About the programme or study
This BMD paper is just one project within the Sea Power Research programme. The broader research draws together practical and diverse experience, theory and academic discussion to promote innovative thinking about Sea Power. The author is most grateful to Raytheon, Lockheed Martin UK and Boeing Defence UK for supporting and sponsoring this research. These companies have a key role in bringing together leading thinkers, decision-makers and practitioners.

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MORE AND more states around the world are buying ballistic-missile defence (BMD) capabilities. Against a perceived background of increased threat, the capability is thought to offer additional resilience, reassurance and stability to national-security equations, as well as providing important messages about national intent and resolve associated with deterrence theories. Indeed, the RUSI Occasional Paper ‘The Validity of Deterrence in the Twenty-First Century’ highlighted investing in a BMD capability as a step mitigating ballistic-missile actions from both state and non-state actors. Such political signals underlie a potential capability requirement that the UK Ministry of Defence (MoD) may have to address. Whilst deployed UK forces have been operating within range of a ballistic-missile threat for some years, a formal military requirement may now be emerging. This requirement has been clearly outlined in recent publications including the MoD’s ‘Global Strategic Trends’ publication. In fact, BMD is the single new capability aspiration within the force-development work of the MoD Main Building and front-line command. The operation of UK forces in a ballistic-missile threat environment and the emergence of a formal defence requirement are likely to be jointly considered within the context of the forthcoming National Security Strategy and associated Strategic Defence and Security Review. As a result, BMD could quickly emerge as both a political and military requirement.

Various UK agencies have been working on such an assumption for some years, albeit timings for any decision have remained uncertain. It appears that internal departmental reports outlining the financial implications of buying into a BMD capability have alarmed some decision-makers. Popular reference is made to costs akin to those of the successor deterrent programme (which may cost approximately £40 billion). Yet such reporting has solely assumed the military requirements, rather than costing the available options, along with the capability they deliver, to meet an additional, broader set of political aspirations aimed at delivering nuanced deterrence and resilience.

This Occasional Paper seeks to provide an independent analysis of potential BMD options for the UK to fill an, as yet, unspecified requirement. The details of that requirement are critical to understanding the full extent of the costs that might be incurred for any given capability. Cost comparisons are challenging to produce in this area on a like-for-like basis. Neither through-life maintenance costs, personnel capitation rates nor integration costs can

be accurately reflected within the unclassified detail that was provided to
the research team: like-for-like cost comparisons are thus made on the best
data available. The aim therefore is to provide an indication of capability-
cost comparisons.

This paper also acknowledges that any political decision to purchase a BMD
capability would be significantly more attractive if it were to be delivered
– at least on some definition of an initial operating capability – within the
lifetime of a specific parliament (five years), so that the purchasing party
would accrue benefits. This may not be a driving factor of any decision
or down-selection of solutions, but the recent trend in delivering military
capability for presentational political gain is clear. Fixed parliamentary terms
have allowed for better-defined timelines to which equipment programmes
must deliver. Technological maturity is clearly important in such a decision
and means that only military off-the-shelf options would fulfil the remit.
The paper acknowledges that such time restrictions would be politically
imposed, rather than being desirable from a military perspective which
focuses on developing needs to meet a specific threat environment. Given
an increasingly revanchist Russia, a chaotic North Africa, a growing threat
from Daesh (also known as the Islamic State of Iraq and Syria) in the Middle
East; and a burgeoning number of well-financed terrorist and fringe groups,
coupled with the potential for weapon proliferation, the emerging security
environment is politically charged and unstable. It certainly seems rational
for politicians to demand increased deterrence and resilience measures as
part of a balanced force package to meet national defence requirements.

The Requirement
Globally deployed British armed forces and UK strategic interests have been
under the threat of ballistic-missile attack for a number of years. The current
proliferation and sophistication of ballistic missiles – of varying ranges,
warheads and precision – make the threat of a future ballistic-missile attack
by state or non-state actors on UK territory, including the UK Overseas
Territories (UKOTs) and deployed British armed forces, a real and increasing
possibility. The proliferation of ballistic missiles to terrorist groups and less-
technologically advanced states has been noted by several intelligence
groups and scholars.3

Whilst the best form of defence is to prevent the missile from being fired, this
paper will not explore all the other mechanisms that form the UK’s capability
to provide BMD. Since the first ballistic-missile attack on the UK mainland in

Missile Defence’, RUSI Journal (Vol. 156, No. 3, June/July 2011); Paul Ingram, ‘Paper
1: Global Strategic Security Trends and Their Impacts on UK security’, Trident
1944, the UK has relied on a combined diplomatic, economic and military response that has offered different forms of deterrent, resilience (including deception, protection and crisis response) and retaliation. Pre-emptive and retaliatory strikes are currently within the remit of the UK armed forces’ expeditionary capability, which will be greatly enhanced following the introduction of the two new aircraft carriers with F-35s embarked.

**ICBMs and Deterrence Theory**

Apart from the US Ground-Based Interceptor, no BMD system currently claims to have a capability against intercontinental ballistic missiles (ICBMs). Their speed and range make such systems – which are almost always fielded with nuclear warheads – extremely difficult to counter. There are also significant political and diplomatic issues associated with claims of capability to counter ICBMs. Such claims, when made, for example, by Poland, would breach international agreements with Russia, undermining an already tense diplomatic relationship and leading to a potential breakdown in political dialogue.

Whilst future technology may allow other countries to develop a counter-ICBM capability, even for the US, current deterrence postures and capabilities remain largely in place. A UK BMD capability does not, therefore, negate the need for the Trident programme (or its successor).

However, national military deterrence is a blend of nuclear and conventional forces underpinned by resolve, communication and intent at the political level. Given the spread of liberal values across Europe, it appears that few non-state actors see massive retaliation as a realistic or likely response from Western powers. Adding to the deterrence and resilience posture of the states through a BMD shield therefore sends a significant message to belligerents and adversaries, and reassures both business and the population.

**The Threat Environment**

The declaration made at the NATO summit in Wales in 2014 indicates broad concerns over the threat posed by ballistic missiles: ‘The threat to NATO populations, territory, and forces posed by the proliferation of ballistic missiles continues to increase and missile defence forms part of a broader response to counter it’.4

The ballistic-missile threat has evolved over the last seventy years. On 8 September 1944, with no warning, a V-2 rocket weighing 13 tons hit Chiswick, southwest London, via the stratosphere at a speed of close to 5,000 kilometres an hour. This first ballistic-missile attack on the UK killed three

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people; however, a year and over 1,500 missiles later, the death toll had risen to around 7,000 Britons. Since the end of the Second World War, geography and technology have limited the threat of ballistic-missile attack on the UK mainland to ICBMs from Russia. This threat continues to be successfully countered by the UK's independent nuclear deterrent. Technology transfer and missile proliferation could render traditional deterrence ineffective against those actors who are unconstrained by the norms of international behaviour. However, missile defence can only complement the role of nuclear weapons in deterrence; it cannot be a substitute.

The US Missile Defense Agency reports an increase of more than 1,200 ballistic missiles added to the global stockpile over the past five years with the total number of ballistic missiles held outside the permanent five members of the UN Security Council at more than 5,900. Deployed UK forces are within range of hundreds of launchers and missiles. According to the intelligence community, current trends indicate that ballistic-missile systems, using advanced liquid- or solid-propellant technologies, are becoming more mobile, resilient, reliable, accurate and capable of striking targets over longer distances. Indeed, recent comments by senior US military officers suggest they anticipate a much-wider proliferation of ballistic missiles over the next decade than previously thought by UK agencies.

Argentina’s foray into building and then dismantling South America’s most advanced ballistic-missile programme demonstrates how a country with little experience can quickly develop a capability. It also shows how diplomatic and domestic pressures can be the best form of BMD. In the 1970s, Argentina – faced with border disputes with Chile and the UK – embarked on an indigenous missile programme that, by the 1980s, had attracted funding and other forms of support from Egypt and Iraq. However, after producing numerous prototypes, under international and domestic pressure, the country terminated the programme in 1993.

Whilst solace can be found in the power of diplomacy in the Argentinean example, for actors not susceptible to such influence it demonstrates the ease with which they could acquire a ballistic-missile capability. Ballistic

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missiles are a ‘poor man’s air force’. They are relatively cheap and offer an easy means of projecting military power at all ranges – from the close tactical battle to intercontinental conflict. This task is made even easier and cheaper if the firer feels unconstrained by international law and stands indifferent to collateral damage. With the technological problems associated with defensive systems outstripping both the cost and development timeline of ballistic missiles, effective BMD systems must be proactive and form part of a larger, multifaceted approach.

Today, the proliferation of ballistic missiles of varying ranges, warheads and precision makes the threat of a future ballistic-missile attack on UK deployed forces a real possibility. With the largest inventory of ballistic missiles in the Middle East, Iran, for example, has the means to develop an intermediate-range ballistic missile (IRBM) in the future that could potentially deliver a weapon of mass destruction in an attack on the UK mainland. Furthermore, Iran’s supply of ballistic missiles to non-state actors such as Hizbullah has set an example. It is possible that within the decade, future incarnations of Daesh could find themselves in possession of IRBMs capable of reaching the UK mainland. In addition, the numbers of medium-range ballistic missiles (MRBMs) that might be acquired by rogue states or renegade terrorist groups could further increase the threat posed by such actors. Due to the geographic position of the UK, the threat to the British mainland from short-range ballistic missiles (SRBMs) is less than from other ballistic-missile groups; however, such missiles are likely to continue to pose a significant threat to deployed UK forces.

Caveats
The current UK national approach to BMD includes economic, diplomatic and cultural (the use of the attractiveness of the state to negate threats) aspects as well as national interests and its military posture, both in terms of continuous at-sea deterrence (CASD) and conventional capabilities. Collectively, these make a ballistic-missile attack against the UK, UKOTs, allies or deployed forces unlikely. Yet in a dynamic threat environment this cannot be guaranteed. Therefore, this paper makes the assumption that even a potential threat must be guarded against: the assessments made here aim to provide costed options that will deliver a military capability to intercept a ballistic missile in flight.

Costings contained within this paper have been derived from open-source information or informed deductions drawn from discussions across the defence and security sectors. As like-for-like comparisons of expenditure are almost impossible given the variety of sources and the issues associated with normalising such figures, costs are currently presented as rough order-of-

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merit (ROM) costs. Follow-on work may address the total through-life costs associated with each option.

The Physics (Made Simple)

A ballistic missile is subjected to the same physics as a thrown ball, expending its fuel on launch and then travelling under the influence of gravity and air resistance. Modern ballistic missiles are launched on a precise trajectory intended to curve up into space, or the outer reaches of the atmosphere, and then descend under gravity to the target. The warhead type could be nuclear, biological, chemical or high-explosive, and each missile can potentially carry a number of warheads that can separate before hitting their respective targets.

Broadly, these can be grouped by range, as shown in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Range (km)</th>
<th>Flight Time/Speed (minutes)</th>
<th>Example Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-range ballistic missile (SRBM)</td>
<td>100–1,000</td>
<td>3–9</td>
<td>Fateh-110</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scud-B</td>
</tr>
<tr>
<td>Medium-range ballistic missile (MRBM)</td>
<td>1,000–3,000</td>
<td>9–19</td>
<td>Shahab-3 ER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BM-25</td>
</tr>
<tr>
<td>Intermediate-range ballistic missile (IRBM)</td>
<td>3,000–5,500</td>
<td>19–26</td>
<td>Shahab-4</td>
</tr>
<tr>
<td>Intercontinental ballistic missile (ICBM)</td>
<td>5,500+</td>
<td>26+</td>
<td>Saffir-2</td>
</tr>
</tbody>
</table>

Source: courtesy of the author.

Their range is also linked to the altitude which they reach during their flight path. That trajectory is generally divided into three phases: boost, midcourse and terminal. Each phase occurs at different ranges and heights depending on the system used, but generically they can be represented diagrammatically as shown in Figure 1.

The type and range of missile threat a state faces also narrows the choices of suitable BMD systems able to counter or intercept that type of vehicle. Factors affecting such decisions include target speed, accuracy, the area to be defended, surveillance inputs, and whether a system might be entirely sovereign or exploit part of an alliance structure. For the UK, there are also important considerations regarding mobility: is the required solution intended only to counter a threat to London, the UK as a whole, UKOTs, close allies (for example, in the Middle East), deployed forces or individual force elements? Whilst the mere statement
of investing in a BMD capability would significantly contribute to the broader posture of national deterrence, acquiring the right system is also important in order to prevent perceptions of the UK as a country which makes claims but has a ‘hollowed-out force’. Such investment would additionally send a clear signal to larger powers such as Russia and China, which understand the intricacies of system capabilities within the current balance of power.

**BMD Systems**

BMD systems rely on interceptors delivering a kill vehicle to destroy the incoming targets. However, identifying these targets when they are in flight as well as possessing a system capable of making decisions in order to defeat an incoming threat within the discrete timeline associated with potential intercept physics, represents an issue. Surveillance, warning, and command and control – including in the intercept vehicle itself – therefore play vital roles in constructing an effective capability.

The nature of BMD surveillance and command and control makes a solely national, independent system an irrational step in most circumstances.

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Fusing the output from specialist – and expensive – sensors possessed by other alliance and coalition partners can only add fidelity to the BMD decision-making dynamic. Networked command and control is also likely to create more-assured and resilient connectivity, in turn providing greater reassurance to allies. Any future UK BMD solution must leverage the investment and capabilities of others in these fields.

**Interceptors**

BMD interceptors can either have a kill vehicle or rely on the missile to act as the interceptor. For example, both the US Ground-Based Interceptor and the US Navy’s SM-3 missile system use an interceptor missile to carry the kill vehicle into space, delivering it within range of its target. The main body of the interceptor then falls away, leaving the kill vehicle to use its own propulsion, communication links and guidance systems to hit the threat missile in the outer atmosphere. Other systems, such as the Patriot PAC-3 missile, fly to an intercept point specified prior to launch by its ground-based fire-solution computer. If required, target data can be updated before the missile’s own seeker acquires the target, allowing it to hit the target missile.

Which type of interceptor is used depends on which part of the trajectory of the incoming missile the interceptor is designed to target:

- **Boost phase:** this is the first few minutes after launch and before the missile has released its warheads. Typically, the boost phase ends at altitudes of 480 kilometres or less and within 1–5 minutes of flight, depending on the range of the missile. A missile in its boost phase is the easiest to detect because the rocket motor provides a highly visible heat signature and the missile and warhead are still together. Destroying a missile in this phase is preferred as it precludes the deployment of any counter-measures. However, to target a missile effectively requires sensors that can detect and relay target information to the interceptor missile in time for it to catch up with an accelerating missile, requiring the interceptor to be in very close proximity to the launch site.

- **Midcourse phase:** this is the longest phase of a missile’s trajectory and follows the boost phase. The midcourse phase of an IRBM fired from Iran and targeting the UK would last around fifteen minutes. Whilst this phase offers the largest window of opportunity for intercepting a missile, with no heat signature and the missile at its furthest distance from the earth, interception is a challenge. However, this is the preferred method of interception for US systems since it destroys the warhead before it enters the earth’s atmosphere. Debris from the intercept is either blown back into space or is burned up in the atmosphere on re-entry.
• Terminal phase: this is the shortest phase and has the longest range. The fastest ballistic missiles can spend fewer than sixty seconds in this stage. The technical capabilities of the interceptor needed to counter threats that are in this phase are the most demanding, as the closing velocities are exceptionally high (in excess of Mach 6). With the warhead seconds away from its target there is little room for error. This requires highly reliable defensive systems to be deployed sufficiently close to the intended target. Even when an intercept is achieved, there is a risk that debris from the engagement will land within the defended area.

At each stage, highly advanced interceptors are required. The successful and reliable countering of incoming missiles requires a flawless performance by a whole range of advanced technical equipment. The various components needed include: radar tracking devices, interceptor-guidance and propulsion systems, on-board sensors and communication links. All of these individual components of the missile-defence architecture must be integrated seamlessly to ensure a successful intercept.

An Independent Capability?
If the UK wishes to possess a fully independent (perhaps even sovereign) capability – in other words, one which does not rely on any other state to detect, assess, target and destroy an incoming missile – it would require a fully integrated and multifaceted system capable of defending the UK mainland, its globally deployed forces and the UKOTs against all known threats. The system would need to be able to intercept all types of ballistic missile. This would require the UK to replicate much of the US approach to BMD and would necessitate:

• A command-and-control and communications system that integrates all the sub-systems of the BMD architecture to allow near-time situational awareness and sensor-to-shooter times, enabling interceptors to target missiles throughout their flight
• At least one ground-based interceptor in the UK capable of intercepting and destroying IRBMs during the midcourse phase of flight using kinetic hit-to-kill technology
• Space-, air-, ground- and sea-based sensors, with ground- and sea-based interceptors capable of intercepting all ballistic-missile types
• Land- or sea-based interceptors permanently based in the Falklands, Cyprus and Gibraltar
• Deployable BMD capabilities with the ability to provide requisite levels of force protection to deployed UK forces. Ideally, such a system would not lead to additional stress for the logistics tail of the deployed force, nor require third-party approval to engage targets (when a British system has to be based in another state).
Such an aspiration must keep in mind that the UK does not have a space programme or a history of developing BMD technology, which for the US dates back to at least President Reagan’s Strategic Defense Initiative. Therefore, unless the US would share its technology with the UK, the costs of developing a sovereign UK capability would be comparable to US spending to date. Various sources quote this as £150–250 billion, with yearly expenditure since 2002 of around £5–6 billion.\textsuperscript{11} If the sovereignty requirement were only applied to the firing chain of a fully integrated and multilayered system capable of defeating all potential threat scenarios, then a start-up cost commensurate with the US Missile Defense Agency spending of £60 billion since 2002, and then yearly costs of £5–6 billion, could be a conservative estimate.\textsuperscript{12}

However, an independent capability is feasible for tactical and theatre defence for deployed forces and UKOTs. Such a capability would provide force protection without the need for third-party approvals for engagement (if fielded at sea), but would nevertheless be significantly more effective if it were integrated into a wider regional surveillance and warning network. This would ideally exploit the sensors of other states, thus reducing potential investments in deployed long-range detection equipment.

**Alliance Integration**

The purchase of a fully independent capability is not, however, necessary or perhaps even prudent. Just as the US relies on partners and in turn shares information for BMD operations with those partners (exploiting long-range tracking facilities stationed across the world which are owned, operated and run by non-US personnel), so too could the UK. The debate over a completely independent BMD system is therefore somewhat academic. Whichever capability the UK chooses to pursue, declaring availability of that system to NATO would be a very strong message to the Alliance at a time of increasing political pressure on the organisation.

NATO already possesses a BMD capability, known as the Active Layered Theatre Ballistic Missile Defence (ALTBMD) programme. Established in September 2005 for the protection of deployed forces, ALTBMD followed the completion of a two-year feasibility study in which eight NATO states and various NATO projects co-operatively participated. As a result of the NATO Lisbon (2010) and Chicago (2012) Summits, the programme was expanded to include the protection of NATO European populations and territory. An interim theatre BMD capability was fielded in 2010 and followed by an interim territorial-defence capability in May 2012. According to a 2009 US


\textsuperscript{12} Ibid., p. 1.
Congressional Budget Office assessment, this capability places the UK under the ALTBMD umbrella from IRBM attack.\textsuperscript{13}

The focus of the programme is the upgrading, testing and integration of NATO’s command-and-control systems and underlying communication network to enable effective information exchanges between various NATO and national missile-defence systems. This integrated system-of-systems architecture will create a larger range of detection, communication and missile-defence capabilities for NATO forces – whether deployed within or beyond NATO’s core area of responsibility – and NATO populations and territories. The programme’s key functions include planning, monitoring, information sharing, interception and consequence management, with the aim that eventually:\textsuperscript{14}

\begin{itemize}
  \item [A] NATO missile defence capability is to provide full coverage and protection for all NATO European populations, territory and forces against the increasing threats posed by the proliferation of ballistic missiles, based on the principles of the indivisibility of Allied security and NATO solidarity, equitable sharing of risks and burdens, as well as reasonable challenge, taking into account the level of threat, affordability and technical feasibility, and in accordance with the latest common threat assessments agreed by the Alliance.
\end{itemize}

When the ALTBMD programme promises so much, why should the UK consider anything more than contributing the minimum level of investment and capability to gain continued support through this capability? The UK has traditionally accepted the need for an independent posture in nuclear deterrence whilst acknowledging that NATO provides similar capability and security guarantees. A similar decision needs to be made with regard to BMD: to what extent is the UK prepared to depend on others for its defence and security? Any answer should consider that UK decision-makers may prefer to make their own choices or rely on others to take action when needed. Similarly, depending on the level of threat, any national BMD capability might require the firing chain to be free from foreign influence. The requirement for this independence of action (‘freedom of action’ as understood in UK MoD parlance) is a fundamental principle in deterrence terms. This presumption of a non-dependent arrangement brings with it legal entanglements for deploying systems overseas. Unless legal protocols are in place with a host state, international law requires the interceptor to be operating from, or on, UK territory. This can include a UK-flagged vessel either in UK territorial waters or on the high seas. There is no legal requirement for the sensors to be operating from UK sovereign territory. Those considerations do not

\begin{footnotes}
\end{footnotes}
exclude continued British participation in ALTBMD, but would mean the UK would likely wish to have its own capability, with the authority to use it when and where it wishes. In considering such options, examination of both cost and capability is required, and an analysis of the latter can be made in terms of the geographic space (the ‘defended area’) that any system protects.

**Defended Areas**

In simple terms, BMD systems can be classified by the area that they are able to defend and the scale of threat that they are able to defeat: both characteristics must be considered together.

Regional defence would provide protection to the entire UK mainland from weapons of an IRBM capability. Such a shield requires a system capable of much greater range, speed and accuracy than is necessary in systems protecting a smaller area. As the only upper-tier system in operational use today, the SM-3 is the sole interceptor capable of this type of defence on such a scale. The level below this might usefully be termed as theatre defence: a system that provides protection across a theatre of operations, much like the Terminal High Altitude Area Defense (THAAD) system. Local, or tactical, defence is the lowest level of BMD protection: this would effectively defend an area within a city, such as key installations, against an SRBM threat. The Patriot system would be a good example of this.

For the UK, scales of effort could be combined: a homeland defence capability could feasibly protect all of the UK, a theatre defence capability could cover Greater London, and a local defence system could protect the City of London or individual nuclear plants within the UK. Whilst such a concept of ‘layered defence’ sounds attractive, systems also need to be able to match the scale of the threat in terms of expected missile numbers. Map 1 is a rough representation of the protective umbrellas provided to the UK by a single THAAD system (the inner circle at 200 km) or SM-3BIIA (the outer circle at 1050 km).

Systems do not need, necessarily, to be fixed geographically: mobility provides a high degree of utility, allowing use away from the system’s core operating base. Whilst they have limited utility in defending the UK, a theatre BMD capability could be used to protect UKOTs in the event of emerging threats, or reassure and protect allies – for example, in the Gulf. Equally, a tactical system could be used to provide protection for deployed UK forces when on expeditionary operations. Seaborne systems are inherently mobile, whilst land-based systems are, in the main, transportable. The latter are dormant when in transit and take time to be activated on arrival at their destination, and the logistics involved in sending them abroad are not insignificant. Deploying a shore battery to the Gulf, for instance, would require strategic lift. The UK possesses sufficient resources and assets to conduct such activities
Map 1: BMD Ranges of London-Based THAAD and SM-3BIIA Systems.

Source: courtesy of the author.

Map 2: BMD Ranges of Bahrain-Based THAAD and SM-3IIA Systems.

Source: courtesy of the author.
without recourse to the civilian logistics market, though this would denude the capacity of other deploying units. Map 2 provides an overview of the umbrella that a THAAD system (inner circle) and SM-3IIA (outer circle) could provide if stationed in Bahrain or off that coastline.

Other states have examined these problems and have opted for a seaborne capability which is integrated within naval force elements. This allows the systems to be deployed within an integrated naval force, and within either a national or alliance surveillance structure. It has the additional advantage of a permanent, understood and exercised command-and-control chain. This approach may generate cost savings, but it must be understood that it can limit the ability of naval units to conduct other tasks. For example, a sea-based BMD system to protect the UK homeland would require a ship on station permanently in times of tension. Given the lack of available platforms, and the already-stretched (and possibly fragile) fleet deployment schedules, this would reduce the availability of such ships to conduct tasks including patrolling, assault, land attack, constabulary duties, escort of shipping, and protection of carrier or amphibious groups. Therefore, the cost savings in choosing such a system might best be understood by accounting for the cost of new naval platforms as well as the BMD systems that would be built into, or operate from, them. The trade-off in those costs must

Figure 2: System for Countering Different BMD Threats.
also acknowledge that some sea-based BMD systems provide defence against a range of ballistic missile-threats.

Figure 2, from the US Missile Defense Agency, depicts the spread of utility from various current and future systems against the threat missiles in terms of range capabilities.

**Current UK Capability and Experimentation**

The UK’s capability is currently confined to detecting and tracking ballistic missiles from RAF Fylingdales, which has housed a US ballistic-missile and warning radar since 1963. This US system, manned by RAF personnel, fulfils missile-warning and space-surveillance tasks for both the US and the UK and provides inputs to the US Missile Defense System in north Yorkshire.

Experimentation at sea with the Royal Navy’s six Type 45 destroyers has also been conducted to ascertain their potential utility in this role. In September 2013, HMS *Daring* demonstrated the ability to detect and track MRBM targets. A follow-on Type 45 experiment is planned for late 2015 to explore the potential of BAE Systems’ Sampson E/F-band active-array multifunction radar in a maritime BMD role. Current UK policy supports continuing contribution to NATO by using BMD to protect allies and experimentation to understand the potential of current capability expansion. It does not, however, fund any BMD intercept capability for the UK, or the integration costs of inserting their surveillance data into the NATO or US BMD structures.

**Future UK Options**

With the future threat of a ballistic-missile attack on the UK mainland, UKOs or deployed armed forces a real possibility, London may need to take action if it wishes to maintain its strategic position and security. In addition, BMD for deployed forces must be part of the minimum acceptable capability if the UK wants to deploy its forces globally.

Options to add a BMD capability to the UK defences could take varying forms: an independent one (discounted above); an association with NATO partners as part of the ALTBMD programme; a new BMD framework with other European partners (for example, with France); or various permutations of BMD capability to enhance the state’s deterrence posture by procuring systems that could add to the international security dynamic against rogue states or non-state actors.

**Defence of UK Mainland**

As part of the integrated NATO ALTBMD, the UK could invest in a semi-independent interceptor capability that would be capable of defending the UK from an IRBM attack. Additional funding could be provided that would enable the UK systems to be integrated with the command-and-control
systems of ALTBMD through a command, control, battle-management and communications network. This would allow ALTBMD sensors to share missile-tracking data with a UK interceptor providing an independent means of self-defence. This capability will require at least one operational interceptor that is capable of interception during a missile’s midcourse phase. The only option available today is the US SM-3, which could be either land- or sea-based, mirroring the US Aegis at-sea-or-ashore concept of operation.

**SM-3**
The SM-3 system is currently integrated into the Aegis platforms of the US Navy and Japanese Maritime Self-Defense Force. It also provides a number of other states with BMD capability. Of note, the Netherlands, Germany, South Korea and Australia are actively considering the SM-3 to meet their BMD requirements. It is a proven and tested technology with a high degree of success during test firings. The system is acknowledged to counter known IRBM threats and has a planned upgrade path that is already funded by other states, notably Japan and South Korea. This investment will ensure that the system continues to be effective against coming generations of IRBMs. Due to the international nature of the programme, those countries that participate benefit from sharing the costs of upgrade pathways. The programme promotes US co-operation, interoperability and technological transfer. The system is already in production and is therefore immediately available, subject to integration into UK platforms.

For the UK to adopt the SM-3 at sea, this could mean converting all six of the Royal Navy’s Type 45 destroyers to carry two silos of eight missiles. These could also be deployed adjacent to the required defended area, to facilitate an engagement during the midcourse or terminal phases or even to intercept during the boost phase. However, there are only six destroyers in the Royal Navy. This number cannot provide a continuous at-sea capability for a dedicated UK BMD whilst also fulfilling their primary role of air defence to deployed forces. To deliver BMD and area air defence simultaneously, potentially in different geographic locations, might require the construction of additional platforms, although such platforms would not necessarily have to be built to the same high standard.

The technical capability of the Sampson radar in the Type 45 (in terms of being able to guide the SM-3 missile) is not yet fully understood; it has also yet to be established whether the ship is structurally able to embark the additional weight in missiles. Managing the weight of carriage and the forces inherent to an SM-3 launch may impose operational constraints. However, non-Aegis integration has been possible for other navies, using indigenous combat systems such as in Japan.
Costs of SM-3 Maritime Option
The purchase of two additional ships to provide dedicated UK homeland protection could cost anywhere between £792 million and £2.5 billion, and current military operating assumptions would require four, rather than two, ships – such figures do not include fitting the system into the Royal Navy’s current platforms. Alternatively, the cost of a capability insertion into new Type 45 ships is estimated at around £492 million. The estimate of £300 million to convert all six ships currently in the fleet is a relatively inexpensive option limited to fitting the ships for, but not necessarily with, the missiles. If this were combined with either the new-ship or land-based option, it could share inventories and, when required to meet new and evolving threats, deploy ‘up threat’ (closer to the area from where the missile is launched) to provide a layered defence.

SM-3 Ashore Costs
Following the US example, it is possible to base the SM-3 ashore. The Aegis ashore installation at Deveselu, Romania, houses SM-3 missiles as part of the second phase of the US European Phased Adaptive Approach (EPAA). Its sister facility at Redzikowo, Poland, will house twenty-four SM-3 missiles as part of the third phase of the EPAA. Japan is also fielding Aegis ashore. The cost of land-basing the interceptor on the UK mainland is estimated at £500 million.

Theatre and Tactical Options
The option above could provide adequate at-sea BMD force-protection for UK armed forces deployed abroad. There are three additional options available to meet these shorter-range threats. These options could be considered either in isolation or in combination.

Aster Missile Family
Aster has already been developed as a land-based, medium-range area-defence system. French and Italian forces use the Aster 30 (with a 120-km range) missile for defence against SRBMs. The system comprises a fire-control system, based on a multifunction electronic scanning radar and a vertical ground launcher mounted on a large vehicle. It is capable of firing eight missiles in rapid sequence. In 2014, France allocated funds to launch the development of Aster Block 1nT in co-operation with Italy. This new version of Aster will extend the anti-ballistic capability of the missile from its current range of 600 km to one of 1,500 km. The development of a new Aster

15. The lower estimate is based on £300 million per ship with associated radars, command systems and two eight-missile silos and £192 million for sixteen missiles.
16. In comparison to UK assumptions over Trident successor linked to continuous system availability.
17. This would cover the cost of fitting each Type 45 destroyer with two eight-missile silos at £300 million and sixteen missiles at £192 million.
18. This figure is based on the US costs for the Aegis ashore in Romania and the test battery in Hawaii. See US Government Accountability Office, ‘Missile Defense’. 
Block 2 missile variant (with a BMD capability) has recently been funded by the French government. Designed as an evolution of the current capability, it will provide extended coverage to protect high-value naval assets at sea, force entry points and harbours, as well as forward-deployed troops.

The UK already uses the Aster system at sea, and thus it is a ‘known’ technology to the MoD. The systems make a European contribution to territorial missile defence for the UK homeland and mainland Europe. It is being designed to engage the latest generation of SRBMs and potentially MRBMs on the basis of proven intercept technology. However, a system capable of tackling the MRBM threat is not yet in production or tested and, notably, is not projected to have capability against the longer-range (IRBM) threats to the UK homeland. The project is funded by France (and will potentially be joined by Italy) and might be available to the UK within five years at an estimated cost of £3 billion for the land variant. No figures or timelines have been obtained for the sea-based system.

When eventually fielded, the current interceptor could provide limited coverage, in a region of 32 km around the firing platform, against SRBMs. However, it could not provide an effective defence against a more modern or complex system (such as MRBMs). Therefore, it would only be an option for some of the UKOTs and some land and air forces deployed inland. It could potentially provide protection to a city-sized area ashore. Aster NT is comparable to the PAC-3: ideally, in the future, the Aster Block 2 would provide defence capabilities comparable to the THAAD defended area.

**PAC-3**

Used during the 1991 and 2003 Gulf Wars to protect troops and territory, the PAC-3 is the most mature system that offers BMD against missiles in their terminal phase. The system comprises a maximum of sixteen interceptor missiles mounted on a trailer, along with fire-control, radar and communications systems, and support equipment which includes an independent power source. PAC-3 is proven and deployable by air transport. This allows ground interceptors to target SRBMs and MRBMs during their terminal phase over a

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20. Calculations estimated from open-source figures available based on previous government-level investment. These are the least clear of all costs represented and should be regarded as less than 50 per cent accurate. $2.5 billion for 900 missiles only (Italy), $2.7 million (2001 prices) per missile, French development grant to MBDA of $3.1 billion (2008 prices). See Tim Ripley, ‘Missile Mission’, Flight Global, <http://www.flightglobal.com/news/articles/missile-mission-132235/>, accessed 8 June 2015.
small area of land. Costs are estimated to be around £158 million per system. However, to be effective, it requires at least ten systems and, as such, costs might more accurately be around £1.58 billion for the equipment alone.

**THAAD**

Designed for the US Army, to provide a wider capability than the PAC-3, THAAD was delivered into service in 2008 and has more than five years of successful operational deployment. It is a counter-ballistic-missile system designed to shoot down SRBMs and MRBMs, with a capability against IRBMs in their terminal phase using a hit-to-kill approach. A THAAD battery typically consists of forty-eight interceptor missiles and six launchers, radar, fire-control and communications systems, and other support equipment.

THAAD is designed to be deployable: it requires approximately seventeen C-17 flights per battery. When deployed overseas, permissions would be required for its use. Such a deployment relies on the accuracy of threat assessments, good intelligence, political resolve and agreement on the threat. THAAD sends a clear political message during crises. Systems have been sold to overseas partners through the US Foreign Military Sales programme and THAAD is assumed to be available to the UK at a cost of $1.96–$3.25 billion per battery.

The US is investigating a THAAD follow-on programme and presidential budget documentation for the fiscal year 2016 indicates concept development for seeker and booster modifications beyond the baseline requirements. These would focus on extended battlespace, defended areas and pacing advanced-threat development of missiles posing a possible threat to UK interests. It would be designed to integrate into existing THAAD units and might be available within the next decade.

**The Wisdom of Crowds**

As the commercial evidence above indicates, the US is recognised as the world leader in BMD. There are a number of countries that are either drawing on this expertise, entering into partnerships or pursuing BMD capability unilaterally. For countries such as Japan, Israel, India and the Gulf States, BMD is now considered a non-discretionary strategic requirement. Russia, China, South Korea, Taiwan, Egypt, Germany, Greece, Kuwait, the Netherlands, Saudi Arabia,

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the United Arab Emirates, Jordan and Spain have all invested in BMD capabilities as well in order to combat the perceived threat from ballistic missiles. Five examples of other countries’ experiences of BMD are outlined below.

**Poland**
Both geography and limited military expeditionary intent mean that Poland’s Tarcza Polski (‘Shield of Poland’) is focused on providing an independent, sovereign response to SRBMs and MRBMs launched from the near abroad. The defence system is intended to dovetail with the NATO BMD, with the US providing the capability to intercept IRBMs. Initial estimates suggest that the programme will cost approximately $3–5 billion over the next ten years. Poland is still negotiating possible options and it is currently unclear what specific capability will be provided in return for such an investment.

**India**
The Indian BMD programme is structured to deliver a two-tiered system: Prithvi Air Defence (PAD) for high-altitude interception and Advanced Air Defence (AAD) for low-altitude interception. The country is still learning how to acquire a sovereign capability and, even though it is supported by its successful space programme, it is unclear how much this BMD programme will cost or how much India is willing to spend.

**Japan**
Currently, Japan uses a combination of four Kongo-class, Aegis-equipped, guided-missile destroyers armed with SM-3s to counter the North Korean IRBM threat. It also possesses the Patriot PAC-3. However, due to concerns over the Patriot’s capability to counter a large-scale missile attack, Japan intends to double its number of BMD destroyers to eight by 2018. The Japanese press has also reported that the Japanese Ministry of Defense is interested in acquiring an Aegis ashore battery. In January 2015, Japan announced its largest-ever defence budget of ¥4.98 trillion (£28 billion), a figure allowing for increased BMD capability within the national Self-Defense Force capability.

**France and Italy**
Both the French and Italian governments consider BMD an essential enabler of homeland protection. France also sees the need for BMD when deploying its forces abroad, and Italy likely equally recognises this requirement,

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although it has not voiced this publicly yet. Their approach has integrated sensors and interceptors from a common French and Italian SAMP/T – this system has conducted successful tests against SRBMs. The development of this system is being conducted jointly but with an ability to be fielded by each state depending on its own national requirements.

The Netherlands
The Dutch armed forces currently operate the Patriot PAC-3 and have four air-defence and command frigates (LCF), which are being equipped with upgraded ‘Smart-L’ radar systems at a cost of €250 million. The radar is due into service in 2018 and will be integrated into NATO’s ALTBMD. Until January 2015, the Dutch deployed two of their Patriot missile batteries in support of a NATO operation to provide BMD on Turkey’s southern border.

The Importance of Geography
Decisions made by these states are taken on a highly contextual basis. A key consideration of such decisions has been the threat geography. The UK is most fortunate to be in an almost unique geographic position in terms of the threat from ballistic missiles. The physical location of the islands in relation to ballistic-missile profiles alters the vulnerability – and thus the investment decision. The fact that the British Isles are a greater distance from potential

Map 3: Ballistic-Missile Threats to the UK at 1,000, 3,000 and 5,500 km.

Source: courtesy of the author.

27. They will be replaced with Spanish Patriot batteries.
firing positions means that the UK faces a lesser and more remote threat than other European states that are physically closer to potential enemies with such capabilities. This creates a unique set of factors for the UK, which contrasts with that of states such as France, Poland or even Italy. As Map 3 shows, the UK’s physical geography might therefore mean that the greatest threat to the UK homeland from ballistic-missile attack emanates from North Africa, rather than the Middle East.

Recognition of the unique British geography should shape potential investment decisions made on the basis of threat assessments rather than political and strategic messaging about deterrence and resilience for the future. Nonetheless, this should not change the requirement for BMD protection to deployed forces, UKOTs or vital national interests abroad.

Conclusion
Opinion within the intelligence community is divided over whether the UK mainland or UKOTs are currently subject to a threat from ballistic missiles; however, deployed UK armed forces have been under the threat of ballistic-missile attacks for a number of years and operate either at risk or under the discretionary protection of others. Few doubt that the missile threat landscape is becoming more dynamic, and that increasing lethality and the proliferation of SRBMs and MRBMs means that, if the UK wishes to maintain the ability to conduct expeditionary operations, it needs to invest in a BMD capability. Geography and technology have previously limited the threat of ballistic-missile attacks on the UK mainland to ICBMs and IRBMs from Russia – a threat that continues to be successfully countered by the UK’s independent nuclear deterrent. However, technology transfer and missile proliferation could render traditional deterrence ineffective against those actors who are unconstrained by the norms of international behaviour. Whilst missile defence cannot provide a substitute for the UK’s independent nuclear deterrent, the reality of the new security environment both nationally and regionally and in terms of vital UK interests, appears likely to radically change the threat to the UK homeland, UKOTs and deployed forces over the coming decade.

Argentina’s brief sortie into developing a ballistic-missile programme is an important lesson from history. While demonstrating the importance of a multifaceted approach to BMD, it highlights how quickly an actor can acquire a ballistic-missile capability which is both cheaper and easier to develop than it is to counter. This means that the development of a BMD capability needs to be proactive and part of a multidisciplinary policy. Today, the proliferation of ballistic missiles of varying ranges, warheads and precision makes a future ballistic-missile attack on UK deployed forces a real possibility. In the future, with the largest inventory of ballistic missiles in the Middle East, Iran has the means to develop a ballistic-missile capability that could deliver a weapon of
mass destruction in an attack on the UK mainland. Iran’s decision to supply Hizbullah with ballistic missiles further demonstrates that states can help non-state actors acquire this technology. There is therefore no guarantee that future incarnations of groups such as Daesh could not find themselves in possession of longer-range ballistic missiles.

However, developing an organic, solely sovereign and independent BMD capability does not seem either financially or militarily prudent. This Occasional Paper has identified a number of alternative options, but the decision over these should be based on the political requirement, itself derived not from an assessment of the ballistic-missile threat alone, but as a wider contribution to the posture of the UK in terms of deterrence, resilience and freedom of manoeuvre.

Investment should not be considered to be prohibitive either. There is no doubt that the cost of providing protection similar to that possessed by the US would be huge. A less-than-perfect solution would entail costs which are more manageable and would leverage the investments already made by others. There are two key assessments that need to be made with regard to any BMD investment that the UK might make. First, there needs to be a decision over whether there is a sufficient geopolitical threat to the UK homeland to warrant investment in a system that provides protection to all of the UK, and second, whether that threat should have a response now or in the longer term. These considerations, in themselves, will drive a decision over whether to pursue a route of off-the-shelf purchases or one of development. When considered alongside the nature of enduring political and industrial relationships, the options could be narrowed even further.

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About the Author

Peter Roberts is a Senior Research Fellow for Sea Power and Maritime Studies at RUSI. He researches and publishes on a range of subjects, including strategy and philosophy, sea power, command and control, naval weapons systems, C4ISR, military education and military use of cyber-warfare. He also oversees conferences, meetings and lectures in these areas. He retired from the Royal Navy in January 2014 after a career as a Warfare Officer, serving as both a Commanding Officer and a National Military Representative in various roles with all three branches of the British armed forces, the US Coast Guard, US Navy, US Marine Corps and intelligence services from a variety of other states. He has served as chairman for several NATO working groups and Five Eyes maritime-tactics symposia. Whilst the latter part of his career was spent advising foreign governments on maritime strategy, his most recent military experience was within defence management and procurement with responsibility for military cyber-warfare, information operations, human and signals intelligence, and maritime ISTAR collection.

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