toby Helm, The Observer, 19 October 2014.
69 “The Andrew Marr Show Interview: Natalie Bennett, MP Green Party Leader” (transcript), BBC, 18 January 2015, page 5. NB, the transcript wrongly identifies Ms Bennett as an MP; the Green Party’s only MP in the 2010 – 15 Parliament is Dr Caroline Lucas, MP for Brighton Pavilion.

70 “The Andrew Marr Show Interview: Natalie Bennett, MP Green Party Leader”, page 5.


72 Interview I, July 2014


75 General Sir Nicholas Houghton, GCB CBE ADC Gen said: “Secondly, the active or operational use of our Armed Forces in Iraq and Afghanistan has blinded some people to the wider utility of our Armed Forces – which, in many respects, exist not to fight conflicts, but rather to preserve peace and stability, albeit through the credible threat of the use of force, through the mechanism we call deterrence.” See “Annual Chief of the Defence Staff Lecture”, RUSI, London, 17 December 2014.

76 “Nuclear Deterrence Theory”, page 32.


79 The destruction of the UK in the event of a strategic nuclear exchange was certainly assumed by at least some of the RAF crews called to cockpit alert (less than five minutes to launch) on the afternoon of Saturday 27 October 1962 at the height of the Cuban Missile Crisis. See recollections of Air Chief Marshal Sir John Willis, “An International History of the Cuban Missile Crisis: A 50-year retrospective (Studies in Intelligence)”, Robin Woolven, edited by David GIOE, Len Scott and Christopher Andrew, Routledge, London, 2014, page 183.


81 See e.g., “Nuclear Deterrence Theory”, page 7; “Deterrence”, pages 27 – 28.

82 “Deterrence”, page 117.

83 “Deterrence”, pages 29 – 32.

84 “Deterrence”, page 85.

85 It is assumed that the UK is not expecting to use nuclear deterrence against nuclear-armed non-state actors that do not exercise control over territory, as nuclear retaliation needs to destroy physical targets. For the hypothetical case of nuclear armed non-state actors that do exercise substantive control over territory – for example, ISIL in Syria and Iraq at the time of writing – it is assumed that such an entity will be deterred as if they were a normal nuclear state.

86 Interview M, December 2014.

87 “Deterrence”, page


89 Article V of NATO’s founding document, the 1949 North Atlantic Treaty (Washington Treaty) states “The Parties agree that an armed attack against one or more of them in Europe or North America shall be considered an attack against them all and consequently they agree that, if such an armed attack occurs, each of them, in exercise of the right of individual or collective self-defence recognised by Article 51 of the Charter of the United Nations, will assist the Party or Parties so attacked by taking forthwith, individually and in concert with the other Parties, such action as it deems necessary, including the use of armed force, to restore and maintain the security of the North Atlantic area.” See generally “A short history of NATO”, NATO, 2 December 2014. Article V has only been invoked once since 1949, in the aftermath of the 11 September 2011 terrorist attacks on the United States, which saw the NATO Airborne Early Warning Force from Geilenkirchen, Germany deployed to the USA and subsequently to Afghanistan. See “Target Lock: Boeing E-3 Sentry – Squadron Service NATO”, Target Lock, 18 January 2015.


Countervalue strategy holds at risk those targets a potential adversary values, and is the essence of deterrence. By contrast, counterforce is the attempt to achieve a “disarming first strike” against a potential adversary’s nuclear forces, robbing them of the ability to launch a devastating counter-attack. As such, it is closely associated with the notion of fighting — and winning — a nuclear war. See “Living with Nuclear Weapons”, Harvard Nuclear Study Group, Harvard University Press, Cambridge MA, 1983, page 92. The Harvard Nuclear Study Group consisted of Albert Carmesale, Paul Doty, Stanley Hoffman, Samuel P. Huntington, Joseph S. Nye, Jr. and Scott D. Sagan.

Cited in “Unacceptable Damage”, page 18, a 1976 draft minute to the Defence Secretary expressed the criterion as “we must be certain of being able to inflict unacceptable damage on Moscow as the seat of the highly centralised Soviet Government system”, In December 1959, it was estimated that Moscow required four 1 Mt warheads to achieve destruction of 50 per cent of the buildings in metropolitan area. See “Nuclear Diplomacy and the Special Relationship”. See e.g., “Why the Trident debate is (largely) one about symbolism”, Mark Urban, Newsnight, BBC, 21 April 2010.

Now Baron Owen of the City of Plymouth CH PC FRCP MB BChir.

Counterforce is a nuclear strategy that emerged from SAC in the Eisenhower Administration as part of their 1954/55 “New Look”. Counterforce is a first-strike doctrine under which one side attempts to destroy an opponent’s ability to strike back by destroying all (or almost all) of their nuclear capability, and in the process to provide the opportunity to win a nuclear war. Even after the emergence of highly survivable second-strike forces (notably SBLMs on SSBNs), counterforce continued to enjoy some support as it avoided the massive destruction of an all-out attack on an adversary’s cities (so called countervalue targets). Counterforce was renamed “damage limitation” under the Reagan Administration, reportedly because “counterforce” sounded “too aggressive”. See “Command and Control”, Eric Schlosser, The Penguin Press, New York, 2013, pages 131, 133, and 434.


MX (Missile eXperimental) was the development programme for what became the LGM-118 Peacekeeper, a solid-fueled ICBM capable of carrying up to 12 W87 300kt warheads 5200nm with a CEP of 90 meters. LGM-118 entered USAF service in 1986 at F. E. Warren Air Force Base, Wyoming, in modified LGM-30 Minuteman silos, and was retired in 2005. See “LGM-118 PEACEKEEPER”, MissileThreat.com, accessed 31 January 2015.

Polaris A3 in USN service carried a W58 warhead with a nominal yield of 200kt; the RN initially used the ET.317 warhead (a UK W58 / W59 hybrid warhead) of 200kt nominal yield, before moving a 225kt variant in the Chevaline warhead. Poseidon C3 used W68 warheads with a nominal yield of 40kt. Trident I C4 used the W76 warhead of 100kt nominal yield, which is the basis for the UK
Trident warhead. In USN service, Trident II D5 uses a combination of W76 series warheads, and W88 warheads with a nominal yield of 475kt; the UK uses only a British version of the 100kt W76 warhead. See “From Polaris to Trident”.

112 “From Polaris to Trident”, pages 151 – 154.

113 Though as shown in “Unacceptable Damage” pages 31 – 35, Duff Group Option 1 was in effect leadership counterforce, and required a high level of precision to destroy the Soviet Union’s hardened leadership bunkers in and around Moscow.


116 See note 46.

117 A 500 rem does will result in 50% and 90% mortality from acute radiation effects alone.

118 A 5-psi airblast will cause most residential buildings collapse, injuries are universal, and will result in widespread fatalities.

119 Third degree burns extend throughout the layers of skin, and are often painless because they destroy the pain nerves. They can cause severe scarring or disablement, and can require amputation.

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120 Data and mapping courtesy of Alex Wellerstien’s Nukemap 2.42 model. See: http://nuclearsecrecy.com/nukemap/.

121 CentreForum analysis based on data and mapping from Alex Wellerstien’s Nukemap 2.42 model. See http://nuclearsecrecy.com/nukemap/?t=b12b0958babff1ecf66df01aa524e695, which suggests that delivering 14 100kt UK W76 Trident warheads against these cities would result in 1.004m deaths and 2.371m injuries.

122 Trident II’s predecessor in USN service was the UGM-73 Poseidon, which carried up to 14 MIRVs. The size of the Poseidon MIRV ellipse – defined by the cross-range manoeuvring capability- varied according to the range and number of warheads. Poseidon with 14 warheads at 1800nm offered almost no cross-range capability, making it an analogue of a Polaris A3 MRV; mounting 10 warheads at 2500nm offered cross-range capability of 150nm, and with six warheads at 3000nm, cross-range capability increased to 300nm. See “From Polaris to Trident”, page 107.

123 Data and mapping courtesy of Alex Wellerstien’s Nukemap 2.42 model. See http://nuclearsecrecy.com/nukemap.

124 Estimates from Alex Wellerstien’s Nukemap 2.42 model, available at http://nuclearsecrecy.com/nukemap/?t=8c2dd5a4d70ca1cd3d05155b46cc

125 Estimates from Alex Wellerstien’s Nukemap 2.42 model, available at http://nuclearsecrecy.com/nukemap/?t=2079f72bcbff4a98f7c05a8a4abf7a7

126 “Nuclear Deterrence Theory”, pages 7 – 9.


128 “Deterrence”, page 121.

129 “Deterrence”, page 71.

130 “Deterrence”, page 70.

131 “Deterrence”, pages 71 – 73.


Retiring Trident

148 The RAF has used English Electric Canberras, Vickers Valiants, Avro Vulcans, Handley-Page Victor, Blackburn Buccaneers, McDonnell-Douglas Phantoms, SEPECAT Jaguars, BAe Harriers and Panavia Tornados for both conventional and nuclear roles between 1956 and 1998. The RN FAA used RED BEARD and WE177A/B/Cs from Vickers-Supermarine Scimitar, de Haviland Sea Vixen and Blackburn Buccaneers, BAe Sea Harrier Is in the carrier-borne nuclear role.
150 WE.177 was a family of three designs for land-based and ship-borne use, with yields across the family varying from 0.5 kilotons (kt) to 450kt, based on US designs supplied through the MDA information exchange, WE.177 entered RAF service in 1966, and was retired by the RAF in 1998. WE.177A had variable yield of 0.5kt or 10kt; WE.177B had a fixed yield of 450kt; WE.177C had a fixed yield of 190kt. That is, WE.177A could deliver the equivalent of 500 or 10,000 tons of TNT; WE.177B would deliver the equivalent of 450,000 tons of TNT; WE.177C would deliver the equivalent of 190,000 tons of TNT. By comparison, the “Little Boy” bomb that destroyed Hiroshima had an explosive yield of 16kt. On retirement, see Strategic Defence Review 1998, ‘Modern forces for a modern world’, Ministry of Defence, CM 3999, July 1998, paragraph 62; more generally see: http://www.nuclear-weapons.info/vw.htm#WE.177
153 See the discussion of NPT Article I at endnote 27.
154 See: http://www.nuclear-weapons.info/vw.htm#WE.177
155 See “F-35 Joint Strike Fighter (JSF) Lightning II”, GlobalSecurity.org
157 Interview E, July 2014.
159 “Feinstein: Cost of B61 Warhead Modernization Doubles”, Jen DiMascio, Aviation Week, 26 July 2012
161 If the B61-12 option was not available, then the modernised WE.177 option could be taken with, though on the basis of the information available, it is likely to be more expensive than an anglicised
B61-12, though there is no reason to suspect that it would be the same price as the Trident-based options.

162 Eurofighter Typhoon has a ground-attack capability, but the design is optimised as an air superiority fighter. Operated with F-35s, it is anticipated that Typhoons will perform an air-to-air role to achieve at least localised air superiority to provide the F-35s the best opportunity of achieving their ground attack mission objectives.


164 JSF was initially a competition between concept demonstrators from Boeing (X-32) and Lockheed Martin / Northrop Grumman / BAE Systems (X-35). The Lockheed Martin-led team was selected on 26 October 2001. See http://www.jsf.mil/history/his_jsf.htm and http://www.jsf.milli/history/his_f35.htm.


166 “UNITED KINGDOM, A Legacy of Innovation” Lockheed Martin, accessed 14 January 2015.


168 The decision to revert to the F-35B disappointed many because of the reduction in capability it entailed, both as a platform and that the abandonment of CATOBAR operations precluded carrier-based fixed wing AEW or COD. See, e.g., “The United Kingdom’s Future Carriers”, Rear Admiral Christopher Parry RN (Ret’d), RUSI Journal, Volume 157 Number 6, 19 December 2012, pages 6 – 7.

169 “Carrier Strike: The 2012 reversion decision”, paragraph 1.9, page 12.


173 It is important to note than an aircraft’s RCS depends on in which direction the radar is looking at the aircraft, known as the aspect. The F-35 has the lowest RCS when viewed from the frontal aspect (open source estimate of 0.0015m$^2$), but has a much higher rear aspect RCS (0.01m$^2$).


176 Interview C, June 2014.

177 SDSR 2010, page 23.


180 See, e.g., “Harrier dispute between Navy and RAF-chiefs sees Army ‘marriage counsellor’ called in”, Thomas Harding, Daily Telegraph, 4 February 2009

181 “Written evidence from Admiral Sir John Woodward GBE KCB and colleagues”, Appendix 1, paragraph 30.

182 For example, the F-35C will have to fulfil a Fleet air defence (AD) role, even though it is not optimised for air-to-air combat as the Typhoon FGR4 is. Consequently, whilst RAF F-35Cs will be predominately used in the deep strike role with very little AD tasking replacing Tornado GR4, FAA F-35Cs will have to conduct a significant amount of AD training.

183 See, e.g., “Winging Friday at NAS Meridian”, Meridian Star, 20 December 2012


185 This 1.5 crews / aircraft ratio reflects historical fast-jet norms. However, given the difficulties that the RN had in manning FAA and JFH squadrons, increasing the available number of qualified aircrew to meet this size of force is likely to constitute a significant challenge for the RN.

186 Historically, the FAA has usually assigned six – eight aircraft per fast jet squadron, in contrast to the
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RAF’s norm of 10 – 12. Allowing for a contribution to the maintenance margin and trials work, 60 FAA F-35Cs would likely translate into 48 front line aircraft, enough to equip six typical FAA squadrons, equating to five frontline squadrons and a training unit.

For brevity’s sake, this paper will refer to the DCA B61 arsenal generically as “B61s” irrespective of the particular Mod available at each base.


On specific European government positions before 2012, see, “U.S. Warheads in Europe: Forward Basing Is Too Base and Forward to Tolerate”, John LaForge, Duluth Reader, 5 April 2012. “Some authors provide a limited operational rationale for the B61s. In the view of Perkovic, Chalmers et al, “Our understanding is that the role of nonstrategic nuclear weapons is now seen within NATO as providing the Alliance with a limited and uniquely configured shared initial nuclear capability. In extreme circumstances of collective self-defense, the combination of DCA with U.S. B61 bombs would allow NATO to decide, by consensus, to cross the nuclear threshold in a manner that was not purely demonstrative. Such a use of nuclear weapons would involve a target, or targets, on the territory of an aggressor but could be observably limited. The preparatory and decisionmaking steps leading up to such use would signal allied resolve to escalate further if necessary, while the combination of weapons and delivery systems would be least likely to be mistaken as forming part of a full-scale nuclear response with strategic forces.

The collective nature of the initial nuclear response with nonstrategic nuclear weapons would be further emphasized by conventionally equipped aircraft from many Alliance nations flying to support it: the Support of Nuclear Operations with Conventional Air Tactics, or SNOWCAT, mission. The nonstrategic nuclear weapons capability is therefore intended to provide an inseparable mix of operational and political utility.” See “Looking Beyond the Chicago Summit: Nuclear Weapons in Europe and the Future of NATO”, George Perkovich, Malcolm Chalmers, Steven Pifer, Paul Schulte, and Jaclyn Tandler, Carnegie Endowment for International Peace, Washington DC, April 2012, page 9.

NATO’s 2012 Deterrence and Defence Posture Review, 20 May 2012, paragraphs 11 and 12. It is believed that there is a 50/50 split between B61-3 and B61-4. Both are variable yield weapons (B61-3 0.3kt/1.5kt/60kt/170kt; B61-4 0.3kt/1.5kt/10kt/45kt) though the differences in maximum yield suggest that they are intended to service different targets. Source: Interview H, July 2014.


The DCA programme operates with the partner nations hosting US nuclear weapons and providing the dual-capable aircraft, crews, bases and base physical security. Operationally, USAF personnel from Munitions Support Squadrons (MUNSS) are responsible for the physical security, maintenance and logistics of the weapons and their associated WS3 vaults. When ordered to do so by the U.S. National Command Authority, MUNSS officers will provide the B61s to the national air forces. This is argued not to be a violation of the NPT’s prohibition on the transfer of nuclear weapons to non-Nuclear Weapons States in that this transfer would only occur following the outbreak of hostilities, when it is argued, the NPT would no longer be binding. See “U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy, Force Levels, and War Planning”, Hans M. Kristensen, Natural Resources Defense Council, Washington DC, February 2005, page 11.

See, e.g. concerns highlighted in “Looking Beyond the Chicago Summit”, page 4, page 9.

Formalised in the “Founding Act on Mutual Relations, Cooperation and Security between NATO and the Russian Federation” signed in Paris on 27 May 1997. Section IV “Political-Military Matters” states “The member States of NATO reiterate that they have no intention, no plan and no reason to deploy nuclear weapons on the territory of new members, nor any need to change any aspect of NATO’s nuclear posture or nuclear policy- and do not foresee any future need to do so. This subsumes the fact that NATO has decided that it has no intention, no plan, and no reason to establish nuclear weapon storage sites on the territory of those members, whether through the
construction of new nuclear storage facilities or the adaptation of old nuclear storage facilities. Nuclear storage sites are understood to be facilities specifically designed for the stationing of nuclear weapons, and include all types of hardened above or below ground facilities (storage bunkers or vaults) designed for storing nuclear weapons.” See “Looking Beyond the Chicago Summit”, page 13.


197 “B61-12 Nuclear Bomb Integration On NATO Aircraft To Start in 2015”, Hans M. Kristensen, Federation of American Scientists, 13 March 2014. It is understood that this will occur in two stages, with the B61-12 operating in unguided mode from F-16s and Tornados, and in guided mode when integrated with the digital avionics of the F-35A. An adaptor kit may be produced to allow Luftwaffe Tornados to operate B61-12 in guided mode at some undefined point in future. See: “Germany’s Tornado Nuclear Weapons Carrier”, Nassauer von Otfrid, Berlin Information-center for Transatlantic Security (BITS), January 2013.

198 An adaptor kit may be produced to allow Luftwaffe Tornados to operate B61-12 in guided mode at some undefined point in future. See “Germany’s Tornado Nuclear Weapons Carrier”, January 2013.

199 NATO DCA F-16s operate as follows: Belgium – 10th Tactical Wing, Kleine Brogel Airbase; Netherlands – 1st Fighter Wing, Volkel Airbase; Turkey – 9th Wing, Balikesir Airbase. See: Slide 10 “B61-12: America’s New Guided Standoff Nuclear Bomb”. Some analysts question whether the Turkish Air Force remains certified to undertake the nuclear mission, e.g. Stephane Delory in “Issues linked to B61-12 deployment in Europe”, Centre d’Etudes de Sécurité International et de Maîtrise des armements (Cesim).

200 NATO DCA Panavia PA-200 Tornados Interdictor / Strike (IDS) variants operate as follows: Germany – 33rd Tactical Air Force Wing, Büchel Airbase; Italy – 6th Wing, Ghedi Torre Airbase. See: Slide 10 “B61-12: America’s New Guided Standoff Nuclear Bomb”. Note: UK Tornado IDSs updated to GR4 standard are not certified for nuclear missions, and do not have a nuclear role.

201 Nuclear capability is due to be introduced from Block IV onwards. It is presumed that earlier F-35As could be retrofitted if required, though the costs are not known. The F-35A’s digital avionics suite will allow the introduction of the B61-12’s guided mode. “US tactical nuclear weapons in Europe, 2011”, page 71.


206 The inability of Typhoon to embark on aircraft carriers means that in the event of a total grounding of F-35C, the UK would be limited to free-fall nuclear strikes from land bases.

207 This would mirror the RAF’s expensively procured V-Force which was based around two advanced designs (Avro Vulcan and Handley Page Victor) with the less advanced Vickers Valiant to provide “insurance” in case of the failure of both advanced designs; all three entered active service. In order to insure against the failure of the insurance Valiant design, there was a fourth design (Shorts Sperrin) of which two prototypes were flown in 1951 and used for trials through the mid-1950s.


210 “U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy”, Appendix A; “The B61 family of nuclear bombs”.

211 “No Nukes At Lakenheath”, Jeffrey Lewis, ArmsControlWonk.org, 26 June 2008.

212 “Air Force Blue Ribbon Review of Nuclear Weapons Policies and Procedures”, chaired by Major


220 Interview F, June 2014.

221 Jeffrey Lewis is Adjunct Professor and Director of East Asia Non-Proliferation Program at the James Martin Center for Non-proliferation Studies for the Middlebury Institute for International Studies at Monterey, Monterey, California. He was previously the Director of the Nuclear Strategy and Non-proliferation Initiative at the New America Foundation, Washington DC.

222 Interview F, June 2014.

223 The B61-4 Type 3E training aid can mimic both B61-3, B61-4 and the now withdrawn B61-10 variants. It is presumed that a similar training aid will be created to mimic the B61-12 prior to its deployment. See “U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy”, pages 21 – 23.

224 The US WS3 nuclear vault can hold four B61s. RAF Lakenheath has 33 WS3 vaults (132 B61s) and Aviano AB has 18 WS3s (72 B61s) for a total between the two bases of 204 B61s, more than the 180 currently deployed for the DCA programme. Data from “US tactical nuclear weapons in Europe, 2011”, pages 66 – 67, page 69.


227 That is, the B61-12 will deliver the equivalent of 300 to 50,000 tons of TNT. See “B61-12: First Pictures Show New Military Capability”, Hans M. Kristensen, Federation of American Scientists, 28 February 2014.

228 The “Little Boy” bomb used against Hiroshima had a yield of 16kt.


230 Targeting an area – e.g., a city – would be illegal under the international law of armed conflict’s requirements of proportionality and discrimination between combatants and non-combatants in all but the most extreme case of belligerent reprisals. As a result, despite their unprecedented destructive power, nuclear weapons are targeted against specific military targets.

231 See “B61 LEP: Increasing NATO Nuclear Capability and Precision Low-Yield Strikes” Hans M. Kristensen, Federation of American Scientists, 15 June 2011. CEP of 30m is for a free flight of less than 100 seconds in a GPS-denied environment with positional data from the launch aircraft; a 5m CEP is possible in a non-GPS denied environment.

232 The B61-12 will use the warhead (“physics package”) of the existing B61-4. See “B61-12: America’s...
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New Guided Standoff Nuclear Bomb*, presentation by Hans. M. Kristensen, Director, Nuclear Information Project, Federation of American Scientists to Women’s Action for New Directions and Women’s Legislators’ Lobby, 30 May 2013.


239 As the Polaris A3TK Chevaline warheads were decommissioned, there was a lack of storage at RNAD Coulport and AWE Aldermaston, requiring the use of the Honington and Marham SSAs.

240 Comparing B61-12 and UK W76 at full yield, B61-12 yields 50kt and W76 100kt. See “Complete List of All U.S. Nuclear Weapons”, Federation of American Scientists, FAS.org, 14 October 2006.

241 If Typhoon is certified for B61-12 carriage to meet German DCA requirements (see Appendix 1) given a post-2019 RAF Typhoon fleet of 107 airframes of required targets would increase to 245 aircraft. In any event, a prudent adversary would attempt to destroy the RAF Typhoon force given their supporting role in an F-35C nuclear strike mission. On post-2019 RAF Typhoon numbers, see: “Management of the Typhoon Project”, Report by the Comptroller and Auditor General, National Audit Office, HC 755, Session 2010–2011, 2 March 2011, paragraph 1.12, page 21.


243 “SAC operations in the Cuban Crisis”, pages 49 – 54.

244 During the Cuban Missile Crisis, CHROME DOME involved 66, and later 76, nuclear armed Boeing B-52s continuously airborne on three tracks: northern Canada; Thule, Greenland; Spain/ Eastern Atlantic. The Thule missions were specifically designed to ensure that Thule Ballistic Missile Early Warning System station could not be destroyed undetected by a Soviet pre-emptive attack. See “SAC operations in the Cuban Crisis of 1962”, pages 36 – 49.

245 “International History of the Cuban Missile Crisis”, page 178.

246 “International History of the Cuban Missile Crisis”, page 17, page 184. Normal V-Force QRA was one crew / squadron at 15 minutes’ notice (RS15), which was sustained from February 1962 to December 1968 when QRA was handed over to the RN Polaris SLBM fleet. Very high force-wide readiness states, (e.g. whole force at RS05) could only be maintained for short periods as crew efficiency and aircraft systems would deteriorate. Recognising this, the formal limit for RS05 was four hours, though oral testimony suggests that it was held for longer than this on the afternoon of 27 October 1962. See “International History of the Cuban Missile Crisis”, page 190. The final, highest state of ground alert was Readiness State 02 (RS02), under which the aircraft had started engines and were ready to launch. Given that fuel was being consumed as the aircraft stood with their engines running, RS02 could only be held for a maximum of 30 minutes before the aircraft would be returned to their servicing areas and topped-off with fuel.

247 Recollections of ACM Sir Michael Beetham RAF, “International History of the Cuban Missile Crisis”, pages 183 and 189.

248 As Russell Leng’s work on the structure of crises shows, there is always a period of escalation. This period of escalation provides the strategic warning that the UK would need to disperse its nuclear-armed aircraft; the act of doing so whilst escalatory would provide clear political signalling that the UK was serious about defending its interests and would not be bullied into submission. See “Interstate Crisis Behaviour 1816 – 1980: Realism versus Reciprocity”, Russell J. Leng, Cambridge University Press, Cambridge, 1993, pages 15 – 19.

ORPs were constructed for the V-Force on the V-Force main bases and dispersal sites. Despite not having been used for nuclear QRA since mid-1969, ORPs are still evident on Google Earth imagery of RAF Cranwell (runway 22), RAF Coningsby (runway 25), RAF Honington (runway 27), RAF Leeming (runway 34), RAF Marham (runway 24), RAF Scampton (runway 05), RAF Valley (runway 32), RAF Waddington (runway 20), RAF Wattisham (runway 05), RAF Wittering (runway 26) and RNAS Yeovilton (runway 27).

“RAF Mildenhall to close amid other Europe consolidations” Stars and Stripes, John Vandiver, 8 January 2015.

Around 80 RAF personnel and 200 civilian staff operate the BMES radar system at RAF Fylingdales. See “RAF Fylingdales: About Us” UK MoD, accessed 15 January 2015. A “UK alone” scenario assumes that the UK would not have access to US missile launch warning from the Satellite Early Warning System (SEWS) through intelligence sharing channels; given that this would be warning of a nuclear missile launch, and with it, an existential threat to the UK it is unlikely that the US would deny the UK SEWS data. On SEWS, see “Defense Support Program (DSP) Satellites”, Fact Sheet, USAF, 11 February 2014.

RAF Marham is 1514nm from Moscow, and 833 nm from Kaliningrad. Based on “Britain and Ballistic Missile Defence”, page 91, this translates in a little over 10 minutes warning for a missile launch in the Moscow area and more than 4.2 minutes for a Kaliningrad launch, as Kaliningrad is further than the 650nm for a 1000nm range missile fired on a “low” profile. Distances courtesy of the Great Circle Mapper (www.gcmap.com), copyright © Karl L. Swartz.

Local V-Force exercises (i.e. a single station) were regularly conducted as Exercise MICK. Full-force dispersal exercises were organised under the name Exercise MICKY FINN. “International History of the Cuban Missile Crisis”, pages 189 – 190. For the whole force deployment exercise 26 – 29 October 1964, see “RAF Nuclear Deterrent Forces”, page 338. Dispersed operations were required to be self-sustaining for up to 28 days.

Boom refuelling is typically twice to three times as fast as probe and drogue refuelling. Airbus quotes maximum fuel flow rates of 4,600 litres / minute from their Air Refuelling Boom System on A330 Multi-Role Tanker Transports, and 2,250 litres / minute (centreline) and 1,500 litres / minute (wing pods) for their A400M probe and drogue tankers. See “A400M: The Versatile Airlifter for the 21st Century”, Airbus Defence & Space accessed 20 January 2015; “Aerial Refuelling Boom System [ARBS]”, Airbus Defence & Space accessed 20 January 2015.

The USN predominately uses probe-and-drogue in-flight refuelling, and therefore the F-35B STOVL and F-35C CATOBAR JSF variants are probe-and-drogue equipped. However, as the F-35A will be numerically the most common variant, demand for boom-equipped tankers for tactical aircraft in Europe is unlikely to decline.
264 UK E-3D Sentry AWACS aircraft are (together with their French equivalents) the only receivers worldwide routinely configured to receive fuel from both flying boom or hose and drogue-equipped tankers. Given the differential refueling rates, flying boom refueling is almost always preferred if a choice is available, but E-3D crews are required to remain proficient in both techniques.

265 Operation EL DORADO CANYON, was conducted by UK based USAF and carrier-based USN and USMC units early in the morning of 15 April 1986 against targets in Tripoli and Benghazi, Libya. The USAF's 18 F-111F Aardvarks and five supporting EF-111A Ravens flew from the UK via the Atlantic and the Straits of Gibraltar after transits of French, Italian and Spanish airspace were denied. See “Raid on Libya, Operation El Dorado Canyon”, Judy G. Endicott, in “Short of War USAF Contingency Operations 1947-1997”, USAF Historical Studies Office, pages 145 – 155, map page 147, discussion page 148.

266 See “Raid on Libya, Operation El Dorado Canyon”, page 148.

267 The Iberian detour forced the USAF to move a significant number of tankers to the UK from the USA at short notice, and appears to have caused some operational frictions as the then-new KC-10A Extender tankers were unfamiliar to most of the F-111F / EF-111A crews. See “Raid on Libya, Operation El Dorado Canyon”, page 151.


269 CATOBAR configured aircraft carriers can of course field organic tankers rather than relying on buddy-buddy refueling from range-limited strike-fighters. Lockheed Martin has periodically proposed rerolling surplus ex-USN S-3 Viking carrier ASW aircraft for AAR and COD roles (see e.g., “How”, Defence Industry Daily, 15 April 2014; “ADEX 2013: Lockheed Martin offers refurbished Viking aircraft to Korean and US navies”, Gareth Jennings, IHS Jane's Defence Weekly, 28 October 2013).

270 When lofted from 45kft at Mach 1.6, 85% of theoretical maximum range is estimated at 40.9km. CentreForum analysis with assistance from Dr. Jeffrey Lewis, Middlebury Institute for International Studies at Monterey, Monterey, California. See worked example at Annex 3.

271 Assumes current a typical 4th generation fighter RCS of c. 5m$^2$ and F-35 head-on aspect RCS of c. 0.0015m$^2$. Detection range data via Dr. Carlo Kopp, www.ausairpower.net/APA-Engagement-Fire-Control.html.

272 This analysis is based on radar tracking of the F-35Cs, and ignores infra-red (heat) guided missiles or IR search systems, as these systems suffer from atmospheric attenuation, largely due to water vapour in the atmosphere and are typically restricted to shorter range (<10nm) engagements.

273 By the insertion of false targets into an enemy radar picture through the use of advanced electronic warfare equipment on the F-35. See General Mike Hostage USAF in “A God's eye view of the battlefield”, Colin Clark, BreakingDefense.com, 6 June 2014.

274 Comprising eight battalions to a maximum of 72 launchers, each armed with 4 – 16 missiles to a maximum of 384 missiles. See “Defense and Strategic Missile S-400 “Triumph””, Military News, Moscow.

275 CentreForum analysis. 90% of the 48.2km theoretical maximum range of a B61-12 launched from 45kft, 45 degrees nose up at 1026 knots / 528 meters per second (M1.6).

276 CentreForum analysis; see Appendix 3.

277 CentreForum analysis. If the $P_i$ of each missile is 85%, then the chances of both missiles missing an individual target is 15% x 15%, or 2.25%. Thus attacking each target with two missiles with an 85% $P_i$ will destroy 97.75% of the targets. Assuming 80 B61-12s are delivered, this means 1.8 bombs will survive to detonation, translating into a certainty of one bomb and a high probability of two bombs.


280 2001 oral testimony of Air Chief Marshal Sir John Willis GCB KBE FRAeS RAF, quoted in “International History of the Cuban Missile Crisis”, page 183. Willis was a 25 year-old Vulcan bomber captain serving on IX Sqn at RAF Coningsby during the 1962 alert.

281 As Major J. Scott Norwood USAF shows, attrition rates matter enormously for sustained air operations. Using the 1991 Gulf War (Operation DESERT STORM), Norwood demonstrates that an
average attrition rate of 1% per wave at of two sorties per aircraft per day, would have destroyed
56% of the percent of total USAF deployed force in 40 days; had it averaged 3% per wave, attrition
would have been 92% of the force in the same period. See “Thunderbolts and Eggshells: Composite
Air Operations during Desert Storm and Implications for USAF Doctrine and Force Structure”,
School of Advanced Airpower Studies, Air University, Maxwell Air Force Base, Alabama, September

282 On the US-led development of COMAO doctrine see “Thunderbolts and Eggshells”.
283 "RAF’s new surveillance aircraft takes to the skies”, Ministry of Defence, 27 May 2014.
284 Interview K, September 2014.
285 CentreForum analysis based on leaving the tanker outbound with full tanks at 1500nm from base /
1000nm from target with inbound tanking from 750nm from target.
286 "UK to study F-35C 'buddy' refuelling”, Philip Ewing, DoD Buzz Online Defense and Acquisition
287 CentreForum analysis. The number of strike aircraft required drives range; the more strike aircraft
required, the fewer able to act as buddy-buddy tankers. Under some scenarios it is possible for a
small number of strike aircraft to be extended to 1250nm radius of action without land-based AAR
support, though we have not found a target set that would require this.
288 Using the C-2A Greyhound as an AAR tanker would represent a new role for the aircraft. Based on
CentreForum analysis of available open-source performance data, it is estimated that a single C-2A
could offload 10 – 12,000lb of fuel at 450nm from the carrier. Though AAR would represent a new
role of the C-2, as the UK’s own experience in the rapid conversion of Hercules C1s to Hercules C1K
tankers during the Falklands War shows, the requirements are well understood and it is unlikely to
present a major technical challenge. Interview L, September 2014. See also “Short History of the
289 CentreForum analysis; Interview M, November 2014.
290 This paper does not directly address nuclear strike missions against the People’s Republic of China,
but the economic and military countervalue targets in China are predominately located within
500nm of the coast, so in the extremely unlikely event that the UK is attacking China alone, the UK
would be operating in the same manner as the DPRK example.
291 3900ft is the airburst height for a 50Kt to maximise the area subjected to a 5 lb per square inch
(psi) overpressure blast wave. 5-psi is the minimum overpressure needed to seriously damage or
destroy unhardened buildings.
292 Data and mapping courtesy of Alex Wellerstien’s Nukemap 2.42 model. See: http://nuclearse-
crecy.com/nukemap/?&kt=50&lat=51.499978&lng=-0.1329081&hob_opt=1&hob_psi=5&hob_
ft=3942&casualties=1&fallout=1&psi=20,5,1.5&zm=12
293 Data and mapping courtesy of Alex Wellerstien’s Nukemap 2.42 model. See: http://nuclearse-
crecy.com/nukemap/?&kt=50&lat=51.499978&lng=-0.1329081&hob_opt=1&hob_psi=5&hob_
ft=3942&casualties=1&fallout=1&psi=20,5,1.5&zm=12.
294 The Queen Elizabeth-class carry up to 36 F-35s each, which in all cases bar the very unlikely sov-
ereign solo operations against the DPRK would operate in concert with land-based F-35Cs. As all
DPRK targets are within 615nm radius of action of a carrier group operating safely in international
waters, there is no need in the very unlikely UK-only DPRK scenarios for buddy-buddy refuelling,
meaning that all of the aircraft can operate in the strike or strike support roles.
295 On the JDAM family weapons generally, see http://www.boeing.com/boeing/defense-space/mis-
siles/jdam/
296 This will be a test of the B61-12’s aerodynamic properties and guidance kit on the Tonopah Test
Range rather than a warhead test. “Sandia National Laboratories completes wind tunnel testing of
B61-12 bomb”, airforce-technology.com, 16 April 2014.
297 “Congress Fully Funds B61 Bomb”, Tom Z. Colina, Arms Control Today, Arms Control Association,
March 2014.
298 Secondary damage is legal damage inflicted on legitimate military targets in the course of attacking
another legitimate military target. For example, the destruction of a number of military oil tankers
in a convoy as a result of the successful attack on a single tanker.
299 Collateral damage is damage inflicted on a civilian or civilian object (e.g. vehicle, building) in the
course of an attack on a legitimate military target. For example, this could include a civilian vehicle that was passing the military oil tanker convoy at the time of the attack. Collateral damage must be minimised at all times, and preferably avoided entirely.


301 Rainout is rain washing radioactive materials from the atmosphere onto the ground following a nuclear explosion. See “Communicating Nuclear Risk”, note 4.

302 In line with the International Court of Justice’s Advisory Opinion, paragraph 97, page 263.

303 The life-extension is proceeding under the Long Overhaul Period (Refuelling) (LOP(R)) programme. See, e.g., “Babcock successfully completes first-of-class MSC installation”, Babcock Media Release, 08 Jan 2014; ”Trident Life Extension Could Cost the UK $2.3bn”, naval-technology.com, 11 November 2010


305 For example, the magnesium stable member on which the guidance system rested proved susceptible to corrosion in extended RN service. See, “From Polaris to Trident”, page 70; generally, see “Dropping the Bomb”, footnote 34, page 18.


317 See Appendix 2.

318 WMD-associated sites shown are: Iran: Arak (Research Reactor), Ardakan (Uranium Milling), Bandar Abbas (Uranium Milling), Bonab (Nuclear R&D for Agriculture), Fasa (Rudan Uranium Conversion Facility), Fordow (Uranium Enrichment), Isfahan (Uranium Conversion Facility), Khondab (Heavy Water production), Mashhad (Uranium Enrichment), Natanz (Uranium Enrichment), Parchin (Explosives implosion tests), Saghand (Uranium mining), Tehran (Nuclear R&D); Israel: Dimona (Reprocessing / Weapons Production); Pakistan: Chagai 1 (Test Site), Chagai 2 (Test Site), Chashma (Nuclear Power Plant / Reprocessing), Dera Ghazi Khan (Uranium Conversion Facility), Golra Sharif (Uranium Enrichment), Kahuta (Uranium Enrichment, R&D), Khushab (Tritium Production), Kundian (Fuel Fabrication), Multan (Heavy Water Production), Sihala (Uranium Enrichment); Saudi Arabia: Al Suleyiyil (IRBM base). Al Watah (IRBM base). Sources: Nuclear Threat Initiative (NTI.org), CNS, IAEA.

319 A constraint on these operations would be the lack of fixed-wing UK MPA / MMA and AAR to support the fleet due to a lack of basing east of PJOB Diego Garcia, BIOT. However, this just underscores how unlikely this scenario is: it is virtually inconceivable that if the DPRK had developed the capability to deliver a nuclear warhead against the UK that allied powers would not also be
concerned. As London is 4680nm from Pyongyang, such a missile could also target Seattle, USA (4475 nm from Pyongyang) or Canberra, Australia (4640 nm from Pyongyang). Therefore, not only is it extremely unlikely that the UK would be acting alone, it is also almost certain that some level of regional land basing would be available to UK MPA / MMA and AAR to support the fleet – e.g. Andersen AFB, Guam. Nonetheless, given the existential threat to the UK in the limiting case, it would be possible to conduct a sovereign UK-only operation without MPA / MMA coverage. Ranges generated by the Great Circle Mapper (www.gcmap.com)- copyright © Karl L. Swartz.

North Korean nuclear and WMD-associated sites shown are: Kanggye arsenal complex, Punggye-ri Test Site, Sohae Missile Test Site, Ryanggang munitions depot, Taechon nuclear power station, Tonghae Missile Test Site and Yongbyon nuclear research facility. The leadership sites are the 14 Presidential palaces at Anju, Changsong, Changsuyong, Hyangsan, Kandong, Nampo, Paektusan, Pyongyang, Ryagwon, Ryokpo, Samsok, Sinuju, and Wonsan. Due to the scale of the map, some of the sites are superimposed.

320 Evolved SA-21 GROWLER SAM (S-400 Triumph) brigade with a maximum of 384 ready missiles.


323 Australia is replacing the Collins-class SSKs under project SEA1000.

324 Canada is considering SSNs to operate under-ice to replace the troubled and ageing Victoria- (ex-RN Upholder-) class SSKs. See “Canada may buy nuclear submarines”, Greg Weston, CBC News, 27 October 2011; “Canada's submarine fleet never worked. It's time to stop ignoring the problem”, Michael Byers and Stewart Webb, The Globe and Mail, 11 June 2013.

325 Such an arrangement would mirror the German / Italian / UK Tri-National Tornado Training Establishment (TTTE) hosted at RAF Cottesmore UK from 1981 to 1999, where Tornado crews from all three countries conducted their conversion training together. TTTE closed when the mid-life update programmes for each country made their national aircraft unique.


329 An excellent historical example of this distrust can be seen in the 1965 Treasury imposition of a £2,000m cap on defence spending by 1970/71 that lead to the cancellation of the TSR-2 strike aircraft and ultimately the closure of the Singapore bases and the withdrawal “East of Suez” in 1971. See “Britain's Retreat from East of Suez: The Choice between Europe and the World? 1945-1968”, page 54 – 58.

330 MoD may need budgetary cover to bring forward the existing decommissioning costs of the Vanguard-class fleet if it were to be retired by 2024. Given that these costs are already budgeted for, this could be brought forward under the budgetary doctrine of inverse capital End-Year Flexibility (EYF) that this author pioneered with Foreign Office spending whilst at HM Treasury in 2001/02.

331 “Trident costs must come from MoD budget, Osborne says”, BBC News 30 July 2010.


333 Trident Missiles, HC Deb 28 October 1980 volume 991 cc183-5 at 185.

334 “Carrier Strike: The 2012 reversion decision”, paragraph 1.9, page 12 provides a figure of £2.0bn in 2012, which was deflated to £2.1bn per ship in 2014.

335 Using the Universal Air Refuelling Receptacle System Installation (UARRSI)


Lot 5 Boeing P-8 Poseidon acquisition cost is quoted as $150m per aircraft per Captain Scott Dillon US Navy at Farnborough 2014. See “Boeing P-8 May Have Inside Track in UK, Eventually”.

Interview B, May 2014.


“Trident Alternatives Review”, Chart 2, page 42.

For example, this could include, but is not limited to, the destruction of Russian tactical nuclear weapons (TNWs) in parallel with a further reduction in strategic warheads.

Interview B, May 2014.

SDSR10 paragraph 3.2, page 37.

“A Tornado in a Teacup?”, 7 September 2012

These costs are not just equipment related; Tornado requires a Weapons Systems Officer (WSO) / Navigator whereas Typhoon does not. Thus, a decision to continue operating Tornado means an open-ended (but small) commitment to training WSOs with the additional cost of the training infrastructure that this entails.


“Looking Beyond the Chicago Summit”, page 11.

“Germany’s Tornado Nuclear Weapons Carrier”, January 2013.

“Germany’s Tornado Nuclear Weapons Carrier”, January 2013.