Centre for Defence Enterprise

The Centre for Defence Enterprise (CDE) proves the value of novel, high-risk, high-potential-benefit research sourced from the broadest possible range of science and technology providers, including academia and small companies, to enable development of cost-effective capability advantage for UK Armed Forces and national security.

Themed Competition: Defence against Airborne Threats

This CDE Themed Competition seeks innovative solutions that could contribute towards defence against airborne threats such as ballistic, subsonic and supersonic cruise missiles, and hypersonic munitions.

Solutions should show disruptively greater efficiency or significantly reduced cost when compared to current solutions.

The total funding available for this competition is £420k.

Competition launch event: Thursday 22nd May 2014 at Altitude 360, Millbank Tower, London.

Competition closes: Thursday 3rd July 2014 at 1700 hrs.

CDE: www.science.mod.uk/enterprise
Dstl: www.dstl.gov.uk

SBRI Government challenges. Ideas from business. Innovative solutions.

[dstl]

Defence Science and Technology Laboratory

Ministry of Defence

Important Information

Proposals for funding must be submitted by **1700 hrs on Thursday 3rd July 2014** using the Centre for Defence Enterprise Portal. Please mark all proposals for this themed competition with **"Defence against Airborne Threats (+ challenge 1,2,3)"** as a prefix in the title (see 'Technology challenge(s)' section below for a description of the challenges under this competition).

- **Technical queries** should be sent to **MDCNovelTech@dstl.gov.uk**. Please see guidance on using this facility under the 'CDE proposal submission process' section
- **General queries** (including how to use the Portal) should be sent directly to CDE at **cde@dstl.gov.uk** or by phone on +44 (0) 1235 438445

This competition is being run by CDE on behalf of the UK Missile Defence Centre (MDC). The Centre was established in 2003 following signature of a Memorandum of Understanding between the UK and US for the conduct of collaborative ballistic defence studies. By establishing a joint industry and MOD centre, the UK government believed it would be best to be able to meet the UK's long-term policy and research requirements.

The UK government elements of the MDC include MOD Head Office, Dstl and AWE. The Industry Partners include BAES (Maritime Services, Naval Ships and Advanced Technology Centre), QinetiQ, MBDA, L3-ASA and Lockheed.

This CDE Themed Competition seeks innovative solutions that could contribute towards defence against airborne threats such as ballistic, subsonic and supersonic cruise missiles, and hypersonic munitions.

Solutions should show disruptively greater efficiency or significantly reduced cost when compared to current solutions.

It is important to consider innovation not just at the whole system level, but also at the level of sub-systems and intra-system interactions.

Introduction

The inefficiency of current defensive systems is adversely affecting the survivability of UK forces in the land, sea and air domains.

UK forces operating in the land, sea and air environments face a wide range of threats including ballistic missiles, subsonic and supersonic land attack and anti-ship cruise missiles and, in the future, hypersonic munitions. The lines between these weapons are being increasingly blurred to the point where it is better to consider them collectively as “smart” or “complex” weapons, especially from the point of view of a defensive system. They pose a challenge to our defences due to their significant speed, manoeuvrability, survivability, accuracy and range.

Some smart weapons hide amongst terrain features and below the radar, remaining undetected for much of their flight. Others fly through thin atmosphere at higher altitudes where they can reach higher speeds, but aerodynamic steering is still practical. The fastest threats are Ballistic Missiles; these weapons make use of trajectories which arc into space, maximising their range and speed at the expense of stealth. For more information on each of these threats, please see Annex A.

Due to the similarity of their operation, systems which defend against these threats will typically be able to engage a number of such threats and tend to be divided into categories depending on timeliness, cost-effectiveness, range and agility constraints. No one system can cost-effectively defend against all of them; consequently layering several different systems is necessary to achieve a complete defence. This combination is known as an integrated air and missile defence system.

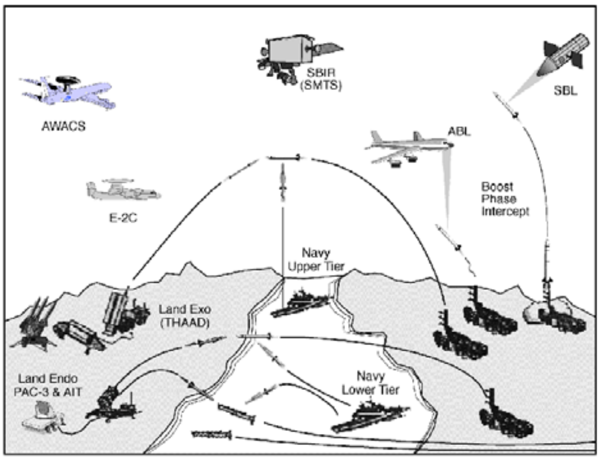

Figure 1: A notional Integrated Air and Missile Defence System, shown engaging cruise and ballistic missiles.

It is vital that UK forces take action to mitigate the increasing threat that these weapons present. While this can be conducted in a number of ways, this themed competition is concerned with two particular components of that mitigation:

- **Counterforce** is the pre-emptive attack or counterattack of the origin of the threat weapon; the persons and devices that launched the missile or munition. It generally takes the form of artillery or air power directed to attack a target immediately before, during or immediately after that target conducts its own attack
- **Active Defence** involves the counterattack of the threat weapon. Active Defence is further subcategorised into:
  - **'Soft Kill' Active Defence**. This involves attacking the threat weapon's sensors, for example by providing it with a convincing decoy, jamming it or blinding it
  - **'Hard Kill' Active Defence**. This involves counterattacking the threat weapon itself (rather than its origin) in an attempt to disable or destroy it before it strikes the defended asset

The defence of an asset is normally achieved through an integrated combination of these forms of defence and others. Most defences against smart weapons tend to address multiple threat types; the US Aegis Combat System, for example, has successfully engaged aircraft, anti-ship missiles and ballistic missiles.

Note that the proposed solutions do not necessarily need to be mounted on or be controlled by the defended asset; many current air and missile defence solutions are entirely separate military units to the assets they defend.

Counterforce

Counterforce works well against easily detected fixed or slow-moving launch points such as ships, airfields and towed artillery. Traditionally, counterforce has been considered to have limited applicability to ballistic missile defence due to the short timelines and long ranges involved in the battle; a modern solid ballistic missile can remain hidden for much of a conflict, and then be revealed and launched hundreds of kilometres in only a few minutes, giving the launcher ample time to hide again before counterforce can be dispatched. Threats can be launched from deep within a country behind heavy air, land and sea defences complicating the problem further. However, we believe that recent advances in various technologies might enable alternative effective counterforce missions against these threats. These could avoid the lengthy delay associated with the dispatch of more traditional air assets, changing the balance of risks involved in such missions.

Soft Kill Active Defence

Current systems that provide soft kill defence usually take the form of acoustic, radio frequency, microwave, infrared or optical jammers, decoys, obscurants and cyber techniques. They are more common than hard kill systems because they tend to be much more cost-effective and have wide applicability to other military capabilities such as intelligence, surveillance and reconnaissance. Soft kill poses problems with kill assessment; it is difficult to know promptly and with high confidence that the soft kill attack has worked because it usually does not result in a large explosion, and does not necessarily change the trajectory of the threat weapon. The approach taken by many current systems is simply to continue applying the soft kill defence until the engagement is decisively over, and to plan the remainder of the defence assuming that the soft kill approach has failed. This can lead to significant inefficiency.

Hard Kill Active Defence

Current systems that provide hard kill defence usually take the form of high performance interceptor missiles such as the Principal Anti-Air Missile System, also known as Sea Viper, or guns such as the Phalanx close-in weapons system. Both forms of system are very effective when applied against low numbers of threats of comparable levels of sophistication. However, missiles currently used for hard kill active defence have severe efficiency limitations. They have a high cost per shot, a low rate of fire and a low magazine capacity which generally means that they are less effective when defending against massed or prolonged attacks by less sophisticated threats. Guns used for hard kill active defence also have efficiency limitations; they have a very limited effective range and a low magazine capacity. Guns usually engage threats only a few seconds before they would strike the defended asset; they have little margin for error and generally result in significant target debris impacting the defended asset.

Competition challenges

We are inviting proof-of-concept research proposals to contribute to the protection of our forces from smart/complex weapon threats using disruptively more efficient and/or cost-effective methods. We welcome all proposals that describe new hard kill, soft kill or counterforce methods that might have capability against smart weapon threats, favouring solutions that are capable of dealing with the most challenging threats; ballistic and hypersonic missiles.

Proposals could address more than one challenge, but do not have to address all challenges.

Challenge 1 – Defence without interceptor missiles

For this challenge we would like bidders to consider entirely new methods for providing defence at range. In particular, how can we effectively defend against smart weapon threats at a range of greater than 10 km without using interceptor missiles, such that the threat does not successfully damage its target?

Novel hard kill, soft kill and counterforce techniques that could contribute to integrated air and missile defence should be submitted against this challenge.

Bidders should estimate and make clear the advantages and limits that their proposed solution might have. Limitations of existing solutions include:

- inability to engage targets that are too fast or agile
- employment only at certain times during the engagement
- significant size, weight, power and cooling requirements
- placing large demands on shared military assets such as intelligence services or multirole fighter aircraft

Challenge 2 – Kill Assessment for non-destructive hard and soft kill defences

Soft kill defences generally interfere with the internal electronics of the smart weapon, so the external appearance of the weapon might remain largely unchanged until it impacts its target and fails to detonate or misses by a small but sufficient distance. In addition to the challenges associated with kill assessment for soft kill active defence, some modern proposals for hard kill active defence present problems in this area. This is a problem in particular for ballistic missile defence, since these threats will continue to follow a ballistic trajectory even if completely electronically disabled.

Proposals which address how we assess whether or not a weapon still poses a threat to us following a hard or soft kill intervention, given that its trajectory is largely unchanged should be submitted against this challenge.

Solutions should be employable from a stand-off range of between 10 km and 40,000 km, in a timely manner and with high confidence.

Challenge 3 – Improving the efficiency or cost-effectiveness of existing hard kill defences

This challenge calls for innovation to be applied to existing methods for hard kill active defence such as interceptor missiles and guns, rather than entirely new approaches, such that the efficiency is increased.

Proposals which could provide an order of magnitude efficiency or cost-effectiveness advantage to current hard kill defence systems should be submitted against this challenge.

Solutions to this challenge may include but are not limited to:

- improved warhead, propellant or guidance concepts for existing missiles
- novel propellants and guidance systems that might support the use of guns at longer ranges, including electrical propellant methods
- better ways of directing scarce defensive resources such as long range sensors or ammunition

Proposals will be expected to explain how the concept might improve a relevant performance metric such as cost effectiveness, volume, probability of hit or fly-out time from launch to engagement. Bidders should keep in mind that we will only fund responses to this challenge that offer an order of magnitude improvement.

What we want

Proof-of-concept proposals that complete by 31st March 2015 and:

- are applicable to a wider range of threats
- consider what would happen if the mass and/or energy emitted by the defensive system fails to engage the threat weapon
- are applicable to ballistic and hypersonic missiles, or have an order of magnitude improvement against less stretching threats such as sub-sonic cruise missiles
- consider what will happen to any debris generated by the engagement
- cover novel technologies that have not yet been applied to the competition's challenges
- cover more developed technologies that have not been applied to the competition's challenges within an integrated air and missile defence context

We will give priority to proposals that either demonstrate or significantly de-risk a concept, but we are willing to consider studies that would progress technologies towards this stage.

What we don't want

We will not fund any proposals that:

- pose an excessive risk of friendly fire or collateral damage (for example, interceptors with nuclear warheads)
- pose an excessive risk to civilian aircraft and/or satellites
- are already being funded as part of other MOD Research Programmes
- are similar to previous failed programmes (for example, airborne chemical oxygen iodine lasers)
- would encounter considerable international political resistance (for example, space-based weaponry)
- are diplomatic or passive solutions (e.g. bunkers)
- provide only marginal improvements to current solutions
- require significant government-provided equipment or infrastructure to complete; any proof-of-concept demonstration should use commercially available resources

Exploitation

Follow-on funding of up to £500,000 will be available under the MDC Novel Technologies theme in the following financial year. This will be divided between projects which are considered to have successfully delivered a valid output to the initial proof-of-concept work and where a valid exploitation path exists.

The intent is that research initially funded through this competition will be exploited via one of the MOD MDC's Tier 1 Industry Partners, which are BAES (Maritime Services, Naval Ships and Advanced Technology Centre), QinetiQ, MBDA, L3-ASA and Lockheed. MOD Contracting for follow-on stages falls outside of the CDE commercial process but will fall within wider MOD commercial processes.

If a successful bid does not fit comfortably within the MDC's strategy, but cannot be ignored due to its quality, the MDC will, with permission from the bidder, expose the project to other funding sources within MOD where appropriate.

Invitation for CDE proposals

This competition will be supported by presentations given at the launch seminar on 22nd May 2014. These will be available to download at:
http://www.science.mod.uk/events/event_detail.aspx?eventid=298
Proposals are invited from industry and academia in the UK and overseas for research that can demonstrate a proof-of-concept to meet one or more of the challenges for "**Defence against Airborne Threats**".

The total funding available for this competition is £420k.

There is no cap on the value of proposals but it is more likely that at this stage a larger number of lower value proposals (eg £40k—£80k) will be funded than a small number of higher value proposals.

Proposals should focus on a short, sharp, proof-of-concept phase – typically, but not exclusively, 3-6 months in duration - with **deliverables completed by 31st March 2015**. Proposals should include a descriptive scoping for a longer programme of any duration but the proposal should be clearly partitioned with a costed proof-of-concept stage which is the focus of this CDE competition. Proposals for further work beyond the proof-of-concept stage will only be considered after the proof-of-concept stage has delivered, using the understanding gained to make an informed decision.

Proposals must include:

- a clear statement defining which of the three challenges the solution is submitted against
- a clear description of what is novel and innovative in the solution
- a clear statement of the programme of work that would be carried out and the outputs (deliverables) from the work
- a clear statement of the expected outcome(s), how this will be proven or demonstrated and how it will provide evidence that the outputs can be exploited
- a statement on the anticipated practicality of adopting the proposed solution
- an outline of any data/equipment requirements of the proposal, and how these will be met. Proposals at the proof-of-concept stage should not be dependent on the provision of data/equipment from MOD

Proposals that do not include the required information are unlikely to be successful.

Proposals will be assessed by subject matter experts from MOD and Dstl using the MOD Performance Assessment Framework (PAF). With bidders permission, deliverables from contracts will be made available to the Tier 1 members of the MDC (with appropriate intellectual property controls for Industry partners) and subject to review by UK MOD.

For successful bidders Dstl will be available to provide advice and/or guidance via an appointed Technical Partner throughout the project and provide the interface with MOD and wider Government stakeholder community. Dstl does not commit to fund any follow on work as a result of any contracts placed via this CDE competition, but more promising ideas will be considered for further funding where appropriate.

CDE proposal submission process

Key dates

- 22nd May 2014 — Competition launch event at Altitude 360, Millbank Tower, London
- TBC — Post-launch webinar
- 3rd July 2014 — Competition closes at 1700 hrs
- 6th August 2014 — Decision Conference
- 22nd August 2014 — Funding decisions released
- 31st March 2015 — Proof-of-concept research complete

Proposals for funding must be submitted by 1700 hrs on Thursday 3rd July 2014 using the CDE Portal. Proposals must be clearly marked with "Defence against Airborne Threats (+ challenge 1,2,3)" as a prefix in the title.

Please plan the timeline for submitting your proposal carefully. If you have not used the CDE Portal before you will need to become familiar with the guidance, including how to open an account starting with the Quick Start Guide.

Other information and guides are available on the CDE website:

- general CDE advice: www.science.mod.uk/engagement/cde/working_with_cde.aspx

- contract & IPR guidance: www.science.mod.uk/engagement/cde/funding_contracts.aspx

- on using the Portal: www.science.mod.uk/engagement/the_portal.aspx. The Portal is optimised for proposals based on physical sciences and engineering and we are aware that proposers sometimes struggle to adapt to using it with social science based proposals. The key points (rather than the detailed questions) that are sought under the main headings still apply and further advice can be obtained from CDE.

Common errors in preparing and submitting a proposal include:

- **character limit** – there is a limit of 1000 characters in each individual descriptive paragraph within the proposal; when completed they must be added to the document; additional paragraphs can be added if 1000 characters is insufficient
- **it is a web-based tool** – please save your work regularly to avoid 'time-outs' that lose work
- **attachments fail** – They must be Word 97-2003 format, portrait format, should have generous margins with no material overhanging the margin and a max size of 1 MB. Please note that attachments should only be used for supplementary information, the main points of your proposal should be written into the online form. Care should also be taken to make sure that attachments are placed in the relevant section (eg technical information should not be attached to the commercial section)
- **failing to properly submit** - **publish is not the same as submit**. You have **not** completed the submission process if your proposal is at the FINAL/PUBLISHED stage (in the status and published status columns respectively); CDE has no sight of the proposal at this stage. To complete submission you need to press 'submit' under the 'Tasks' column. This changes the status of your proposal to 'SUBMITTED'; it will then change (normally after a few days, often sooner) to 'RECEIVED' indicating that the proposal has been accepted by CDE for assessment

For a proposal to be accepted for assessment:

- the standard terms and conditions of CDE must be unequivocally accepted
- there must be at least one deliverable against which payment can be made
- the commercial section of the proposal must be completed

Please do not leave submission of your proposal until just before the deadline. Past experience has shown that the Portal becomes heavily loaded near the competition close resulting in slow operation (up to one hour to publish rather than a few minutes) and that, with the pressure of the deadline, mistakes are made that mean proposals are not submitted or accepted.

Proposals and content placed on the Portal should not contain classified information.

Queries and help

As part of the proposal preparation process, queries and clarifications are welcomed:

- **Technical queries** about this specific competition should be sent to **MDCNovelTech@dstl.gov.uk**.
  Capacity to answer these queries is limited in terms of volume and scope. Queries should be limited to a few simple questions or if provided with a short (few paragraphs) description of your proposal, the technical team will provide, *without commitment or prejudice*, broad yes/no answers. This query facility is not to be used for extensive technical discussions, detailed review of proposals or supporting the iterative development of ideas. Whilst all reasonable efforts will be made to answer queries, CDE and Dstl reserve the right to impose management controls when higher than average volumes of queries or resource demands restrict fair access to all potential proposal submitters

- **General queries** (including how to use the Portal) should be sent directly to CDE at **cde@dstl.gov.uk**

Annex A – Threat Weapon Characteristics.

This information is provided only to assist bidders who do not have direct experience of these threats and is not intended to be exhaustive. Many approaches that work well against more conventional targets will fail against the threats described in this competition due to reasons that can be understood via simple order of magnitude calculations, and it is recommended that bidders carry out basic tests of this nature when writing their proposals.

Ballistic Missiles

Typical short and medium range ballistic missile trajectories are shown in Figure 2 below. Ballistic Missiles are generally under thrust only for the first few minutes of their flight, and use ballistic trajectories to maximise the range which can be achieved using this thrust. Shortly after the engine cuts off, the re-entry vehicle (the portion of the ballistic missile designed to protect the warhead during atmospheric re-entry) will generally separate from the rest of the missile in order to enhance the accuracy of the system and reduce its vulnerability to ballistic missile defence by presenting a smaller target, although for some shorter range systems this is considered unnecessary. In terms of construction, ballistic missiles are (with the exception of the re-entry vehicle) generally very similar to space launch vehicles. Older ballistic missiles tend to be very inaccurate which relegates them to a strategic role, but newer models are increasing in accuracy to the point where they are tactically useful. They are categorised according to range into short range ballistic missiles (SRBMs), medium range (MRBM), Intermediate range (IRBM) and intercontinental (ICBM). The tables below the figure contain some more basic numbers to inform potential bidders on the problem.

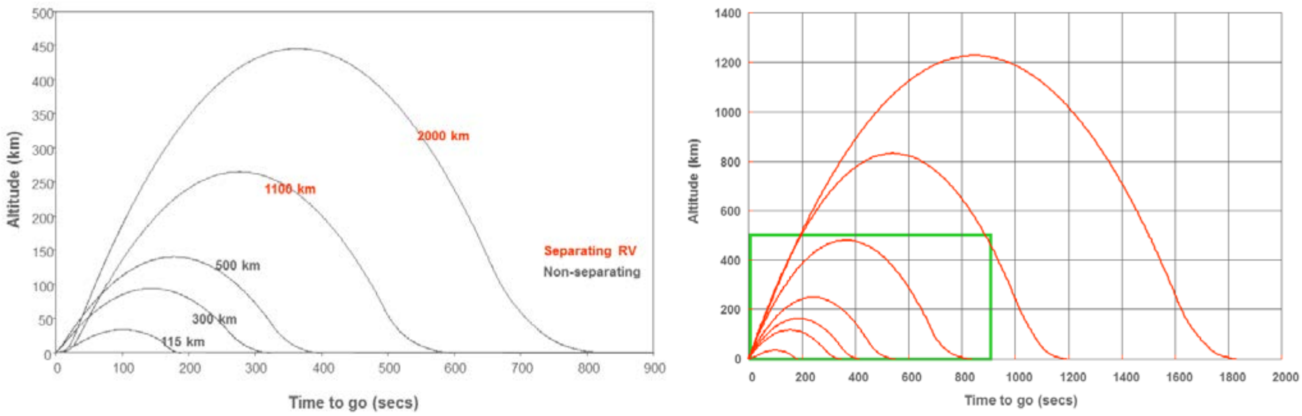

Figure 2: Trajectories associated with Short and Medium Range (left) and Intermediate Range and Intercontinental (right) Ballistic Missiles. The over-ground range of the system is shown next to each line on the left, and the green box on the right contains each of the trajectories detailed on the left.

	SRBM	MRBM	IRBM	ICBM
Range (kilometres)	90-1000	1000-3500	2500-5500	5500+
Flight Time (minutes)	1-6	6-20	20-35	35+
Boost engine burn time (seconds)	50-70	80-120	120-180	180-300
Velocity at engine cut-off (km/s)	1-2	2-4.5	4.5-6.5	7+
Re-entry vehicle behaviour	Mostly non-separating	Separating		
Mass at engine ignition (metric tonnes)	2-6	6-15	15-30	40-200

Table 1: Some kinematic characteristics of typical Ballistic Missiles

	SRBM	MRBM	IRBM	ICBM
Propellant	Solid or liquid		Mostly solid, but some liquid	
Booster & internal materials	Steel, Aluminium			Steel, Aluminium, Composites
Re-entry vehicle thermal protection system materials	Steel, Cork, Asbestos	Graphite and Carbon	Graphite, Silica, Carbon Phenolic	Carbon, Silica, Quartz Phenolic
Diameter at engine ignition (m)	0.8-1.3	0.8-1.3	1.5+	2+
Length at engine ignition (m)	5-8	6-12	10-15	15+
Length of RV after separation (m)	1-3			1-4

Table 2: Some construction characteristics of typical Ballistic Missiles

Cruise Missiles

A cruise missile is essentially an armed, unmanned, expendable aircraft designed to follow a predefined flight profile to its target, and then detonate a warhead in close proximity to it. They normally follow a flat trajectory for much of their flight and are powered similarly to conventional aircraft, but might use different altitudes during different points of their flight in order to balance fuel efficiency (at higher altitudes), with stealth (at lower altitudes). They generally use a mixture of guidance methods and sensors in order to follow a path that optimally transits the air defences around the target, for example by flying below the radar or in the shadow of terrain (as shown in Figure 3 below), and can travel within meters of the land/sea when required. While ballistic missiles are categorised according to their range, cruise missiles are categorised according to their intended target. The broadest categories are anti-ship cruise missiles, land attack cruise missiles and strategic cruise missiles. All categories can be launched from land, sea or air. Cruise missiles are cheaper than ballistic missiles and more accurate, but slower and more vulnerable to soft kill techniques.

	Anti-ship	Land-attack	Strategic
Range (km)	50-500	180-600	2000-3000
Speed (km/s)	0.2-1.5	0.2-0.3	0.2-1.5
Length (m)	5-8	5-8	6-12
Diameter (m)	0.4-0.6	0.4-0.6	0.6-0.9
Mass at launch (metric tonnes)	1.3-4	1.3-4	3-6
Turbojet engines	yes	yes	yes
Ramjet engines	yes	no	yes
Rocket engines	yes	no	yes

Table 3: Some Characteristics of typical cruise missiles

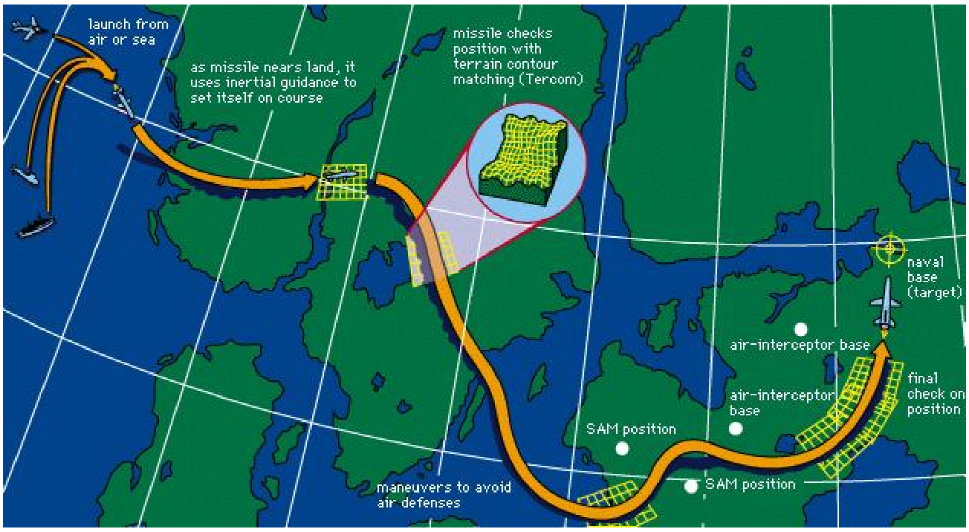

Figure 3: A typical flight path of a Land attack cruise missile, taken from L. Freedman, Atlas of Global Strategy, copyright © Andromeda Oxford Ltd.

Hypersonic Missiles

Hypersonic missiles, which are defined as missiles that travel faster than Mach 5 (1.7 km/s) under powered atmospheric flight, are under development by the US, Russia, India and China. They combine the unpredictable trajectory of cruise missiles with the speed of ballistic missiles and are being investigated for anti-ship and strategic roles. A hypersonic strategic weapon would be much harder to intercept than a ballistic missile, while an anti-ship hypersonic missile would be visible to its target for less than 20 seconds before impact.