The Hague Centre for Strategic Studies

Surviving the Deadly Skies

Integrated Air and Missile Defence 2021-2035

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Executive Summary

This report argues that interacting geopolitical and technological trends have raised the type and level of threats that European states face from ballistic missiles or cruise missiles, manned and unmanned aircraft, or other weapon systems. This adds serious urgency to the need for better and more integrated air and missile defence (IAMD) for European states. Current European air and missile defence capabilities are not up to the task to effectively defend against the full spectrum of threats.

The transparency of the battlefield is increasing due to improved space-based sensors and sensors based on unmanned systems. At the same time, technologies for more precision, speed, and integration of air and missile weapons systems are becoming more accessible to more actors. Consequently, not only great powers, but regional powers and non-state actors as well, are more able than before to use or to threaten with the use of these weapons. European military infrastructure and forces, as well as civilian targets, are particularly vulnerable to attacks that use an extensive mix of sophisticated and unsophisticated weapons to overwhelm and confuse the defender.

Air and missile defence is thus relevant at the strategic, theatre, and tactical level

Active air and missile defence systems consist of sensors, interceptors, and command and control (C2) nodes. The challenge for the defender is to find threats as early as possible, to track them, and to stop them with an interceptor. A range of different types of sensors are required at different stages, and although the interceptor is generally a missile, alternatives exist. This complex of systems is tied together through C2 units. Both human operators and automated units process the information from the sensors and send out commands to the launchers. These defensive systems are generally designed for various types of threats but are often stronger versus certain threats than others. Defensive systems can be based on land, sea, air, or space, and combined across these domains. They defend against threats to everything from cities and civilian infrastructure in our homelands, to military infrastructure and deployed units far from home. Air and missile defence is thus relevant at the strategic, theatre, and tactical level.

In short, active air and missile defence is a demanding and high-stake task. Attackers and defenders are engaged in a highly competitive struggle for advantage. Defenders therefore not only rely on active defence, but also on passive defence measures: concealment, dispersion, mobility, and hardening. Moreover, deterrence and arms control measures should highly reduce the risks that adversaries in fact use these weapons. Defenders may also employ pre-emptive measures, attempting to destroy hostile capabilities using air power or cyber weapons before they can launch (another) attack.

The report focuses on active defence measures and underlines that they have become newly important again. Recent illustrations are easy to find, from the 2021 Israel-Hamas conflict, the 2020 Nagorno-Karabakh conflict, to the 2019 attack on the Saudi oilfields. All show how minor states and non-state actors can creatively and effectively use missiles and unmanned vehicles to find and destroy targets, either bypassing defences or saturating them.

Even more worrying is what could happen at a larger scale. Russia and China have invested in missile arsenals to hold ports, airbases, C2-nodes, and major military forces at risk. These so-called anti-access area denial (A2/AD) capabilities can either stop or raise the costs of forces operating in their vicinity or dissuade them from coming to the aid of allies and partners under direct threat. Russia and China, alongside the United States and other major states, are also investing in hypersonic weapons, which adds another level of speed and unpredictability to great power politics.

For European states, improved air and missile defences are therefore not only a question of protecting their populations and militaries on a national basis: alliance commitments, the geographic reach and the complexity of the threats require multinational approaches as well. The rate at which the threat environment is developing, and the impact across the strategic, theatre, and tactical levels require a greater sense of political urgency in European capitals.

The notion that the US may be (or become) overcommitted militarily in multiple regions means that a viable air and missile defence has strong implications for European strategic autonomy and European commitments to NATO. European states need solutions if the US is incapable of quickly acting in Europe, both to protect their own security and to maintain the credibility of NATO as a whole. It also creates manoeuvre space for the US during crises in multiple regions and can dampen paths to rapid escalation up to and including the nuclear level by the major powers during a crisis. The changing air and missile threat environment spells out the need for European industrial solutions. Air and missile defence against threats to European population, infrastructure, and forces represents a minimal capability that Europeans should be able to master without depending on others. But it is also a matter of strengthening the transatlantic relationship, as the alliance cannot effectively deter threats without core assets in individual member states being properly protected. The specific parts of the report can be broken down as follows.

Threats

The conventional nature of the threat particularly stands out

The threat environment is changing due to interacting geopolitical and technological developments. The report finds three geopolitical developments that together directly and indirectly affect European security: (1) the intensifying competition between the US, and Russia and China has created new incentives to (2) invest in military technologies in Europe and Asia, specifically missile-related technologies. This trend is reinforced by (3) the dynamics regarding minor states and non-state actors in the regions surrounding Europe.

The conventional nature of the threat particularly stands out. Since the end of the Cold War, the focus in missile defence has been on defending against small numbers of nuclear-armed, but fairly unsophisticated, ballistic missiles from so-called rogue states in the European periphery. However, the increasing quality and quantity of conventional missiles should be cause to reconsider this focus. Particularly because these missile capabilities are now supplemented by unmanned vehicles that contribute to a more transparent battlefield and to precision attacks, and be used to destroy crucial nodes to pave the way for more sophisticated weapons. The 2020 war in Nagorno-Karabakh was an illustration of new creative ways to use these kinds of assets; yet, while highly destructive, it was still small-scale compared to what a potential conflict between major states would look like.

To offset the ability of the US to project power in their vicinity, peer competitors Russia and China are adding to their ability to strike at military infrastructure and at forces on land, sea, and in the air. Their arsenal includes short- and intermediate-range ballistic and cruise missiles, manned and unmanned aircraft, and possibly in the near future hypersonic weapons. Through these capabilities, Russia can raise the difficulty for American and Western European forces to reinforce NATO's Eastern Flank. While probably not the most immediate threat to the security of Europe's northeast, these capabilities still make it more difficult to rule out Russia creating a *fait accompli*. In addition, most of these missile technologies can be used to target cities with nuclear or other non-conventional warheads. Russia could potentially use these capabilities to blackmail European allies and the US to forego assistance to allies.

Russia can raise the difficulty for American and Western European forces to reinforce NATO's Eastern Flank

In the maritime domain, regional powers like Iran can threaten ships further and further from shore, also using non-state proxies, thus undermining the safe passage of European vessels to and from the Indian Ocean and through the Persian Gulf. Moreover, minor states and non-state actors are increasingly effective in exploiting the possibilities of combining unmanned aerial vehicles for sensing, loitering munitions, and rockets and artillery. This particularly poses a threat against land-based military units at the tactical level. This renders, for instance, stability missions of European land forces riskier than before.

Technological developments matter as well. The report recognises four trends and developments: (1) increased accessibility due to declining costs; (2) improvements in precision and transparency; (3) compression of time and space diminishing reaction time; and (4) the ability to combine different weapons during an attack and confuse and overwhelm a defender.

Unmanned vehicles will have an effect at all levels and across the land, sea, and air domains. Specifically, unmanned vehicles can enable or multiply the effects of other capabilities. They can contribute persistent sensing to increase the transparency of the battlefield, or, in their more sophisticated form, increase the precision of more sophisticated weapons. As loitering munitions, they can be used to destroy key C2 or radar installations, and by removing these key nodes, clear the way for larger-scale, and more sophisticated attacks. While more advanced models may stay out of reach of many states and non-state actors, in general they are quickly becoming more accessible to more actors.

In the maritime domain, regional powers like Iran can threaten ships further and further from shore, also using non-state proxies

The extent to which hypersonic weapons will present a threat in the short-term is uncertain. Yet, they could undermine stability in the medium-to-long term. Given the limited number of states that are likely to have access to them, their effect might not be felt at the strategic level where most nuclear-armed states already have ample capabilities. What is arguably underrated is the potential ability of hypersonic weapons to quickly eliminate key military infrastructure – ports, airbases, C2-nodes – and thereby reshape the parameters of the conflict at the theatre level. Their speed, manoeuvrability, and ability to be deployed from multiple platforms could achieve significant effects during a conventional theatre-level conflict.

One of the report's central messages is that, more than individual technologies, the real emerging danger regarding air and missile threats lies in the emerging ability to combine different types of weapons, with vastly different qualities, to overwhelm and confuse the defender's systems, or blind them by striking at specific nodes. After the Cold War, European states have become used to treating most of the dangers of air and missile threats as distinct problems at the strategic and tactical level, while being able to largely ignore theatre-level threats by major states. In the emerging threat environment, combinations of high-end and low-end weapons pose a major challenge, while defences at the theatre-level are specifically underdeveloped, not necessarily in terms of technologies, but in terms of conceptual and doctrinal employment, as well as numbers of interceptors. Our study underlines that the conventional threat at the theatre level against military infrastructure such as ports, airports, nodes, as well as high-value naval vessels has been underrated.

In summary, technological developments, conceptual and doctrinal innovation, and investments in numbers have given potential aggressors distinct advantages. The ability to combine various weapon systems in attacks, with more varied sensors, has created a 360-degree threat environment. Weapon systems with varying levels of sophistication can be brought together to saturate, confuse, and overwhelm the defender's systems. Whether ballistic missiles or hypersonic weapons, fighter-bomber aircraft, cruise missiles, or unmanned aerial vehicles, each weapon system has distinct advantages in terms of speed, trajectory, manoeuvrability, expendability, and costs to leverage against the defender's systems. The threat is no longer primarily from small numbers of ballistic missiles from so-called rogue states, and from non-state actors. It is not only a matter of new or emerging sophisticated technologies like hypersonic weapons, but also one of raw numbers of weapons of varying kinds of sophistication, and especially the creative employment of these weapons. European answers regarding defence should also be sought in technology, numbers, and conceptual and doctrinal innovation. In short, rather than exploring the relative qualities of specific defensive systems versus specific weapons, throughout this report we specifically look at the question of air and missile defence through a comprehensive *strategic* lens.

Solutions

The study suggests a number of solutions to improve active air and missile defence in Europe.

European answers regarding defence should be sought in technology, numbers, and conceptual and doctrinal innovation

Stop overlooking the mid- and lower-level threats. The attention in air and missile defences over the past decades has been given primarily to higher-level strategic threats. But with the growing possibility of combining weapon systems for conventional attacks at the theatre level, investments should go there. The use of unmanned vehicles at every threat level, though for different purposes and often to pave the way for more destructive or sophisticated weapons, underlines that investments towards better point defence against UAVs are both necessary and cost-effective. The risk is that combination attacks will quickly exhaust the limited stock of high-end interceptors.

Combine defensive solutions. For successful air and missile defence, European states should not only invest in high-end technologies for the high-end threats, such as high energy weapons against hypersonic weapons, but also stimulate creative employments of emerging and existing technologies. After all, the emerging threat environment is not primarily a consequence of rapid technological advances, but rather of the attention paid to effectively combine existing weapons with newer systems, and of the investment in numbers of weapons. Consequently, improved passive defence measures such as dispersion, concealment, mobility, and hardening should be combined with the active defence measures. These measures are needed to offset the improvements in precision and battlefield transparency. Alongside improvement in active and passive defence measures, preventive solutions such as airpower, special forces, and cyber operations should be considered as effective solutions.

Invest in stocks. European states should continue to invest in numbers of interceptors, whether land-, sea-, or air-based systems. Numbers matter, especially when adversaries rely on saturation attacks with combinations of weapons to confuse and overwhelm defensive systems. Without built-in redundancies in interceptor stocks, the defensive system as a whole will become brittle. While this is costly, the price pales in comparison to the costs of losing the targets that are defended. But European states can be smarter about their acquisition processes and coordinate their acquisition processes to ensure a better deal from the producers. Pressuring industrial players towards greater interoperability between systems would facilitate sharing interceptors between land- and sea-based systems and between European states and the US.

Integrate weapons, technologies, and investments. European states should better integrate their air and missile defence systems both nationally and internationally, within Europe and with the US. Further investments in the technologies to better integrate the various air-based systems of sensors, interceptors, and C2-nodes that make up active air and missile defence would pay high dividends. This is a matter of getting more out of what is already there, not a cost-saving measure. European projects underway as part of the Permanent Structured Cooperation and the European Defence Funds hold a great deal of promise. Yet this is not only in part a matter of technological solutions and smart acquisition policies, but also a matter of synchronising employment practices through simulations, testing, and exercises. The Netherlands could play a role, specifically with its sea-based sensing capabilities, which provide it with a mobile and flexible niche capability.

European states should better integrate their air and missile defence systems both nationally and internationally, within Europe and with the US

Underline political-strategic urgency. None of these solutions can be implemented without a shared European political urgency for investments in air and missile defence, as an integral part of the strive towards more strategic autonomy. These are political choices, not just technological matters. In the current constellation, European states are highly dependent on the US for strategic missile defence and theatre level defences. European improvements in integrated air and missile defence would go far in building the European ability to conduct conventional deterrence through its own anti-access area denial capabilities. Given that Europe can no longer be sure that the US can quickly reinforce both the Euro-Atlantic and the Indo-Pacific theatres, strengthening Europe's ability to protect key civilian and military infrastructure is required to protect high-value European assets as well as to raise the costs of aggression against Europe, while also buying allies time in case the US cannot quickly reinforce the European theatre.

In summary, strengthening air and missile defence within Europe is necessary and should receive much greater attention in the public debate, despite its technical nature. It cannot be a matter for individual governments on a national basis. Given the intricacies of the emerging threat environment, it is necessary to combine European defensive assets in smarter and more effective ways.

List of Acronyms and Abbreviations

A2/AD	Anti-Access Area Denial
AAM	Air to Air Missile
ADAR	Air Defence Artillery Regiment
ADEs	Armoured Division Equivalents
AEA	Airborne Electronic Attack
AI	Artificial Intelligence
ALTBMD	Active Layered Theatre Ballistic Missile Defence
AMD	Air and Missile Defence
ARH	Active Radar Homing
ASCM	Anti-Ship Cruise Missile
ASW	Anti-Submarine Warfare
ATGM	Anti-Tank Guided Missiles
BMD	Ballistic Missile Defence
C2	Command and Control
C2BMC	Command and Control, Battle Management and Communications
C3	Command, Control, and Communications
CARD	Coordinated Annual Review on Defence
C-UAS	Counter-Unmanned Aerial Systems
DEWs	Directed Energy Weapons
ECOWAR	EU Collaborative Warfare Capabilities
ECW	Electronic Counter-Warfare
EDA	European Defence Agency
EDI	European Deterrence Initiative
EHAAP	European High Atmosphere Airship Platform
EMASoH	European Mission for Maritime Awareness in the Strait of Hormuz
EPAA	European Phased Adaptive Approach
ESSM	Evolved Sea sparrow Missiles
EU	European Union
EUMILCOM	Strategic C2 System for CSDP Missions and Operations
EURAS	EU Radio Navigation Solution
EU-SSA-N	European Military Space Surveillance Awareness Network
EW	Electronic Warfare
FAADC2	Forward Area Air Defence Command and Control
FONOPs	Freedom of Navigation Operations
FY2021	Fiscal Year 2021
GBAD	Ground-Based Air Defence
GEO	Geosynchronous Equatorial Orbit
GNSS	Galileo Global Navigation Satellite System
GPS	Global Positioning System
G-RAM	Guided Rockets, Artillery, and Mortars
HALE	High-Altitude Long-Endurance
HCM	Hypersonic Cruise Missile
HELs	High-Energy Lasers
HGV	Hypersonic Glide Vehicle
HPMs	High Power Microwave Weapons
IAMD	Integrated Air and Missile Defence
ICBM	Intercontinental Ballistic Missile
ICT	Information and Communications Technology
INF	Intermediate-Range Nuclear Forces
IRGCN	Islamic Revolutionary Guard Corps Navy
ISR	Intelligence, Surveillance, and Reconnaissance
JCPOA	Joint Comprehensive Plan of Action
LEO	Low Earth Orbit
MALE	Medium-Altitude Long-Endurance
MANPADS	Man-Portable Systems
MARV	Manoeuvrable Re-entry Vehicles
MIRV	Multiple Independent Re-Entry Vehicles
MMR	Multi Mission Radar
M-SHORAD	Manoeuvre Short Range Air Defence
NATO	North Atlantic Treaty Organization
New START	New Strategic Arms Reduction Treaty
ODB	Offense-Defence Balance
OODA	Observe, Orient, Decide, Act
PAAMS	Principal Anti-Air Missile System
PESCO	Permanent Structured Cooperation
PLA	People's Liberation Army
PLAN	People's Liberation Army Navy
PNT	Positioning, Navigation and Timing
PRC	People's Republic of China
RAM	Rockets, Artillery, and Munitions
RPA	Remoted Piloted Aircraft

RPAS	Remoted Piloted Aircraft Systems
SAM	Surface to Air Missile
SBIRS	Space-Based Infrared System
SEAD	Suppression of Enemy Air Defence Systems
SHORAD	Short Range Air Defence
SLCMs	Sea-Launched Cruise Missiles
SSBN	Strategic Ballistic Missile Submarines
SVTT	Surface Vessel Torpedo Tubes
TERCOM	Terrain Contour Matching System
TNT	Trinitrotoluene
TWISTER	Timely Warning and Interception with Space-based Theatre Surveillance
UASs	Unmanned Aerial Systems
UAVs	Unmanned Aerial Vehicles
UK	United Kingdom
US	United States
UUVs	Unmanned Underwater Vehicles
VLS	Vertical Launch System
V-SHORAD	Very Short Range Air Defence
WMD	Weapons of Mass Destruction

1 Introduction

The character of peace and conflict in the coming decades will be strongly shaped by air and missile threats for three reasons. First, the width and depth of air and missile threats is expanding. Second, the strategic advantages to be gained by using them are more varied. Third, the types and number of actors that have access to air and missile systems are growing. Previously only available to great powers, at least on the sophisticated end of the spectrum, they are now proliferating. In parallel, great and middle powers are using and combining decades-old technologies more effectively than before. Simply put, it is not the introduction of a single new technology or an improvement of every existing technology, but rather the cumulative effect of interacting political and technological trends and developments that matters. It has created a so-called 360-degree threat environment. As discussed in this study, in the current and emerging geostrategic environment these developments will impact Europe in multiple ways and defending against them will require a multifaceted approach. Our starting point in this report, is to examine the strengths and weaknesses of existing European air and missile defences in light of this changing threat environment from a *strategic* point of view that includes not only technological possibilities and limits, but also concepts and doctrine, as well as numbers.

A comprehensive reappraisal is needed of defence against air and missile threats, how to integrate various defensive measures, and how to cooperate and coordinate with partners and allies

Therefore, a comprehensive reappraisal is needed of defence against air and missile threats, how to integrate various defensive measures, and how to cooperate and coordinate with partners and allies. The urgency of this reappraisal follows from the changing threat environment but also from the relative neglect of the topic for three decades – or at least the uneven look at certain weapon systems within the threat spectrum. As the risk of conflict between major powers faded in the post-Cold War decades, Western policymakers, planners and scholars believed air and missile defence had diminished in importance.

Air and missile threats impact political-strategic outcomes on three levels. At the strategic level, they threaten societies, cities, and civilian infrastructure on national territory. At the theatre level, they threaten military infrastructure, ports, airfields, bases, command and control (C2), and high-value assets that ensure the ability to deter, fight and defeat opponents. At the tactical level, they threaten military units in operations. The first and third levels have received some attention in recent decades; the second hardly any.

During the Cold War, air and missile threats were central to European collective defence.[1] But Western states largely neglected land-based air and missile defence in the two decades afterwards. There were two exceptions to this overall neglect: the need to defend against small numbers of ballistic missiles from rogue states like Iraq, Iran, and North Korea, potentially armed with weapons of mass destruction;[2] and the protection of expeditionary forces against guided rockets, artillery and mortars (G-RAM), the latter largely in the context of irregular

1 Thomas G. Mahnken, "Weapons: The Growth & Spread of the Precision-Strike Regime," *Daedalus* 140, no. 3 (2011): 45–57.

2 William J. Clinton, "National Security Strategy 1995" (Washington D.C.: White House, February 1, 1995), 13–15, http://nssarchive.us/national-security-strategy-1995/; George W. Bush, *The National Security Strategy of the United States of America* (Washington D.C.: White House, 2002), 14; Barack H. Obama, *National Security Strategy of the United States (2010)* (Diane Publishing, 2010), 4, 23–24.

warfare.[3] The withdrawal by the George W. Bush administration from the Anti-Ballistic Missile Treaty with Russia in 2002 was intended to ensure the US could place the Aegis missile defence system in Europe to guard against a potential Iranian missile threat, even though it ended up further damaging US-Russian relations.[4]

During those years the air and missile threat environment evolved significantly, with European air and missile defences not keeping up with the developments, whether the proliferation of missiles or the maturation of emerging technologies. Crucially, Europe can currently no longer fully rely on the United States being both willing and able to provide security at all times.[5] Europeans are striving for more strategic autonomy, and must therefore invest in futureproof integrated air and missile defence (IAMD). In doing so, policymakers face a choice over whether, when, and how to balance the need for investment in protecting (national) high-value targets, namely societal and economic security, and the requirement for protecting military assets at the theatre and the tactical level, namely military security.

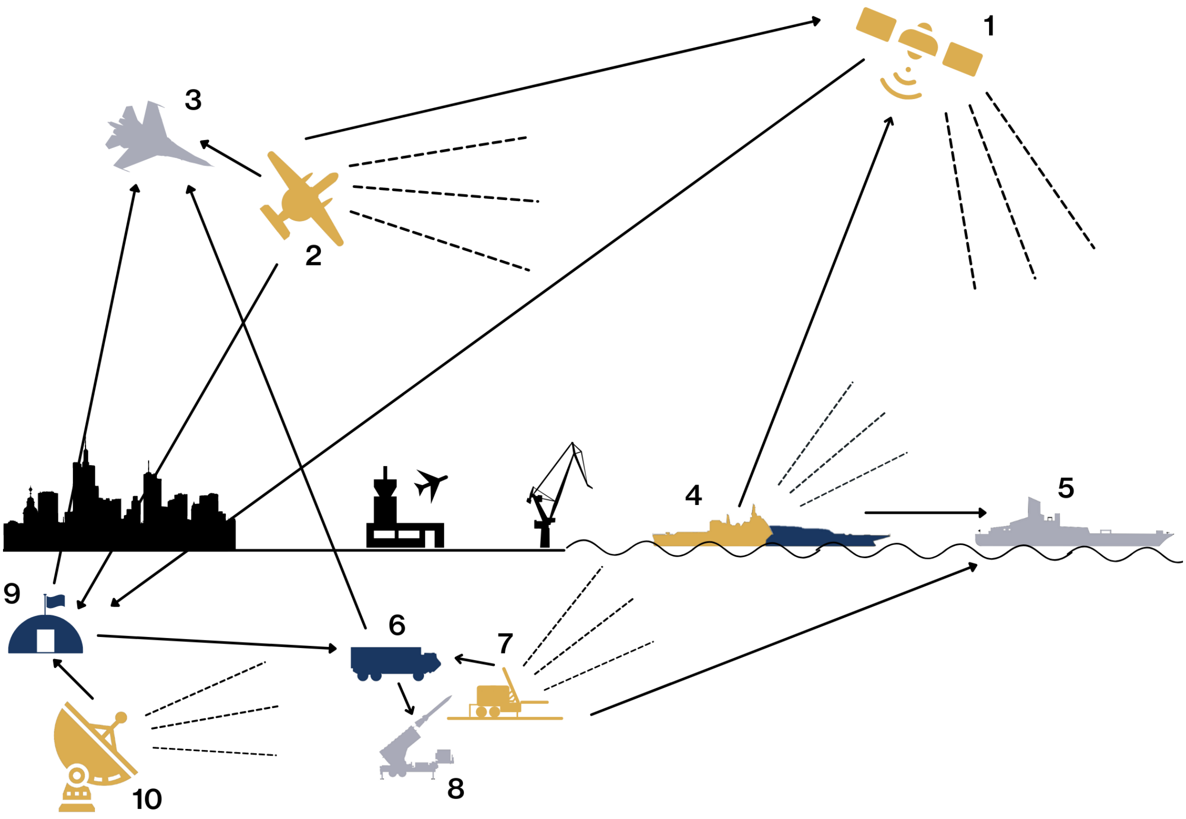


Figure 1. Illustration of active air and missile defence (not exhaustive)

3 Carl Rehberg and Mark Gunzinger, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases* (Centre for Strategic and Budgetary Assessments, 2018), 2; International Institute for Strategic Studies, "Emerging AirDefence Challenges," in *Military Balance 2019* (London: International Institute for Strategic Studies, 2018), https://www.iiss.org/publications/the-military-balance/the-military-balance-2019/xmb2019-bonus-content.

4 Wade Boese, "U.S. Withdraws From ABM Treaty; Global Response Muted," Arms Control Association, 2002, https://www.armscontrol.org/act/2002-07/news/us-withdraws-abm-treaty-global-response-muted.

5 Paul Van Hooft, "The United States May Be Willing, but No Longer Always Able: The Need for Transatlantic Burden Sharing in the Pacific Century," in *The Future of European Strategy in a Changing Geopolitical Environment: Challenges and Prospects*, ed. Michiel Foulon and Jack Thompson (The Hague, Netherlands: The Hague Centre for Strategic Studies, 2021).

This study is our contribution to put air and missile threats back in the limelight. It addresses the entire suite of air and missile threats and of solutions to defend against these within the context of European defence. The study points to the levels of potential conflict where the shift between offense and defence may be most pronounced due to the combination of technology, concepts and doctrine, and numbers. The emphasis within IAMD is on active defence: the complex of sensors, interceptors, and command and control or battle management systems (see Figure 1, for an illustration). It looks at how these active defence measures can counter current threats and identifies potential shortfalls. However, the study also addresses preventive measures – whether through arms control, deterrence, or offensive action – as well as passive defence – concealment, redundancy, hardening. The study is structured as follows:

- Chapter 2 provides an outline of seven big picture trends to corroborate and illustrate the assertions made in this introduction.
- Chapter 3 follows up with a description of the three levels of impact (strategic, theatre, tactical) and surveys key air and missile systems. It appraises the principal developments in these capabilities and highlights key risks at the three levels.
- Because of the technological intricacies of the topic, the strategic implications are often difficult to grasp. We have therefore included three vignettes of recent real-world uses of air and missile weapon systems to illustrate the trends we discuss in chapter three. The first of these examines the 2019 attack on the Saudi oilfields and illustrates the limits of the employment of current systems in the emerging 360-degree threat environment.
- Chapter 4 assesses the implications of the developments of the threat environment at the three levels of impact and offers four likely scenarios to illuminate the potential for air and missile threats in armed conflicts in the timeframe between now and 2035.
- The second vignette looks at the 2021 Israeli-Hezbollah conflict and underlines the uneven exchange between expensive missile defences and numerous cheaper missiles .
- Chapter 5 explains the logic of the offense-defence balance across the three levels which serves as an analytical framework to consider trends in the myriad of air and missiles threats. It synthesises the insights from the preceding Chapters and applies these to the offense-defence balance.
- The third vignette focuses on the 2020 Nagorno-Karabakh conflict which illustrates the creative and effective use of old and new capabilities.
- On that basis, chapter 6 outlines the broader solution set to deal with air and missile threats that encompasses prevention, passive defence, and active defence.
- Chapter 7 turns to active defence solutions. It offers an overview of European capabilities and identifies capability gaps in the existing capability portfolios.
- Chapter 8 provides recommendations for European states where to focus their IAMD development efforts.
- Finally, chapter 9 specifies these recommendations for the Netherlands.

2 Trends and Developments in Air and Missile Threats

The fact that air and missile defence has returned to the agenda with such force is not exclusively or primarily a consequence of supposedly miraculous technologies such as hypersonic missiles. We rather see the interaction of multiple simultaneous political and technological trends. In this study we identify seven developments that underline the clear and present danger of air and missile threats (see Figure 2 for an illustration of air and missile threats).

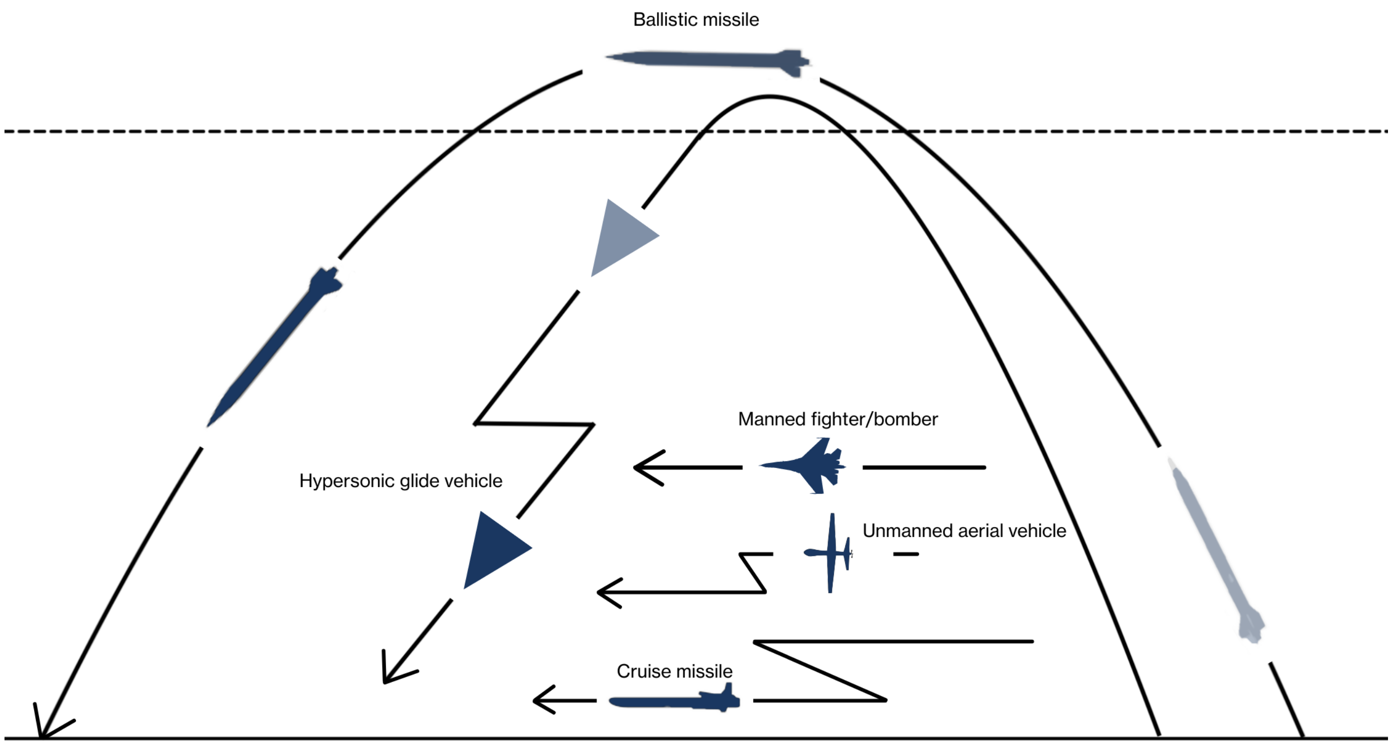


Figure 2. Diversity of air and missile threats illustration (not exhaustive)

2.1 The future is the past is the future: The return of great power competition

The Russian annexation of Crimea and intervention into Ukraine in 2014 brought back the threat of major interstate conflict to Europe. The rapid economic and military rise of China, its aggressive regional posturing, hybrid tactics and use of paramilitary naval forces did the same in Asia

The first development is the return of great power competition between the US and a rising China and a revanchist Russia. The Russian annexation of Crimea and intervention into Ukraine in 2014 brought back the threat of major interstate conflict to Europe. The rapid economic and military rise of China, its aggressive regional posturing, hybrid tactics and use of paramilitary naval forces did the same in Asia. The 2018 US National Defense Strategy underlined that near-peer competitors were once again the primary focus of US strategy.[6] European states, too, acknowledged the re-emergence of interstate competition observing a "renaissance of traditional power politics".[7] During the Trump administration, the realisation dawned on both sides of the Atlantic that the US could well be overleveraged with its commitments in multiple regions.[8] This certainly underlined that Europeans cannot ignore developments in Asia, neither the political-strategic, nor the military-technological.

European states both in- and outside of NATO face a Russia that is willing to leverage its arsenal of ballistic and cruise missiles – whether armed with conventional or nuclear warheads – to threaten both forces and infrastructure. The Russian leadership does not shy away from issuing threats in the context of coercive diplomacy and hybrid warfare campaigns in Ukraine and Syria and creating *faits accomplis* where and when possible.[9] The withdrawal of the US from the Intermediate-Range Nuclear Forces (INF) Treaty in response to Russia allegedly using its SSC-8 cruise missile for land-based launchers marked another setback for the international arms control architecture. Existing treaties have been under sustained pressure for many years including persistent violations of the Open Skies Treaty (followed recently by US and Russian withdrawal), of the Vienna Document and of the Treaty of Conventional Armed Forces in Europe with Russia's halting its compliance in 2008 and suspending of its participation in 2015.[10] Consequently, NATO is again planning for air operations against "any peer-state actor".[11] While Russia and the US extended New START in early 2021, global strategic stability arrangements are increasingly struggling to address the multipolar nature of today's world. In yet another sign of the return of great power competition across regions,

6 Jim Mattis, "National Defense Strategy of the United States of America" (Washington D.C: Department of Defense, 2018).

7 "White Paper on German Security Policy and the Future of the Bundeswehr" (The Federal Government of Germany, 2016), 38, https://issat.dcaf.ch/download/111704/2027268/2016%20White%20Paper.pdf.

8 Hans Brands and Eva Braden Montgomery, "One War Is Not Enough: Strategy and Force Planning for Great-Power Competition," *Texas National Security Review* 2, no. 3 (March 11, 2020), http://tnsr.org/2020/03/one-war-is-not-enough-strategy-and-force-planning-for-great-power-competition/.

9 For an account of the Crimean Annexation Crisis, including Russia's reference to its arsenal of missiles, see Lawrence Freedman, *Ukraine and the Art of Strategy* (Oxford University Press, 2019). See also: Dmitry Adamsky, "Deterrence à La Ruse: Its Uniqueness, Sources and Implications," in *NL ARMS Netherlands Annual Review of Military Studies 2020: Deterrence in the 21st Century—Insights from Theory and Practice*, ed. Frans Osinga and Tim Sweijs, NL ARMS (The Hague: T.M.C. Asser Press, 2021), 161–75, https://doi.org/10.1007/978-94-6265-419-8_9.For a counterview, that argues that it is unclear whether Russia would indeed pursue a so-called "escalate to deescalate" strategy where it leverages its nuclear weapons after a territorial landgrab is unclear see Kristin Ven Bruusgaard, "Russian Nuclear Strategy and Conventional Inferiority," *Journal of Strategic Studies* 44, no. 5(2021): 3-35, https://doi.org/10.1080/01402390.2020.1818070.

10 "In response to US claims that the Russian SSC-8 Screwdriver missile is a breach of the Intermediate-Range Nuclear Forces (INF) Treaty, Russia accuses the US of violating the treaty with its ground-launched variant of the Mk-41 Vertical Launching System, which the US has stationed in Romania as a component of the US anti-ballistic missile (ABM) defence shield." Kristian Kennedy, "Destabilizing Missile Politics Return to Europe, Part II: For Russia, Pershing II Redux?," NAOC, July 12, 2018, https://natoassociation.ca/destabilizing-missile-politics-return-to-europe-part-ii-for-russia-pershing-ii-redux/.

11 "NATO's Joint Air Power Strategy" (NATO, June 26, 2018), https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2018_06/20180626_20180626-joint-airpower-strategy.pdf.

the American withdrawal from the INF Treaty was as much a response to Russia as it was to ensure the US had leeway in the Western Pacific to respond to China's missile efforts. China has become the pacing threat for US planning.[12] For Europeans, the lesson should not only be the interconnectedness of regional developments, but the fact that Europe is not considered the central location of competition in the coming decades.

2.2 **Bigger, better, faster, stronger:** Improvement and adaptation of existing technologies by major powers

The great powers have made continuous technological improvements that have improved the accuracy, range, speed, and manoeuvrability of their stand-off weapons. The military-technological aspects are discussed below in §2.5 and §2.6, but there is also both a nuclear and a conventional aspect to these developments. First, it undermines the survivability of their respective nuclear deterrents. Second, the improvements in various air and missile weapons are having a cumulative political-strategic effect by raising the costs for power projection. Improvements in missile technology together with innovations in sensor technology, have led to a series of capabilities that are referred to as anti-access area denial (A2/AD) capabilities.[13] Given how much US hegemony, and its ability to reassure allies and deter adversaries, depends on its command of the commons and ability to access regions,[14] A2/AD may substantially hamper US military dominance. China and Russia have invested heavily in these short- and intermediate range missile capabilities.[15] China in particular has proven to be an innovator of missile technologies, developing and deploying more ballistic and cruise missiles with which it can target US forces and infrastructure in the Western Pacific at increasingly greater ranges, thereby drastically changing the strategic calculus for the US and its partners in the region.

China in particular has proven to be an innovator of missile technologies

2.3 **Catching up:** Continuing maturation of existing technologies among lesser powers

At the same time, the existing missile and air threat from lesser regional powers is maturing to offset conventional US advantages. These developments are not only intended to raise the costs of US access but to gain a credible deterrent. North Korea has conducted multiple successful ballistic missile tests, firing ballistic missiles over Japan in powerful demonstration

12 Brian W. Everstine, "Austin Highlights China Threat in First Briefing," *Air Force Magazine*, February 19, 2021, https://www.airforcemag.com/austin-highlights-china-threat-in-first-briefing/.

13 Sam Tangredi, *Anti-Access Warfare: Countering Anti-Access and Area-Denial Strategies*, Naval Institute Press (Naval Institute Press, 2013); Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security* 41, no. 1 (2016): 7–48; James Johnson, "Washington's Perceptions and Misperceptions of Beijing's Anti-Access Area-Denial (A2-AD) 'Strategy': Implications for Military Escalation Control and Strategic Stability," *The Pacific Review* 30, no. 3 (May 4, 2017): 271–88, https://doi.org/10.1080/09512748.2016.1239129.

14 Barry R. Posen, "Command of the Commons: The Military Foundation of US Hegemony," *International Security* 28, no. 1 (2003): 5–46; Eva Braden Montgomery, "Contested Primacy in the Western Pacific: China's Rise and the Future of U.S. Power Projection," *International Security* 38, no. 4 (2014): 115–49; Paul van Hooft, "All-In or All-Out: Why Insularity Pushes and Pulls American Grand Strategy to Extremes," *Security Studies* 29, no. 4 (August 7, 2020): 701-729, https://doi.org/10.1080/09636412.2020.1811461.

15 Douglas Barrie, "Trends in Missile Technologies," IISS, March 11, 2019, https://www.iiss.org/blogs/analysis/2019/03/trends-in-missile-technologies.

of its ability to threaten a major regional state with its nuclear program.[16] Despite the agreement's seeming progress on containing possible Iranian nuclear program, President Trump's unilateral withdrawal from the Joint Comprehensive Plan of Action (JCPOA) has reopened uncertainty regarding Iranian capabilities and the threat of its ballistic and cruise missiles.[17] However, most of the Iranian missile systems, including its guided rockets, artillery and mortars (G-RAM), are intended to raise the costs for maritime access in its vicinity, with a particular ability to combine missile and air attacks with those of small crafts.

2.4 **More bangs, less bucks:** Declining costs driving vertical and horizontal proliferation

Cruise missiles, unmanned aerial vehicles, and loitering munitions have become easier and cheaper to produce and are proliferating more widely

A fourth development is that the lower costs of missile technologies and unmanned aerial systems compared to, for example, advanced 4^{th} or 5^{th} generation aircraft, have made them more accessible to a range of actors.[18] Cruise missiles, unmanned aerial vehicles (UAVs), and loitering munitions have become easier and cheaper to produce and are proliferating more widely.[19] In part this is a direct effect of the prevalence of cheaper platforms, in part it is an effect of improving the efficiency of the higher-end, more expensive missile systems through their integration with other technologies. While the offensive capabilities of loitering attack munitions and weaponised UAVs receive a great deal of attention, it is the contribution that sophisticated, but also fairly unsophisticated and cheaper UAVs can make to persistent intelligence, surveillance and reconnaissance (ISR) tasks that is understated. Their manoeuvrability and ability to remain close to the ground are sufficient to bypass most ground-based radar defences, and they are expendable.

We thus see both horizontal and vertical proliferation. *Horizontal proliferation* means more state and non-state actors have access to weapons, including lesser powers and insurgent groups. A growing number of states have become missile producers.[20] Many lesser powers have consequently acquired missiles with which to target the infrastructure of major powers, such as bases, airfields, and production facilities, as well as their ships and other military forces on sea or land. UAVs have evolved from sensor platforms to cover a range of offensive

16 BBC News, "North Korea Threatens Japan with 'Real Ballistic Missile,'" *BBC News*, November 30, 2019, https://www.bbc.com/news/world-asia-50613051.

17 BBC News, "Iran Resumes Enriching Uranium to 20% Purity at Fordo Facility," *BBC News*, January 4, 2021, https://www.bbc.com/news/world-middle-east-55530366.

18 Enterprise Capability Collaboration Team and US Air Force, *Air Superiority 2030 Flight Plan* (Washington, DC: US Department of Defense, May, 2016).

19 We recognise this is not an uncontroversial point; advanced MALE and HALE UAV proliferation is constrained by costs. However, low-end UAVs are easier and cheaper to produce, and increase the effectiveness of other low-end and high-end systems. For a sceptical take on proliferation, see: Andrea Gilli and Mauro Gilli, "The Diffusion of Drone Warfare? Industrial, Organizational, and Infrastructural Constraints," *Security Studies* 25, no. 1 (2016): 50–84; Michael C. Horowitz, Sarah E. Kreps, and Matthew Fuhrmann, "Separating Fact from Fiction in the Debate over Drone Proliferation," *International Security* 41, no. 2 (2016): 7–42; George Nacouzi et al., *Assessment of the Proliferation of Certain Remotely Piloted Aircraft Systems: Response to Section 1276 of the National Defense Authorization Act for Fiscal Year 2017* (RAND Corporation, 2018), https://doi.org/10.7249/RR2369; "Why Taking Pilots out of Planes Has Been More Expensive than Anticipated | The Economist," March 11, 2021, https://www.economist.com/united-states/2021/03/11/why-taking-pilots-out-of-planes-has-been-more-expensive-than-anticipated.

20 Emmanuelle Maitre and Lauriane Héau, "Current Trends in Ballistic Missile Proliferation" (HCoC, September 21, 2020), https://www.nonproliferation.eu/hcoc/current-trends-in-ballistic-missile-proliferation/; Jeffrey Lewis, "Middle East Missile Mania: It's Not Just Iran," NTI | Nuclear Threat Initiative, May 28, 2019, https://www.nti.org/analysis/articles/middle-east-missile-mania-its-not-just-iran/.

uses. The low costs and relative ease with which commercial off-the-shelf UAVs can be fitted for military purposes have significant tactical implications. The dual-use nature of the technology suggests speedier diffusion through the international system.[21] A rapidly increasing group of actors in conflict situations and beyond now have unprecedented persistent aerial awareness, increasing the vulnerability of civilians, forces, and installations.[22]

Vertical proliferation means that major powers have more types and greater numbers of platforms at their disposal, which will enable doctrinal innovations for attackers. This may result in the shift from ballistic missiles targeted at a small number of high-value assets, to the threat of salvos (potentially) directed at a wide palette of infrastructure, airbases, ports, and forces. Defence against missiles is relatively difficult and costly;[23] defence against salvos is a different ballgame, but likely to be also complex and costly (albeit for quite other reasons).

2.5 **Nowhere to hide:** Precision and transparency

Armed forces are facing an increasingly transparent and therefore lethal environment

Armed forces are facing an increasingly transparent and therefore lethal environment as a consequence of improvements in sensor quality, the growing variety of signals they can register, persistent sensing, and advances in communication and computing through artificial intelligence and machine learning.[24] At the strategic and theatre level, the increase in persistent remote sensing due to the proliferation of loitering ISR UAVs and satellites in Low Earth Orbit enables attackers to acquire and attack high-value targets more effectively than before, with possible implications for the stability of deterrence and inadvertent escalation.[25] Particularly smaller UAVs used for ISR make battlefields more transparent (and dangerous if combined with strike payloads; the conflicts in Yemen and Nagorno-Karabakh have shown the importance of this trend).[26]

Traditional means of passive defence, including hardening, mobility, and concealment, are being undermined. At the theatre and tactical level, battlefield conduct is transforming due

21 Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton University Press, 2010).

22 Jack McDonald, "Drones and the European Union: Prospects for a Common Future" (Chatham House, February 2018), https://www.chathamhouse.org/sites/default/files/publications/research/2018-02-05-drones-eu-mcdonald.pdf.

23 Mortars and artillery are even harder to defend against, but do not have the same ability to present a theatre-level threat.

24 Elsa B. Kania, "Battlefield Singularity," *Artificial Intelligence, Military Revolution, and China's Future Military Power, CNAS*, 2017; Keir A. Lieber and Daryl G. Press, "The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence," *International Security* 41, no. 4 (2017): 9–49; James S Johnson, "Artificial Intelligence: A Threat to Strategic Stability," *Strategic Studies Quarterly* 14, no. 1 (2020): 16–39.

25 Lieber and Press, "The New Era of Counterforce," 2017; Caitlin Talmadge, "Would China Go Nuclear? Assessing the Risk of Chinese Nuclear Escalation in a Conventional War with the United States," *International Security* 41, no. 4 (2017): 50–92.

26 Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense" (Centre for Strategic and International Studies, December 8, 2020), https://www.csis.org/analysis/airand-missile-war-nagorno-karabakh-lessons-future-strike-and-defense.drones, and rocket artillery. The fighting, which began in late September, concluded on November 10 through a Moscow-brokered truce that resulted in the deployment of some 2,000 Russian peacekeepers and significant Armenian territorial concessions. Azerbaijan was the clear military victor, with both Russia and Turkey also benefiting politically from the war's outcome. The 44-day war featured a diverse array of legacy and advanced air and missile strike and defense platforms. The ballistic missiles used spanned generations, from older Soviet-era Scud and Tochka missiles to the newer and more advanced Iskander and the Israeli-made LORA (LOng Range Attack

to the increased difficulty in concealing surface forces. As political scientist Stephen Biddle argues, the modern system of land warfare was built around the effective use of cover and concealment through terrain.[27] However, the increase in persistent sensing and strike capabilities using UAVs and loitering munitions has made the modern battlefield significantly more transparent and lethal. As the ferocity of fighting in the 2020 conflict between Azerbaijan and Armenia shows, also lesser powers can target their adversaries with lethal doses of precision if they manage to integrate advanced with more traditional technologies, blurring the distinction in effectiveness between high-end and low-end technologies (see also §2.2 and §2.3).[28]

Particularly the ability to link disparate systems is driving change. ISR UAVs can provide acquisition and targeting information that enable effectors – including ballistic missiles, cruise missiles and G-RAM – to strike, or strike targets themselves.[29] Loitering munitions can approach air defence radars without being detected and/or identified as a threat and destroy them. This in turn creates a permissive environment for bombers and cruise and ballistic missiles.[30] Even while many of the relevant technologies have not yet sufficiently matured or become accessible to all actors, their cumulative interaction has the potential to transform the ability to wage war, early glimpses of which we are already seeing in conflict theatres around the world today.

The integration of multiple technologies, in combination with advancements in speed and range of existing missile technologies, is compressing time and space for the defender

2.6 **No time to think:** Compressing space and time, shrinking windows of decision-making

The integration of multiple technologies, in combination with advancements in speed and range of existing missile technologies, is compressing time and space for the defender. Ballistic missiles, as well as hypersonic missiles, can bridge massive distances in little time – with the latter potentially avoiding detection by flying under the radar and by manoeuvring. Yet their high per unit costs makes them mainly suited for high-value targets such as infrastructure, ports, bases, and central nodes used for communication, command and control.[31] The proliferation of efficient and manoeuvrable relatively cheap platforms – such as loitering

27 Although in close interaction with other elements: "The key elements of modern-system offensive tactics are cover, concealment, dispersion, small-unit independent manoeuvre, suppression, and combined arms integration." Stephen Biddle, *Military Power: Explaining Defeat and Victory in Modern Battle* (Princeton University Press, 2004), https://press.princeton.edu/books/paperback/9780691128023/military-power.

28 Shaikh and Rumbaugh, "The Air and Missile War in Nagorno-Karabakh."drones, and rocket artillery. The fighting, which began in late September, concluded on November 10 through a Moscow-brokered truce that resulted in the deployment of some 2,000 Russian peacekeepers and significant Armenian territorial concessions. Azerbaijan was the clear military victor, with both Russia and Turkey also benefiting politically from the war's outcome. The 44-day war featured a diverse array of legacy and advanced air and missile strike and defense platforms. The ballistic missiles used spanned generations, from older Soviet-era Scud and Tochka missiles to the newer and more advanced Iskander and the Israeli-made LORA (LOng Range Attack

29 Thomas Karako and Wes Rumbaugh, *Distributed Defense: New Operational Concepts for Integrated Air and Missile Defense* (Rowman & Littlefield, 2017), 1.

30 For example, in June 2017, North Korea used a drone to survey the THAAD site in South Korea. Had the drone been armed with an improvised explosive device and destroyed the TPY-2 radar on which the THAAD battery depends, it might have virtually incapacitated the THAAD capability on the Korean peninsula. Karako and Rumbaugh, 10–12.

31 Other vulnerabilities exist to be exploited by the combined use of different platforms. For example, NATO's Aegis Ashore-based ballistic missile defence capability largely depends on two radars: the TPY-2 radar in Turkey and the SPY-1 radar in Romania. A possible THAAD system in Europe would largely rely on a single TPY-2. A UAV or loitering munition could significantly damage the radar, crippling a possible response to a ballistic missile attack on valuable targets.

munitions and UAVs – facilitates attacker strategies and tactics that rely on overwhelming the defender (see §2.7). As sensing, computing, artificial intelligence, and systems integration improve, the window of time for decision makers to assess the nature of the threat, articulate the appropriate response, and execute that response, is shrinking.[32]

2.7 **Everything at once:** Combined attacks to overwhelm defence systems

Competent actors may saturate, confuse, and overwhelm their adversaries' defences through simultaneous attacks with hundreds of guided ballistic missiles, cruise missiles, hypersonic glide vehicles, loitering munitions, and armed and unarmed UAVs

The seventh development is the logical culmination of the previous developments: the threat of combining multiple weapons - new and old, complex and simple, expensive and cheap - with more effective sensors into a single, so-called salvo attack. Competent actors may saturate, confuse, and overwhelm their adversaries' defences through simultaneous attacks with hundreds of guided ballistic missiles, cruise missiles, hypersonic glide vehicles, loitering munitions, and armed and unarmed UAVs.[33]

The integration of US and NATO air and missile defence systems is arguably less suited for current challenges than defences that were deployed and employed to defend against more conventional air and missile threats a few decades ago.[34] This is a consequence of the preoccupation over the past three decades on defeating small numbers of ballistic missiles by so-called rogue states,[35] which culminated in the European Phases Adaptive Approach (EPAA). While there have been clear advances in terms linking the air and missile defence systems of the US, NATO, Australia, and Japan through the Link-16 standardised communications system, at the same time, conceptual and doctrinal integration has been neglected. Air and missile defences have been to put to more specialised use, and their employment thus contains blind spots and single points of failures that leave them open to exploitation. Due to practices that give preference to range, land-based radar coverage is often sectored in its employment; to produce a robust capability against multi-directional threats is too costly.[36] Often also the interceptors are directed towards specific sectors, leaving them vulnerable to being outflanked. The 2019 attacks on the Saudi oil fields illustrated the vulnerability of Patriot Radars to multiple, multi-directional threats.[37]

At the theatre and tactical levels, renewed great power competition has increased the likelihood of such complex salvos combining limited numbers of expensive, high-end systems with larger numbers of lower-cost and more expendable weapons. Salvos add to the already complex and cluttered battlespace to further confuse defence systems through sheer saturation. Furthermore, they also allow the attacker to combine the distinct properties of

32 Christian Brose, *The Kill Chain: Defending America in the Future of High-Tech Warfare* (Hachette UK, 2020).

33 Rehberg and Gunzinger, *Air and Missile Defense at a Crossroads*, 35. Karako and Rumbaugh, *Distributed Defense*, 1. Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses* (Centre for Strategic and Budgetary Assessments, 2016).

34 For example, the Patriot command and control was originally linked to HAWK batteries. US stopped participating in multinational 360° MEADS Multifunction Fire Control Radar combined with 360° surveillance radar, in 2012. Karako and Rumbaugh, *Distributed Defense*, 14.

35 Rehberg and Gunzinger, *Air and Missile Defense at a Crossroads*, 2.

36 Karako and Rumbaugh, *Distributed Defense*, 4.

37 Ben Hubbard, Palko Karasz, and Stanley Reed, "Two Major Saudi Oil Installations Hit by Drone Strike, and U.S. Blames Iran," *The New York Times*, September 14, 2019, sec. World, https://www.nytimes.com/2019/09/14/world/middleeast/saudi-arabia-refineries-drone-attack.html.

various systems, such as the speed of hypersonic missiles with the manoeuvrability of cruise missiles,[38] combined with the easy integration of UAVs.[39] Moreover, the speed at which intercepting missiles can be reloaded becomes highly relevant – if reloads are even available due to small numbers of interceptor stocks.[40] The complexity of building a system of systems in both a technological and an organisational sense, as well as the depth of resources needed, suggests that the most sophisticated salvo attacks will remain available only to major powers.[41] Yet recent events in conflict theatres show that combined attacks employing a mixture of aerial platforms from Abqaiq to Nagorno Karabakh to Donbass are already part and parcel of contemporary armed conflict.

Finally, the future development of artificial intelligence (AI) offers attackers the chance to significantly accelerate and better coordinate air and missile attacks.[42] AI-driven systems are able collect, systematise and elaborate ground and space-based radar and satellite imagery in large amounts and at velocities far superior to that of human operators. [43] AI can be applied to both defensive and offensive systems. Currently, most of the targeting processes of air and missile systems – attacks and intercepts - are carried out with human operators *in the loop* deciding about specific targets.[44] With the application of advanced AI-technologies, the role of human operators will become *on the loop*, where "programs select the calculated targets and need human approval before attack or allocate humans a time-restricted veto before attack."[45]

38 Rehberg and Gunzinger, *Air and Missile Defense at a Crossroads*, 3. For example, China's PLA could combine a simultaneous attack from the YJ-83 cruise missile traveling 0.9 Mach from a 100 miles with that of a DF-17 hypersonic glide vehicle traveling at Mach 15 from 1,500 miles. Alan Cummings, "Hypersonic Weapons: Tactical Uses and Strategic Goals," War on the Rocks, November 12, 2019, https://warontherocks.com/2019/11/hypersonic-weapons-tactical-uses-and-strategic-goals/.

39 Rudimentary tactics are emerging among non-state actors. In western Syria in 2018, non-state actors deployed a grouping of ten UAVs equipped with explosives to attack Russia's Hmeimim airbase. Colin Ritsick, "Top 35 Most Expensive Military Drones," Military Machine, February 16, 2020, https://militarymachine.com/top-35-most-expensive-military-drones/.

40 According to official Chinese sources, its DF-21D (carrier killer) brigades can quickly reload and launch multiple salvo strikes within a few hours. "Ballistic and Cruise Missile Threat" (National Air and Space Intelligence Centre, 2020), 22.

41 We extrapolate from scholars such as: Horowitz, *The Diffusion of Military Power*.

42 Several states are currently developing military AI, with China planning to lead the AI field by 2030, Russia declaring its intention to pursue intensive AI R&D, and the US' Department of Defense steadily augmenting the budget for research in this field (from €600 m in FY 2016 to €927 m in FY 2020). Daniel S Hoadley and Nathan J Lucas, "Artificial Intelligence and National Security" (Congressional Research Service, 2018), 1. "FY2020 Budget Request Overview" (United States Department of Defense, March 2019), 1–9, https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2020/fy2020_Budget_Request_Overview_Book.pdf. Hoadley and Lucas, "Artificial Intelligence and National Security," 1.

43 Amandeep Singh Gill, "Artificial Intelligence and International Security: The Long View," *Ethics & International Affairs* 33, no. 02 (2019): 170, https://doi.org/10.1017/S0892679419000145. Phil Stewart, "Deep in the Pentagon, a Secret AI Program to Find Hidden Nuclear Missiles," *Reuters*, June 5, 2018, https://www.reuters.com/article/us-usa-pentagon-missiles-ai-insight-idUSKCN1J114J.

44 Tom FA Watts and Ingvild Bode, "Meaning-Less Human Control: Lessons from Air Defence Systems for LAWS" (University of Southern Denmark: Centre for War Studies, 2021), 19, https://zenodo.org/record/4485695.

45 Watts and Bode, 19.

3. **Weapon Systems and Levels of Impact**

Missiles of all kinds ensure the capability to cause significant material and human damage, as well as the accordant psychological effect, at relatively low costs, over long distances, with little risks to the attacker, and with little warning and limited options for the defender

Aircraft and missiles fall under what can be defined more broadly as aerospace power. As such, they have qualities that give them specific advantages and disadvantages compared to surface warfare on land or sea by infantry, armour, or ships. Unencumbered by the friction of land or water, aerospace power allows for sudden concentrations of destructive power. In turn, this concentration of destructive power can enable defensive and offensive actions on the surface or be used to interdict the adversaries reinforcements and supplies.[46] The exploitation of the third vertical dimension over terrain provides speed, reach, and elevation for observation and strike.[47] Finally, the speed allows for the exploitation of time, reach and elevation for the exploitation of space. These three qualities together allow for operations deep inside the adversary's territory, or directed at isolated or well-protected locations that surface units cannot reach without incurring great costs.

Within that broader grouping of aerospace power, variations within aircraft and missiles come with their own specific advantages and disadvantages that make them more suited for striking certain targets at certain levels than for others. For example, though bombers were historically central to the development of thinking about airpower due to their ability to deliver destruction over long ranges, when compared to the latest generation of fighter-bomber aircraft, missiles would have specific advantages. Missiles possess greater speed over aircraft and add expendability, relatively lower costs, and/or more limited logistical tails. Missiles of all kinds ensure the capability to cause significant material and human damage, as well as the accordant psychological effect, at relatively low costs, over long distances, with little risks to the attacker, and with little warning and limited options for the defender.[48] Similarly, unmanned aerial vehicles (UAVs) are also more expendable and cheaper, while most types are also more limited in terms of logistical tails. The potential for surprise and destruction applies to missiles and unmanned aerial vehicles as well, with the additional advantage that they require much less effort from the attacker in terms of concepts, doctrine, training, and logistical support. Aircraft and missiles should not be expected to hold territory or perform counterinsurgency. However, surface warfare tends to be extraordinarily costly for both attacker and defender, and airpower opens many doors.[49] Moreover, air and missile systems thus created new possibilities for, in John Boyd's terminology, getting inside and disrupting an adversary's Observe, Orient, Decide, Act (OODA) loop at the tactical and theatre level.[50]

46 Philip S. Meilinger, *The Paths Of Heaven: The Evolution Of Airpower Theory: The School Of Advanced Airpower Studies* (Lancer Publishers, 2000). Submarines added a vertical dimension below the surface.

47 Space-based assets have added to these dimensions.

48 R Clarke S, "The Regional Emergence of Strategic Missiles: A Force of Rooks for a Black King" (Air Power Studies Centre, 1997), https://fas.org/irp/threat/missile/paper55.htm.

49 Colin S. Gray, "The Airpower Advantage in Future Warfare: The Need for Strategy" (Air University Maxwell, Airpower Research, 2007).

50 For an overview of Boyd's development of the ODAA concept, see Frans PB Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd* (Routledge, 2007).

Historically, aerospace power has tended to primarily benefit major military powers, as manned aircraft require serious logistical support and material and human resource investments. In contrast, due to their relative low costs and expendability, missiles and UAVs enable asymmetric strategies and tactics for weaker actors that cannot hope to defeat a major state through force-on-force operations, but instead seek to raise costs for the more powerful actor.[51] They can do so directly through their offensive potential or, in the case of UAVs, in their potential to increase overall awareness of the battlefield as enablers. Their attractiveness to minor powers and non-state actors cannot be overstated. Finally, the ability to inflict significant damage at range, with speed, and from nearly all directions makes aircraft and missiles exquisitely suited for deterrence. Indeed, airpower's potential to strike materially and psychologically crippling blows was recognised at its conception.[52]

During the Second World War, air defence against bombers proved more effective than expected and, though causing extensive destruction, strategic bombing arguably failed to decide the outcome of the war, most certainly in the European theatre.[53] Also for moral reasons, massive bombing has since largely ceased to be a strategy of choice. The advent of nuclear weapons, however, combined with later innovations in missile technology, satellites, and assorted other technologies, ensured that air and missile systems, with their advantages in speed, reach, and elevation, could pose a credible and standoff threat. It proved hard to defend against such missiles. This in turn paved the way for the emergence of deterrence by punishment as a defensive strategy because it raised the costs to far outweigh the benefits of attack.

3.1 **Threat Levels:** strategic, theatre, and tactical

Based on their characteristics, air and missile weapon systems pose different types of threat to Europe. To categorise the various air and missile threats and possible defensive solutions, we distinguish between threats at the strategic, the theatre and the tactical level. Figure 3 summarises the features of these levels, which are further elaborate below.

51 The US and NATO Europe's ability to gain air superiority, and US precision-strike capabilities, in fact emerged as an asymmetric response to Soviet and Warsaw Pact conventional preponderance.

52 The debates of the 1920s to 1940s on European peace and security took place in the "shadow of the bomber"; strategic bombing campaigns would allow for crippling blows that would break the political will to resist and soon end wars. British Prime Minister Chamberlain argued that the "bomber always gets through", and his fear of German strategic bombing partially motivated his willingness to appease Germany. Uri Bialer, *The Shadow of the Bomber. The Fear of Air Attack and British Politics, 1932–1939* (London: Royal Historical Society, 1980), https://doi.org/10.2307/2619397.

53 Richard Overy, *The Bombing War: Europe, 1939-1945* (Penguin UK, 2013).

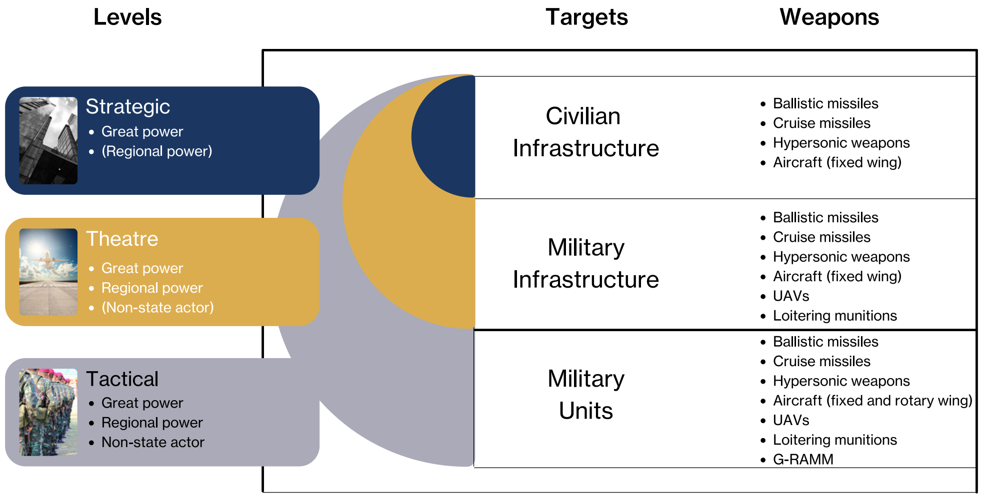


Figure 3. Summary of levels, targets, and weapons

Attacks on infrastructure and major platforms can provide support of, or cover for, land- or sea-based offensives; or enable a defence against offensive actions by hitting the attacker's follow-on forces

3.1.1 **Strategic threats**

Targeting society and populations means an actor can strike against civilian infrastructure such as cities, industry, airports, or seaports. This ability predominantly serves to coerce the adversary – through the threat or the actual execution of attacks – into either taking or refraining from actions, to break its political will or to attrite its resources. Deterrence by punishment is central here, the ability to raise the costs for unfavourable actions by destroying what the adversary arguably values most.[54] Consequently, if the attacker and defender are more or less symmetrical in conventional capabilities and the ability to target each other's society and populations, mutual deterrence is likely to dominate and military competition may continue at lower levels of intensity.[55] If the distribution of conventional capabilities between both is asymmetrical, then the weaker actor gains relatively more. Nuclear warheads – or other weapons of mass destruction (WMD) – most effectively deter. However, the destructive power of the new generation of advanced conventional weapons and their improved precision is such that their deterrence potential is much closer to that of nuclear weapons than previous conventional weapons.[56] Long-range precision attacks, due to the costliness of the weapons and the complexity of the supporting ISR capabilities, primarily remain the domain of the major powers, as elaborated below.

3.1.2 **Theatre threats**

Targeting military infrastructure covers military bases including airfields, ports, or army bases and staging areas; logistics and communications nodes; and major military platforms such as aircraft carriers, long-range precision weapons, and strategic or nuclear forces. In the European context, these can include forward deployed as well as domestically deployed forces and bases. Targeting military assets fulfil a great range of potential purposes. Attacks on infrastructure and major platforms can provide support of, or cover for, land- or sea-based offensives; or enable a defence against offensive actions by hitting the attacker's follow-on

54 Michael J. Mazarr et al., "What Deters and Why: Exploring Requirements for Effective Deterrence of Interstate Aggression" (RAND, 2018), 7-8, https://www.rand.org/pubs/research_reports/RR2451.html.

55 Michael Krepon, "The Stability-Instability Paradox, Misperception, and Escalation Control in South Asia," *Prospects for Peace in South Asia*, 2003, 261–279.

56 Andrew Futter and Benjamin Zala, "Strategic Non-Nuclear Weapons and the Onset of a Third Nuclear Age," *European Journal of International Security*, 2018, 1–21.

forces.[57] Deterrence by punishment remains a possibility, the loss of high-value military targets which are difficult to replace, such as aircraft carriers, can also represent deterrence by punishment.

The attacker's ability to impede the freedom of action of military forces can also affect the political freedom of action to fulfil alliance obligations. If states have to pay a heavy price (or are thus threatened) for operating in areas contested by missiles, aircraft, or other technologies, they are likelier to refrain from coming to the assistance of allies.[58] Defence against air and missile threats can thus be a necessary component of reassurance and alliance cohesion. Depending on the relative proximity to the adversary, the defender can be targeted by an entire range of weapons, including salvos of ballistic and cruise missiles, aircraft and UAVs. Deterrence by denial is a strategy that major powers may be able to execute in more sophisticated manners, but minor powers have also proven adept at raising the costs of power projection in their vicinity.

The attacker's ability to impede the freedom of action of military forces can also affect the political freedom of action to fulfil alliance obligations

3.1.3 **Tactical threats**

Threats at the tactical level would involve attacks on forces during operations, on forward operating bases or while moving. These attacks can accomplish offensive, defensive and deterrent objectives and may include the entire range of weaponry. The increasing quality and decreasing costs of UAVs and loitering munitions add new possibilities for the attacker. All major powers, minor powers and non-state actors can consequently attack at the tactical level.

Figure 3 illustrates the levels, the targets and the weapons most relevant to each.

3.2 **Weapon systems and their characteristics**

What are the effects of the trends in air and missile weapon systems at the strategic, theatre, and tactical levels? The answer is not as straightforward as it might seem. The ways in and the extent to which weapons systems are threats cannot be judged simply based on their general technological properties, but rather on how they are employed by specific actors for specific purposes in specific contexts.[59] However, their properties in terms of speed, trajectory and manoeuvrability, range, accuracy, susceptibility to countermeasures and cost profile do suggest their strategic uses to particular actors. The competition for military-technological dominance is one of hiders (mobility, concealment) and seekers (accuracy, precision); of quality (accuracy, manoeuvrability, payloads) and quantity (redundancy, saturation, hardening). This section provides an overview of the various air and missile weapon systems, comparing and contrasting them, highlighting their strategic roles and identifying the levels they predominantly impact.

57 For the development of AirLand Battle, see: Robert Frank Futrell, "Ideas, Concepts, Doctrine, Vol. 1. Basic Thinking in the United States Air Force, 1961–1984," *Air University Press*, 1989, 585–566; Douglas W. Skinner, "Airland Battle Doctrine" (Centre for Naval Analysis, 1988).

58 See, for example, Posen's discussion of the incompatibility of British and French doctrines with their alliance commitments during the 1930s. Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*, 1st ed. (Cornell University Press, 1984), https://www.jstor.org/stable/10.7591/j.ctt1287fp3.

59 Kendrick Kuo, "Military Innovation and Technological Determinism: British and US Ways of Carrier Warfare, 1919–1945," *Journal of Global Security Studies* 6, no. 3 (2021).

3.2.1 Ballistic missiles

Ballistic missiles have arguably been the pacing threat for US air and missile defence planners since the end of the Cold War[60] and have thus informed much of the NATO and European debate. Ballistic missiles combine the potential to strike targets at great distances with the ability to do so at great speeds. They are defined by the specific trajectory they travel, a parabolic curve that consists of three distinct phases: the boost phase within the atmosphere as the missile is powered by a rocket to exit the atmosphere; the midcourse phase as it glides outside of the atmosphere; and the terminal phase as the missile re-enters the atmosphere. During their plunge back into the atmosphere in the terminal phase of their trajectory, re-entry vehicles travel at speeds ranging from 0.9 km/sec (Mach 2.6) to 6-8 km/sec (Mach 23+) at the time of re-entry.[61] These speeds allow only small windows of opportunity for their detection and even less for their interception. When used within a theatre, or when their trajectories are depressed, their flight times are even shorter.[62] A ballistic missile on a depressed trajectory at Mach 20 covers 6,700 km in seventeen minutes – faster than a hypersonic missile.[63] Ballistic missiles are more effective than cruise missiles against certain targets. One ballistic missile armed with conventional submunitions – multiple smaller bombs that would disperse over a wide area – can accomplish the same damage to an airbase with runway and a fighter wing that it would take a dozen cruise missiles.[64]

Ballistic missiles present a formidable conventional weapon for striking high-value targets within the theatre. Though associated in popular imagination primarily with nuclear weapons, ballistic missiles are dual-capable and may carry both conventional and non-conventional warheads, the latter encompassing weapons of mass destruction (nuclear, biological, and chemical weapons).[65] The ranges that ballistic missiles cover vary: from close range ballistic missiles (50-300 km); short range ballistic missiles (300-1,000 km); medium-range ballistic missiles (1,000-3,000 km); intermediate-range ballistic missiles (3,000-5,500 km); to intercontinental ballistic missiles (>5,500 km). The platforms that can launch ballistic missiles are similarly varied: they can be deployed in silos, on road- or rail-mobile launchers, surface ships and submarines, or aircraft. Each platform offers different possibilities for pre-launch survivability and effectiveness.[66]

60 Rehberg and Gunzinger, *Air and Missile Defense at a Crossroads*, 2. International Institute for Strategic Studies, "Emerging AirDefence Challenges."

61 "Fact Sheet: Ballistic vs. Cruise Missiles" (The Centre for Arms Control ad Non-Proliferation), accessed December 23, 2020, https://www.thalesgroup.com/sites/default/files/database/d7/asset/document/03_p185749_thales_squire_leaflet.pdf; "2020 BALLISTIC AND CRUISE MISSILE THREAT_FINAL_2OCT_REDUCEDFILE.Pdf," accessed April 22, 2021, https://media.defense.gov/2021/Jan/11/2002563190/-1/-1/1/2020%20BALLISTIC%20AND%20CRUISE%20MISSILE%20THREAT_FINAL_2OCT_REDUCEDFILE.PDF.

62 Maitre and Héau, "Current Trends in Ballistic Missile Proliferation"; Ivan Oelrich, "Cool Your Jets: Some Perspective on the Hyping of Hypersonic Weapons," *Bulletin of the Atomic Scientists* 76, no. 1 (2020): 37–45.

63 Defense Science Board, "Time Critical Conventional Strike from Strategic Standoff" (Washington D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, March 2009).

64 John Stillion and David T. Orletsky, "Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks," *Rand Corporation*, 1999, 13; Thomas G. Mahnken, *The Cruise Missile Challenge* (Centre for Budgetary Assessments, 2005), 34–35.

65 US Air Force Defense Intelligence, Ballistic Missile Analysis Committee, "Ballistic and Cruise Missile Threat," 6; Maitre and Héau, "Current Trends in Ballistic Missile Proliferation."

66 Fixed launchers like silos may be located but can be hardened against pre-emptive attack. Mobility allows launchers the possibility to evade attack, or conceal themselves. Submarines in particular excel at concealment and are very difficult to track down. Strategic Ballistic Missile submarines are therefore considered the most effective means to ensure a secure second strike nuclear deterrent. Moreover, ships and airplanes can be moved from one theatre to another, thereby increasing the number of targets under threat. "Ballistic and Cruise Missile Threat," 8. For different approaches to survivability and how technological changes are undermining these, see also: Keir A. Lieber and Daryl G. Press, "The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence," *International Security* 41, no. 4 (2017): 9–49.

Ballistic missiles can further ensure their post-launch survivability. First, when still outside the atmosphere, a ballistic missile can release multiple independently targetable re-entry vehicles (MIRV) that each follow distinct trajectories towards separate targets.[67] Second, the missile can depress its trajectory below the minimal energy trajectory – with a trade-off in terms of payload weight and range – to shorten its flight time and diminish the window of opportunity for the defender to respond.[68] Third, though ballistic missiles are traditionally in free fall during the final part of their trajectory, re-entry vehicles could use their aerodynamic features to outmanoeuvre the defender's interceptors with Manoeuvrable Re-entry Vehicles (MARV).[69] Fourth, the ballistic missile can deploy countermeasures to interceptors, including decoys, flares, chaff, jamming,[70] as well as penetration aids, electronic warfare capabilities to deceive, obscure or jam sensors that detect and track the missiles and re-entry vehicles to penetrate a ballistic missile defence system.[71]

The effectiveness of ballistic missiles primarily depends on their precision, which in turn primarily depends on their guidance system.[72] A high-quality inertial guidance system that uses GPS, or its Russian or Chinese equivalents, can deliver an intercontinental ballistic missile's (ICBM) re-entry vehicle within a few hundred meters of its target.[73] Satellite-aided navigation and manoeuvring re-entry vehicles with terminal sensors can be used to considerably improve accuracy.[74] Laser guidance to the target also delivers precision, which can be provided by unmanned vehicles that are expendable and can approach the target.[75]

Ballistic missiles are thus characterised by their ability to approach targets at great distances, at high speeds and with increasing precision. The variety in ranges and launch platforms, as well as their dual capability, renders ballistic missiles suitable for a broad range of operations, while a variety of tactics, including the use of re-entry vehicles and countermeasures, increase their survivability otherwise impaired by ballistic missiles' predictable flightpaths. Though the focus for decades has been on the interception of a small number of ballistic missiles armed with nuclear warheads, it is in fact the growing number of short-to-medium range ballistic missiles with conventional warheads that presents an underrated threat at the theatre level.

3.2.2 **Cruise missiles**

Cruise missiles markedly contrast with ballistic missiles. They fly within the atmosphere driven by (a) air breathing engines (pulsejet, ramjet, turbojet, or turbofan); (b) rockets; or (c) propellers. Ballistic missiles are fast but their trajectory is predictable. What cruise missiles lack in speed and range, they make up in unpredictability, due to their manoeuvrability and ability to fly at varying altitudes. Together with their relatively small size, reduced radar-signature, and

67 A Multiple re-entry vehicle payload (MRV) which releases multiple payloads above single target is a variation of MIRV.

68 "Ballistic and Cruise Missile Threat," 9.

69 Matthew Bunn, *Technology of Ballistic Missile Reentry Vehicles* (Program in Science and Technology for International Security, Massachusetts, 1984). "Ballistic and Cruise Missile Threat," 12.

70 Steve Fetter et al., "Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System," 2000; Oelrich, "Cool Your Jets," 41.

71 "Ballistic and Cruise Missile Threat," 9.

72 "Ballistic and Cruise Missile Threat," 9.

73 "Ballistic and Cruise Missile Threat," 9.

74 "Ballistic and Cruise Missile Threat," 9.

75 Lieber and Press, "The New Era of Counterforce," 2017, 22.

masking flight profiles using terrain features, these characteristics make cruise missiles well-suited for evasion of defender systems and precision attacks.[76]

Unlike the re-entry vehicles of (most) ballistic missiles, the manoeuvrability of the cruise missiles allows them to execute updates to correct their navigation during their flight as they close in on their target.[77] Cruise missiles receive guidance during launch, midcourse, and terminal phases from respectively: (1) an inertial navigation system; (2) a satellite navigation system; (3) a terrain contour matching system (TERCOM); (4) a radar or optical scene matching system; (5) from a more accurate scene matching system or optical or radar-based sensor within the target area; or (6) active radar homing (ARH) seekers that can find and track targets autonomously.

Cruise missiles are primarily categorised by their mission targets; either as a land-attack cruise missile or as an anti-ship cruise missile. At their most accurate, a land-attack cruise missile can be placed within feet of its target, which ensures they are a formidable threat to military operations.[78] At the low end, land-attack cruise missiles are essentially converted UAVs or aircraft with guidance system, which makes them available to minor powers and non-state actors.[79] Anti-ship cruise missiles are the most common incarnation. They present the principle long-range threat to naval ships, triggering changes in naval tactics.[80] Within the military competition between the US and China, they have contributed to raising the costs of American power projection into the Western Pacific significantly.

Cruise missiles are highly effective, and, importantly, cheaper per unit than ballistic missiles – yet their defence has received much less attention compared to the threat of ballistic missiles.[81] Cruise missiles can fly at altitudes close to the ground, using terrain features for concealment. Operators tend to direct the search beams of ground-based multi-function radars at high elevation to track possible ballistic missiles. If they do not appropriately divide their search time, the chance that cruise missiles will approach undetected increases. Defenders would be wise to combine input from airborne sensors that are not as limited by the terrain-hugging evasiveness of cruise missiles. Their manoeuvrability allows cruise missiles, when multiple are deployed, to avoid air defences and to potentially hit their targets from all directions. In addition to their inherently low visual, infrared and radar signatures, compared to ballistic missiles, newer models incorporate stealth to further reduce their signatures.[82] Provided they are detected, cruise missiles are easier to intercept than ballistic missiles. However, because they come at lower costs, they are more attractive for salvo attacks that can overwhelm the defender by saturating his air and missile defence system.

Like ballistic missiles, they can be launched from aircrafts, ships, submarines, or from ground-based mobile launchers. However, for cruise missiles, much more basic transport, erector and launching systems suffice.[83] Given their relative simplicity and small size, cruise missiles can

76 International Institute for Strategic Studies, "Emerging AirDefence Challenges." Uses Kh-101 as example. In the competition with defenders with increasingly capable air defenses, designers have again invested in increasing the speed of their cruise missiles to ensure survivability.

77 Mahnken, *The Cruise Missile Challenge*, 2005, 32–33.

78 "Ballistic and Cruise Missile Threat," 34–35.

79 Mahnken, *The Cruise Missile Challenge*, 2005, 22..

80 Toshi Yoshihara and James R. Holmes, *Red Star Over the Pacific, Second Edition: China's Rise and the Challenge to U.S. Maritime Strategy*, Revised edition (Annapolis, Maryland: Naval Institute Press, 2018); Thomas G. Mahnken, *The Cruise Missile Challenge* (Centre for Budgetary Assessments, 2005), 13.

81 Mahnken, *The Cruise Missile Challenge*, 2005, 5.

82 Mahnken, 5, 33.

83 Mahnken, 32–33.

Cruise missiles are thus highly effective weapons to evade defence systems and carry out precision attacks. This is thanks to their manoeuvrability, ensuring they have less predictable flight patterns, and their ability to fly at varying altitudes, as well as their relatively simplicity and small size, reduced radar-signature and use of terrain masking flight profiles

even be launched from containers or civilian vessels, giving them serious advantages in terms of mobility and concealment. This not only boosts their pre-launch survivability but also raises their surprise attack capability.[84]

Despite not having the speed and range of ballistic missiles, cruise missiles are thus highly effective weapons to evade defence systems and carry out precision attacks. This is thanks to their manoeuvrability, ensuring they have less predictable flight patterns, and their ability to fly at varying altitudes, as well as their relatively simplicity and small size, reduced radar-signature and use of terrain masking flight profiles. Particularly, the ability to change flightpath mid-course renders them useful to engage mobile targets at sea. Their relatively low costs have spurred proliferation, both among state and non-state actors.

3.2.3 **Hypersonic missiles**

Hypersonic weapons are the latest supposed silver bullet weapon purported to be "unstoppable"[85] and a "game changer"[86]. Where ballistic missiles excel in speed and range, and cruise missiles in manoeuvrability, hypersonic weapons hypothetically combine all three. Hypersonic weapons come in two distinct types that are often conflated: hypersonic glide vehicles (HGV) and hypersonic cruise missiles (HCM).[87] The glide vehicles are "the cousins of ballistic warheads".[88] They are launched through high velocity rocket boosters into the upper atmosphere, separate from the boosters at anywhere around 50km altitude to above 100 km, then use momentum and control surfaces to glide and skip through the upper atmosphere before crashing onto their targets.[89] The cruise missile variants produce thrust from oxygen from the air, whereas rockets do so from the oxidizers they carry. Though not yet a mature technology, scramjets (or ramjets up to Mach 6) – airbreathing high-speed jet engines for powered flight – would be particularly dangerous.[90] However, while scramjets are not yet a maturing technology, interim hypersonic missiles that use rocket motors are conceivable in the shorter term.

Glide vehicles would reach speeds in excess of Mach 5 (more than 6,000 km/hr) up to Mach 20 (24,500 km/hr) together with manoeuvrability at lower altitudes. The combination ensures a highly flexible offensive weapon that could hold at risk and strike targets within a 1,000 km radius of the launch aircraft within minutes, with the latter's mobility both increasing the range and decreasing the response time.[91] Moreover, for many radars, a HGV is difficult to detect

84 "Ballistic and Cruise Missile Threat," 35. For example, the Russian Club-K cruise missile "container launcher" looks like a standard shipping container, which would allow it to be launched from cargo ships, trains, or commercial trucks.

85 R. Jeffrey Smith, "Hypersonic Missiles Are Unstoppable. And They're Starting a New Global Arms Race," *The New York Times*, June 19, 2019, https://www.nytimes.com/2019/06/19/magazine/hypersonic-missiles.html.

86 Steven Simon, "Hypersonic Missiles Are a Game Changer," *The New York Times*, January 2, 2020, https://www.nytimes.com/2020/01/02/opinion/hypersonic-missiles.html.

87 Oelrich, "Cool Your Jets," 38.

88 Richard H. Speier et al., "Hypersonic Missile Nonproliferation: Hindering the Spread of a New Class of Weapons," September 27, 2017, 13, https://www.rand.org/pubs/research_reports/RR2137.html.

89 "Ballistic and Cruise Missile Threat," 3; Oelrich, "Cool Your Jets," 38.

90 A hypersonic cruise missile would accelerate to Mach 4 or 5 before a supersonic combustion ramjet (scramjet), further accelerates and then maintains the missile's speed. It could fly altitudes (20-30km), the upper limits of most surface-to-air missiles, increasing the difficulty for the defender. A glide vehicle will fly above those limits (40-100km), yet still below the altitudes designed to intercept the re-entry vehicles of ballistic missiles. Kelly M. Sayler, "Hypersonic Weapons: Background and Issues for Congress" (Congressional Research Service, December 1, 2020), 2; Cummings, "Hypersonic Weapons"; Speier et al., "Hypersonic Missile Nonproliferation," 13–14.

91 Speier et al., "Hypersonic Missile Nonproliferation," 13.

due to the plasma wave its speed creates.[92] Hypersonic weapons can deliver nuclear or conventional warheads. Moreover, they can also destroy or damage an unhardened target solely through the high kinetic energy created by their high speed, combined with accuracy.[93] Russia has put into service the Avangard glide vehicle, which has an intercontinental range. China has been vaguer about its development but has showcased its DF-17 missile, with which it can strike US bases in the region.[94] Russia, China, and the US are developing, or already fielding, hypersonic weapons but multiple other countries are exploring them as well, most notably France and India.[95]

If hypersonic glide vehicles would work as advertised, they would be extremely destabilising. Hypersonic attacks could occur with very little warning time and the unpredictability of their targeting would further compress the timeline for response.[96] For example, an attack on the US homeland from Russia would see decision-time reduced from 25 minutes response time for an ICBM to six minutes for a hypersonic weapon. For a short-to-medium range air launched hypersonic cruise missile attack against a target in Western Europe, that time would be less than three minutes. Hypersonic weapons would not come cheap.[97] Consequently, hypersonic weapons are likelier to be used against high-value targets in states or assets that have advanced air and missile defence which would allow them to intercept other attacks.[98] These targets may include carrier groups, command and control centres, mobile missile launchers or air defence radars.[99]

Do hypersonic gliders – generally considered the more dangerous of the two considering the present-day immaturity of the hypersonic cruise missiles[100] – indeed represent an unholy trinity of speed, manoeuvrability, and range? As Ivan Oelrich argues, there are direct trade-offs among the three dimensions because low atmospheric flight imposes fundamental physical limitations.[101] The greater the range, the more the glider loses its speed. A sharp turn to avoid an interceptor or redirect to a target will come at a "very steep price in speed".[102] Continuous hypersonic flight is therefore constrained to a "relatively narrow altitude-velocity corridor".[103]

92 The extreme temperatures might create a plasma wave that blocks lower-frequency radar waves, they would also create intense emissions in the infrared range that would remain visible to existing space-based sensors – such as the Defense Support Program and the Space-Based Infrared System – during launch and for the majority of the flight. These can then relay the trajectory of the missile to a ground-based radar. Modern radars operate over a band of frequencies and could be cued once they know what to expect. Cameron L. Tracy and David Wright, "Modeling the Performance of Hypersonic Boost-Glide Missiles," *Science & Global Security*, 2020, 2, 16–17; Oelrich, "Cool Your Jets," 41–42.

93 Speier et al., "Hypersonic Missile Nonproliferation," 13.

94 Catherine Wong, "China's Advanced DF-17 Hypersonic Missile Likely to Have Been Part of Recent Military Drill," *South China Morning Post*, January 5, 2021, https://www.scmp.com/news/china/military/article/3116545/chinas-advanced-df-17-hypersonic-missile-likely-have-been-part; Cummings, "Hypersonic Weapons."

95 Speier et al., "Hypersonic Missile Nonproliferation," 21–22, 53–95.

96 Speier et al., xiii, 16.

97 While it is not clear how much Russia and China have spent on developing and fielding these weapons, it is clear that, without even fielding them, the United States has dedicated 3,5 $bn to hypersonic weapons programs for the FY2021, or about 3% of the total research and development budget. Sayler, "Hypersonic Weapons: Background and Issues for Congress," 1.

98 Speier et al., "Hypersonic Missile Nonproliferation," 17. Han Kristensen, a nuclear expert with the Federation of American Scientists in Washington, D.C., against anything other than "higher-value targets such as command-and-control, bases and potentially large ships". David Axe, "Russia's Hypersonic Strike Force Is Mostly For Show," Forbes, December 17, 2020, https://www.forbes.com/sites/davidaxe/2020/12/17/russias-hypersonic-strike-force-is-mostly-for-show/.

99 Oelrich, "Cool Your Jets," 39.

100 Tracy and Wright, "Modeling the Performance of Hypersonic Boost-Glide Missiles," 3.

101 Oelrich, "Cool Your Jets," 37.

102 Oelrich, 38.

103 Tracy and Wright, "Modeling the Performance of Hypersonic Boost-Glide Missiles," 9.

Not being able to defend against a long-range missile threat is neither a new problem nor one that will be solved anytime soon, though the flexibility of hypersonic weapons specifically in their air-launched version could make them particularly interesting at the theatre level against conventional targets

Hypersonic glide missiles would not necessarily achieve speeds above those of ballistic missiles and may underperform relative to ballistic missiles. In fact, Cameron Tracy and David Wright's modelling suggests ground-launched hypersonic gliders have "modest delivery time advantages" over ballistic missiles traveling on minimum energy trajectories and, at inter-continental distances, hypersonic glider actually travel more slowly than ballistic missiles on a depressed trajectory.[104] Indeed, depressed trajectory missiles were considered avenues towards surprise attacks in the latter stages of the Cold War.[105] A HGV does have an advantage over ballistic missiles due to the lower altitudes they can travel at, which can significantly delay detection. In turn, the possibilities of hypersonic cruise missiles are more limited than advertised because hypersonic propulsion is extremely challenging.[106] Hard physical limits constrain the possibilities of hypersonic missiles to focus on either speed or manoeuvrability or range.

The hypersonic missile threat does not seem to represent a true game changer. In the short-to-medium range of five to ten years, the advances represent an evolution rather than a revolution in offensive technology.[107] As the technologies mature in the ten to twenty year time-frame, provided certain technological limitations can in fact be overcome, this could very well change. That said, current-day hypersonic weapons would still represent a considerable challenge to defenders. But the same holds for ballistic missiles. Not being able to defend against a long-range missile threat is neither a new problem nor one that will be solved anytime soon,[108] though the flexibility of hypersonic weapons specifically in their air-launched version could make them particularly interesting at the theatre level against conventional targets.

The introduction of hypersonic glide vehicles and cruise missiles promises an unprecedented combination of speed, manoeuvrability and range, rendering them particularly useful when facing highly advanced defence systems, also partly due to their high costs. Yet in practice, trade-offs appear between the three dimensions, raising questions as to their truly revolutionary nature. These may be overcome over the next several decades, however, and defenders must continue to develop responses.

3.2.4 Aircraft (fixed wing and rotary wing)

Aircraft are versatile platforms that can fulfil a range of offensive, defensive, and observational tasks with a variety of weapon payloads. Their versatility combined with range, speed, manoeuvrability and possibly stealth ensures they remain a key asset within modern

104 Tracy and Wright, "Modeling the Performance of Hypersonic Boost-Glide Missiles."Ballistic missiles travel along the minimum energy trajectory with a high arching path mostly above the atmosphere, to conserve energy. While doing so, they travel at higher speeds than a hypersonic missile, but because they cover a greater distance, it takes longer to arrive at the target. However, if a ballistic missiles takes an other than optimal path, specifically by going lower according to a depressed trajectory (at some price to range or payload), its flight path is significantly reduced and the time to the target drastically shortened. Oelrich, "Cool Your Jets," 39. A ballistic missile on a depressed trajectory could reach the speed of 6,700 km in 17 minutes, which correlates to Mach 20, faster than a hypersonic missile. Defense Science Board, "Time Critical Conventional Strike from Strategic Standoff."

105 Lisbeth Gronlund and David C. Wright, "Depressed Trajectory SLBMS: A Technical Evaluation and Arms Control Possibilities," *Science & Global Security* 3, no. 1–2 (1992): 101–159; Oelrich, "Cool Your Jets," 39.

106 Ramjet engines have a narrow speed envelope in which they operate unless fuel combustion and air compression negate each other, which would drastically constrain any attempts at manoeuvre. Oelrich, "Cool Your Jets," 43.

107 Tracy and Wright, "Modeling the Performance of Hypersonic Boost-Glide Missiles," 2; Heather Venable and Clarence Abercrombie, "Muting the Hype over Hypersonics: The Offense-Defense Balance in Historical Perspective," War on the Rocks, May 28, 2019, https://warontherocks.com/2019/05/muting-the-hype-over-hypersonics-the-offense-defense-balance-in-historical-perspective/; Cummings, "Hypersonic Weapons."

108 Oelrich, "Cool Your Jets," 41.

conventional warfare.[109] This centrality, at least in Western thinking, has persisted despite recent technological developments in UAVs. The use of airpower has indeed been the focal point of US military strategy, as operations in Serbia, Afghanistan, and Iraq have shown,[110] though arguably also revealing the limits of airpower to decisively shape political outcomes on the surface. Air superiority is achieved through superior fighter aircraft, as well as pilot training, aircraft maintenance, weapon supply and force multipliers, such as radars. Development and acquisition come at a high – and ever increasing – price,[111] which makes it difficult for even major powers to keep up with the US.[112]

Combat aircraft are intended to operate in hostile airspaces where they will need to avoid detection, tracking and engagement both by an enemy's air defence systems including hostile aircraft. Fixed-wing combat aircraft include fighters, bombers, electronic warfare (EW) aircraft and maritime patrol aircraft. Fighters engage in air-to-air combat, can fly at supersonic speeds and are as manoeuvrable as they are versatile.[113] They carry air-to-air combat missiles and air guns, as well as air-to-surface missiles as many fighters can perform a secondary ground-attack role. A fighter's principal mission is to establish air superiority through denying enemy air power.[114] Bombers are the delivery mechanisms not just for bombs but also cruise missiles and ballistic missiles to hit ground and naval targets on the strategic, theatre, and tactical levels. Long-range heavy or strategic bombers can carry both conventional or nuclear weapons which may be deployed against strategic targets such as bases, industrial sites, infrastructures and cities.[115] Electronic-warfare (EW) aircraft are designed to suppress enemy radars and radio systems using jamming capabilities. Finally, maritime patrol aircraft are long-endurance systems aimed to detect and destroy enemy ships and submarines using air-to-surface weapons, torpedoes and underwater mines.[116]

Multi-role aircraft can perform both fighter and bomber functions, making them highly versatile.[117] If properly equipped, they can switch roles mid-operation. In practice, many fighters are now fighter-bombers since only the largest air forces can afford to purchase dedicated

109 E. Taylor Francis, "Air Supremacy in Airpower Theory" (Air University Press, 2020), 13–19, https://www.jstor.org/stable/resrep24881.8.

110 Karl P. Mueller, "Air Power" (RAND, 2010), https://www.rand.org/content/dam/rand/pubs/reprints/2010/RAND_RP1412.pdf.

111 The procurement of 12 F-35 Lightning II fighters currently costs more than $1.1 billion dollars, not including pilot training, maintenance, operation and fuel costs. This is about five times the price of the F-4 Phantom fighter-bombers used during the Vietnam War (costing about $20 million per unit). The cost of training for a fifth generation pilot is estimated at $11 million, while the cost per flying hour (including operation and support costs) for an F-35 is at least $17,000. Maj jules "jay" Hurst, "Small Unmanned Aerial Systems and Tactical Air Control," *Air & Space Power Journal*, Spring 2019, https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-33_Issue-1/F-Hurst.pdf.

112 Andrea Gilli and Mauro Gilli, "Why China Has Not Caught up yet: Military-Technological Superiority and the Limits of Imitation, Reverse Engineering, and Cyber Espionage," *International Security* 43, no. 3 (2019): 141–189.

113 Present days' fighters include the US F-16, F-22, and F-35; the Russian Su-30MKI, Su-34, Su-35, and MiG-29; and the Chinese J-10.

114 Kanchan Biswas, "Military Aviation Principles," IntechOpen, 2019, https://www.intechopen.com/books/military-engineering/military-aviation-principles.

115 Strategic or heavy bombers that are currently in service include the US B-2 Spirit and B-52, the Soviet-era Tu-95, and the Chinese H-20. Shorter-range, tactical bombers are aimed at countering enemy military activity on the battlefield and supporting offensive operations. Tactical bombers currently in use include the Chinese JH-7, the Russian MiG-27, and the Mirage 2000D. Recent operations in Iraq and Afghanistan showed the use of strategic bombers attacking tactical targets, but that has been caused due to the absence of real strategic targets to attack.

116 Kanchan Biswas, "Military Aviation Principles," in *Military Engineering*, ed. George Dekoulis (IntechOpen, 2020), https://doi.org/10.5772/intechopen.87087.

117 Multirole fighters include the Euro fighter Typhoon and Dassault Rafale – the first of which was originally designed as air superiority fighter.

aircraft. The F-35, for example, is a fighter-bomber but can also take on EW-tasks as one of its roles.

In addition to these various combat roles, fixed-wing aircraft have a broad range of features that determine their detectability, versatility and manoeuvrability. Fourth-generation aircraft (1970-1990) are high-manoeuvrability fighters with sophisticated multimode avionics and weapons systems, capable of switching from air-to-ground modes.[118] New features emerged in the 1990s, such as lighter composite material with stealth coating, high-altitude super-cruise capability, digital avionics, and sophisticated weapons, including beyond visual range air-to-air missiles (AAM), GPS-guided missiles. The latest, fifth-generation aircraft are best known for their high-performance aerodynamic shaping and very low observable stealth features. This radar-wave absorbing coating reduces the range at which aircraft can be detected, tracked, and engaged – making them particularly suited to target air defence systems. In addition, fifth-generation fighters make use of integrated avionics and computer systems which combine information provided by the aircraft's multi-spectral sensors with off-board data to provide pilots with the highest level of operational awareness and network-centric capability.[119] They have multi-role capabilities and often exceptional levels of manoeuvrability.[120] Fourth and fifth generation aircraft have a range of less than 700 miles without air to air refuelling; with endurance generally limited due to pilot rest requirements.[121]

Rotary-wing aircraft, or helicopters, can hover, fly at very low altitudes, have an extremely high manoeuvrability and can depart from virtually any point. Those used in anti-tank and close air support roles are equipped with anti-tank guided missiles, guns and rockets, and capable sensors.[122] Helicopters used for antisubmarine warfare can be both ship- and land-based and use torpedoes for attack.[123] Observation helicopters are equipped with optical sensor systems including low-light video and forward-looking infrared cameras to perform ISR functions, whereby target data is fed into laser- infra-red or radio frequency-guided missiles to guide them to their targets.[124] Other types of military helicopters are dedicated towards transport, medical evacuation, combat search and rescue, or general utility functions. Various helicopter types are multirole, capable of carrying out a range of missions including ground attack, air assault, logistics, evacuation and troop transfer.[125]

118 Aircraft within this category are the F-16 Fighting Falcon and F-117 Nighthawk – both equipped with radar-absorbing stealth coating technology to reduce detectability – and the F-15, F18-A, Mirage 2000, and Soviet-era MiG-29 and Su-27.

119 Deborah Lee James and Daniel Gouré, "The Implications of Fifth-Generation Aircraft for Transatlantic Airpower" (Atlantic Council | Scowcroft Centre for Strategy and Security, October 2019), https://www.atlanticcouncil.org/wp-content/uploads/2019/10/FINAL-AirPower-Domain-Report-WEB-1.pdf.

120 Fifth-generation fighter jets that are currently being operated are the US F-22 Raptor and F-35 Lightning II as well as the Chinese Chengdu J-20, while the Russian Sukhoi Su-57 is currently being developed. It should be added however that two RAND commentators contend that the Su-57 will likely be a modernised fourth-generation fighter jet rather than a fifth-generation, Ryan Bauer and Peter A. Wilson, "Russia's Su-57 Heavy Fighter Bomber: Is It Really a Fifth-Generation Aircraft?," RAND, August 17, 2020, https://www.rand.org/blog/2020/08/russias-su-57-heavy-fighter-bomber-is-it-really-a-5th.html.

121 Maj Jules "Jay" Jules, "Small Unmanned Aerial Systems and Tactical Air Control," *Air & Space Power Journal*, 2019, https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-33_Issue-1/F-Hurst.pdf.

122 Biswas, "Military Aviation Principles"; Attack helicopters currently in use include the Russian Ka-50/Ka-52 Hokum, the Mi-28 Havoc and the Mi-24 Hind; the Chinese Z-10; the Turkish T-129, and the Eurocopter Tiger. Logan Nye, "The 9 Best Military Attack Helicopters in the World," Insider, December 4, 2018, https://www.insider.com/the-9-best-military-attack-helicopters-in-the-world-2018.

123 Biswas, "Military Aviation Principles"; ASW helicopters include the US MH-60R Seahwawk, the NH90 (in use by France, Germany, Italy and the Netherlands), the Chinese Z-18F, and the Russian Ka-27. "Top 10 Anti-Submarine Warfare (ASW) Helicopters," Military-Today.com, accessed April 9, 2021, http://www.military-today.com/helicopters/top_10_asw_helicopters.htm.

124 Biswas, "Military Aviation Principles," 2019.

125 Biswas.

Combat aircraft are thus diverse, making them deployable for a wide variety of missions. Fixed and rotary wing aircraft are versatile, manoeuvrable and precise, while functions such as EW capabilities and stealth increase their survivability. Yet, the onboard presence of pilots makes them vulnerable too and strain mission endurance.

3.2.5 Unmanned aerial vehicles

UAVs, also referred to as unmanned aerial systems (UAS), remotely piloted aircraft (RPA), remotely piloted aircraft systems (RPAS), or drones, are guided by a pilot on the ground and are capable of flying autonomously.[126] They consist of the aircraft itself, a ground control station, a communication link and a launch and retrieval system.[127] In terms of functions, there are three basic types: intelligence, surveillance and reconnaissance (ISR) UAVs, loitering munitions and unmanned combat autonomous vehicles. ISR UAVs provide intelligence and targeting information. Loitering munitions are designed to be able to "loiter" for extended periods of time in wait for a suitable target and then to explode on impact on that target. They are often portable, equipped with electro-optical and infrared cameras, and meant to provide ground units such as infantry with a guided precision munition.[128] Unmanned combat autonomous vehicles can fulfil more complex offensive functions and are usually equipped with bombs, missiles or anti-tank guided missiles (ATGMs).[129]

While classifications differ,[130] the NATO Standardization Agreement 4670 categorises UAVs into three classes, largely based on their maximum take-off weight, with additional subcategories based on characteristics such as size, flight endurance, and capabilities.[131] Class I UAVs, including fixed- and rotary-wing aircraft and a small number of hybrid models, range from tiny handheld models to larger, multirole systems. They combine vertical take-off and landing and horizontal flight and are usually equipped with an electro-optical and infrared sensor package. The majority of Class I systems are unarmed and used to carry out reconnaissance and surveillance missions, yet various loitering munitions also belong within Class I.[132] Class II UAVs or so-called tactical UAVs can be fixed-[133] or rotary-wing and can be equipped with multiple payloads including electro-optical and infrared sensors, laser designators or

126 A. Watts, V. Ambrosia, and Everett A. Hinkley, "Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use," *Remote Sensing*, 2012, https://doi.org/10.3390/rs4061671.

127 Kimon P. Valavanis and George J. Vachtsevanos, *Handbook of Unmanned Aerial Vehicles* (Springer Netherlands, 2015), https://link.springer.com/referencework/10.1007%2F978-90-481-9707-1; Remotely piloted aircraft is commonly used to refer to systems for which pilots have been trained to similar standards as manned aircraft pilots. "Joint Air Operations," Joint Publication 3-30 (Joint Chiefs of Staff, July 25, 2019), https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_30.pdf. Military personnel tends to use unmanned to describe smaller UAVs of up to 600 kilograms (Class I and II), and remotely piloted to describe larger types (Class III).

128 Dan Gettinger and Arthur Holland Michel, "Loitering Munitions In Focus," Centre for the Study of the Drone, 2017, https://dronecentre.bard.edu/loitering-munitions-in-focus/.

129 Shashank Kumar, "A Brief Review on Unmanned Combat Aerial Vehicle (U.C.A.V)," *SSRN Electronic Journal*, 2020, https://doi.org/10.2139/ssrn.3593220.

130 The Missile Technology Control Regime (MTCR) distinguishes between Category I and II UAVs, based on range and payload. Category I includes UAVs capable of delivered a payload of at least 500 kg to a range of at least 300 km, and Category II include those systems that hold less sensitive dual-use components and complete systems with a range of at least 300 km, regardless of payload. Nacouzi et al., *Assessment of the Proliferation of Certain Remotely Piloted Aircraft Systems*.

131 Dan Gettinger, "The Drone Databook" (Centre for the Study of the Drone, 2019), https://dronecentre.bard.edu/files/2019/10/CSD-Drone-Databook-Web.pdf.

132 Class I (<150 kg) UAVs a top speed of 100 km/h, a maximum range of 80 km and a payload capacity up to 5 kg. They operate at altitudes up to 2 km. Class I UAVs are launched by hand or pneumatic rail. Subcategories of Class I include Nano (<0,5 kg), Micro (0,5 – 2 kg), Mini (2 – 20 kg) and Small (20 – 150 kg). Examples of Class I UAVs are Black Widow (Micro), the Turkish Bayraktar (Mini), and Scan Eagle (Small).

133 Requiring a small runway for launch and recovery.

illuminators for targeting, and communications relay equipment. Typical Class II UAVs are unarmed but some models can be equipped with lightweight ordnance such as air-to-ground guided missiles.[134] Class III UAVs, finally, include vehicles referred to as medium-altitude long-endurance (MALE) or high-altitude long-endurance (HALE).[135] This class includes fixed- and rotary-wing aircraft, capable of carrying various weapons, with some restricted to ISR purposes.[136]

The properties and abilities of the different UAV classes differ starkly

The properties and abilities of the different UAV classes differ starkly. The absence of pilots not only eliminates the risks to military personnel, it also vastly increases flight endurance. As their names imply, both MALE and HALE aircraft have a particularly long endurance, typically up to 24 hours or even several days, with the latter particularly suitable for (overseas) ISR purposes. Current generation UAVs' slow speed and lack of defensive capabilities make the aircraft vulnerable to air defence systems. They have therefore been particularly useful in operations where air superiority is guaranteed – in other words, against non-state actors. While seemingly less strategically relevant than larger, combat-capable UAVs, smaller drones have major military implications.

Class I UAVs pose three types of threats against critical infrastructures, through (1) spying and tracking; (2) carrying chemical, radiological, biological, nuclear, and explosive materials towards fixed or moving targets; and (3) intercepting wireless networks, breaching computer systems and conducting cyberattacks by hovering or landing on buildings.[137] Due to their low-altitude, Class I UAVs are more vulnerable to attack from traditional air defences. Yet their low radar, infrared acoustic and visual signatures make them hard to detect and hard to intercept.[138] In the 2020 Nagorno-Karabakh war, for example, the relatively slow and low-flying Bayraktar TB2 drone could not be picked up by Armenia's older radars and escaped the Soviet-era surface-to-air missiles designed to hit fast-moving fighter jets, missiles and other more traditional air threats.[139] Operational mistakes worsened the problem. Armenian surveillance saw no danger in old Soviet-era Antonov aircraft the Azeris used; however, by illuminating these aircraft, the radar systems gave away their positions for anti-radiation missiles and drones deployed by the Azeris. The effectiveness of UAVs in the suppression and destruction of air defence systems was similarly shown in Syria and Libya.[140] Finally, UAVs' relatively low costs should be noted. Especially with the customisation of commercial drones

134 Class II (150-600 kg) have a top speed of 200 km/h, a typical endurance of up to 10 hours, a 100-200 km range, and able to carry a payload capacity up to 70 kg. The operation altitude of tactical UAVs is up to 3 km. An example of a Class II UAV is the Hermes 450.

135 Class III (>600 kg) UAVs have a top speed of 600 km/h, a payload capacity of several hundred kg and an endurance of up to 24 hours (with HALE aircraft capable of reaching an endurance up to 32 hours). Depending on the communications equipment used, some Class III models have a range of several thousand km. This class has a maximum operating altitude of up to 65,000 ft.

136 Class III includes three subcategories: MALE, HALE, and Strike/Combat. Example platforms include the Reaper (Strike/combat), Global Hawk (HALE) and Heron (MALE).

137 Georgia Lykou, Dimitrios Moustakas, and Dimitris Gritzalis, "Defending Airports from UAS: A Survey on Cyber-Attacks and Counter-Drone Sensing Technologies," *Sensors* 20, no. 12 (January 2020), https://doi.org/10.3390/s20123537.

138 Timothy Coffey and John A. Montgomery, "The Emergence of Mini UAVs for Military Applications," National Defense University Press, December 1, 2002, https://ndupress.ndu.edu/Media/News/News-Article-View/Article/1014563/the-emergence-of-mini-uavs-for-military-applications/.

139 Pierre Tran, "Drone Warfare: Working Countermeasures," *Second Line of Defense* (blog), February 7, 2021, https://sldinfo.com/2021/02/drone-warfare-working-countermeasures/.

140 Guowei Cai, Jorge Dias, and Lakmal Seneviratne, "A Survey of Small-Scale Unmanned Aerial Vehicles: Recent Advances and Future Development Trends," *Unmanned Systems* 02, no. 02 (April 1, 2014): 175–99, https://doi.org/10.1142/S2301385014300017; A Turkish Bayraktar TB2 is estimated at a few million US dollar, while the US MQ-9 Reaper costs $64 million per unit (including four aircraft, sensors, and C2 station). "MQ-9 Reaper," U.S. Air Force, accessed December 11, 2020, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104470/mq-9-reaper/.

for some basic tasks, the cost exchange for the defender and attacker can be highly uneven, as was shown in 2017 when a Patriot missile – reported to have cost $3 million - shot a $200 dollar drone bought from Amazon.[141]

Indeed, UAVs come in many shapes and forms, complicating a general characterisation. While typically slower than other types of air threats, and with a relatively low survivability, they pose distinct challenges to air defence systems, not least because the latter have simply not yet adapted to this new threat. The use of UAVs in combination with other air weapons, or as part of larger UAV swarms, make them particularly dangerous, today but even more so in the future.

Guided Rockets, Artillery and Mortars (G-RAM)

G-RAM encompass a range of different weapon systems, ranging from small portable mortars to rockets or missile launching artillery systems with a range of a couple of hundred kilometres. G-RAM has the greatest impact at the tactical level, but effective use of G-RAM enables broader offensive, defensive, or deterrent functions.[142] These systems are produced and used globally, with the simpler systems, such as 107mm unguided rockets and small 81/82 mortars, easy to operate and used extensively by irregular operating forces.[143] G-RAM are generally used to attack slow moving or static targets and force adversaries to either spend resources on counter systems or avoid being in static positions. Unguided rockets and projectiles follow predictable flight paths, making them easy to track and intercept, but guided rockets and projectiles can follow unpredictable flight paths, complicating interception. Defence against G-RAM is further challenged by the small size of the rockets and projectiles, making them hard to hit.

G-RAM is often included in the threat palette for IAMD. This is a somewhat unfortunate doctrinal choice because the threat of mortars and conventional artillery requires quite different defensive approaches than the threat of ICBMs, fighter planes or cruise missiles. Conceptually, defence against G-RAM fits better under force protection, which is a national responsibility. We raise the subject here because G-RAM are often used in combination with UAVs, whereby the former functions as an effector and the latter as a sensor. G-RAM compounds the conceptual challenge posed by UAVs, namely the asymmetry in costs: a simple unguided projectile or rocket, costing at times no more than a few hundred dollars, must be intercepted by an expensive system.[144]

141 Chris Baraniuk, "Small Drone 'Shot with Patriot Missile,'" *BBC News*, March 15, 2017, sec. Technology, https://www.bbc.com/news/technology-39277940.

142 One should compare it with the analogy of a pistol. That is not a strategic weapon, but used to assassinate a president it will have strategic implications.

143 'In the 1980s, Afghan rebels fired hundreds of 107 mm and 122 mm rockets at Soviet and Afghan government military compounds, killing dozens of troops, disrupting transport routes, and destroying aircraft, ammunition, fuel, and other supplies worth millions of dollars.' Matt Schroeder, "Types, Manufacturers, and Importers of Artillery Rockets," Rogue Rocketeers (Small Arms Survey, 2014), 15, https://www.jstor.org/stable/resrep10725.9.

144 A simple 155mm High Explosive round (fuse, shell, propellant charge, and firing cartridge) costs less than $2.000 at the official market; according to the Dutch Defence Materiel Organisation.

3.3 **Summary:** Weapon systems and impacts

Table 1 below summarises the key characteristics of the weapon systems discussed in this chapter, distinguishing between the principal levels of impact, advantage and disadvantages, their costs, possibility to defend against them, and trends in proliferation and adoption and key actors. We note that the developments in the current threat environment increase the risk to both civilian and economic security and military security.

Weapon system	Level(s) of impact	Advantage (attacker)	Disadvantage (attacker)	Defence	Costs	Trend
Ballistic missiles	Strategic; theatre	Speed, trajectory, (possible) range	Predictable trajectory, difficult to transport and hide	Highly difficult	High	Proliferation, depending on complexity
Cruise missiles	Theatre	Manoeuvrability, varying altitudes, limited logistical tail	Less suited for certain targets, lower speeds	Difficult	Medium	Proliferation
Hypersonic missiles	Strategic; theatre	Range, speed, manoeuvrability	Trade-offs between them, logistical tails	Highly difficult	Very high	Limited proliferation
Aircraft (manned)	Strategic; theatre; tactical	Fixed wing: versatility, range, speed, manoeuvrability; rotary wing: manoeuvrability	Logistical tail, expensive, not expendable	Difficult for 5th gen; less for previous generations and rotary wings	Very high for newer generations	Stealth, difficult to catch up with us, limited proliferation
Aircraft (unmanned)	Theatre; tactical	Loitering, persistent sensing, versatile but expendable	Limited ranges, logistical tail depending on class	Difficulty depends on class, but especially on saturation	Moderate to cheap, depending on class	Proliferation, depending on class
G-ram	Tactical	Highly difficult to intercept	Limited range, limited guidance	Highly difficult	Cheap	Proliferation

Table 1. Weapon systems and key characteristics

Vignette 1: The Attack on Abqaiq-Khurais, September 14 2019

To the defenders of the Abqaiq oil processing plant, the night of 14 September seemed like any other – long, boring and dull. The radar screens did not indicate anything dangerous and in the witching hours of the night the human mind is unfocused and easy to distract. Although quite aware of the economic and strategic importance of the vital installations they were defending, the war in Yemen was distant. Nevertheless, a modern multi-layered defence had been provided. Considering its dangerous neighbourhood, Saudi-Arabia had invested in a capable and advanced radar detection network along with good command and control systems. A Patriot battery gave long range air defence and anti-ballistic missile capability while close in protection was assured by three batteries of 35mm guns and one of short-range missiles, all with radar guidance. By any reasonable standard, these were strong defences.

Seemingly out of nowhere eighteen UAVs and seven cruise missiles hit the Khurais oilfield and the Abqaiq processing plants around 4:00 AM. The defenders were completely surprised. The strategic air detection radars had not given any warning against the low flying attackers and the dedicated air defence systems had not come into play – the chanceless small-arms fire of the guards was little more than a defiant gesture. Although there were no casualties, the precision of the strike was remarkable. Three of the vital processing trains in Abqaiq had been hit at precisely the same spot. Fires erupted and increased the destruction. Combined, the damage of this short, swift attack was sufficient to knock out the Abqaiq plant for weeks. Figure 4 shows the effects of the attack on Abqaiq oil processing plant. Where the attack had come from was uncertain at this stage. Iran was the clear and obvious candidate but the missiles had left few traces and it would take a while to recover their debris from the wreckage and identify them properly. Things were further complicated by the Yemenite Houthi rebels proudly claiming the responsibility for the attack, even if the sheer distance of the targets from Yemen should have made this an impossibility.

Figure 4. Effects of attack on Abqaiq oil processing plant

This single limited and brief strike more than halved Saudi oil production from 9,8 to 4,1 million barrels a day, which cut down total world production by 5%. The impact on the world markets was direct, even if reserve stocks were available and repairs were immediately taken in hand. The uncertainty of the provenance of the attack made a clear answer difficult. The earlier skilful Houthi attacks on targets in Southern Saudi Arabia, and the similarity of the weapons used, gave their claim a degree of credibility that made it harder to deny, while the inability to unveil sensitive data combined with the lack of trust of the international community in the Trump administration made it difficult to point the finger squarely at Iran.[145]

Tactical Drivers

Cruise missiles and drones: The difference between a cruise missile and an armed drone is largely semantic. In essence, both are unmanned aircraft intended to fly to their targets and dive straight into them. To make them dangerous conventional weapons two things are needed: the missiles must be difficult to intercept and must be sufficiently precise. The first challenge can be solved by having cruise missiles fly extremely low and by flying around known defences. Precision can be solved in different ways but all demand quite advanced technology. In the past, solving these two problems was only within reach of the superpowers. Now, even second and third rank powers can access this technology. The *Quds* and *Soumar* cruise missiles used by the Houthi and Iran are good examples. Although far less capable than their American *Tomahawk* counterpart their 700- and 1,200- kilometre range, sizeable warhead and precision make them capable enough weapons. These classic cruise missiles are now joined by a new family of armed drones that are far lighter and simpler than cruise missiles but which still possess enough range and accuracy to strike deep in Saudi territory.[146]

Classic cruise missiles are now joined by a new family of armed drones that are far lighter and simpler than cruise missiles but which still possess enough range and accuracy

Patriot Missile System: Originally designed during the Cold War to kill Warsaw Pact aircraft, the secondary Anti-Ballistic Missile capability of the Patriot has become its main function – this is both a sign of the growing danger of Ballistic Missiles and a clear indicator of the unprecedented level of air superiority enjoyed during the last decades by Western forces. It is an extremely capable system but like all the ground-based air defences it suffers some unavoidable limitations. The most serious one is the radar horizon: the electromagnetic waves used by a radar follow straight lines while the earth has a curvature, meaning the lower the target, the shorter the distance at which a ground-based radar can detect it. But an additional disadvantage of the Patriot is that its Phased Array Radar covers only a 120° sector rather than the full 360°. If an attack is not launched from an expected direction, fast reaction is not possible.

Salient Facts

The attack on Abqaiq and Khurais clearly illustrates the vulnerability of infrastructure against even a small and limited attack. Strategically, this was a clear warning by Iran, pointing out both to the US and Saudi-Arabia what it could do if the Cold War would turn hot. If one attack could cause such disruption, what would happen in the case of a persistent campaign? Tactically, it clearly shows the threat of low-flying, slow and light drones

145 BBC New, *Weapons debris 'proves Iran is behind them'*, September 18 2019 https://www.bbc.com/news/world-middle-east-49746645

146 Michael Knights, *Implications of Houthi Missile and Drone Improvements*, April 1 2021 https://www.washington-institute.org/policy-analysis/yemens-southern-hezbollah-implications-houthi-missile-and-drone-improvements

and cruise missiles. The defences of Abqaiq were considerable but they were focused on the classic threats of manned aircraft and ballistic missiles. The fact that drone and cruise missile capabilities are now in reach of third rank powers and even non-state actors makes it even more mandatory that future defences will take these threats for granted and can deal with them.

It is very interesting to see how the inability to squarely point a finger at Iran made it politically difficult to retaliate. As cruise missiles and drones further proliferate, we must expect that the attribution of an attack will become more and more difficult to make. Who is responsible? The producer, the sponsor or the party making the attack itself? Especially in counterinsurgency operations and with non-state actors involved this quandary can and will manifest itself more and more in the future.

The strike also clearly illustrates the classic dilemma of the defender. The attacker has the initiative and can decide where, when, and how he will pounce while the defender must defend every valuable target. Clearly, it is impossible to do so everywhere, so choices will have to be made and some targets will have to be left more vulnerable than others. The failure of the Saudi defences also shows how important it is for defenders to always be alert - easier said than done deep in the rear at the end of a boring night. And truth be said, defenders of a quiet spot deep in the hinterland will seldom be the pick of the pack. If we add that the reaction time needed is measured in seconds – even a subsonic cruise missile reaches its target fast – it is difficult to avoid the conclusion that further automation of close in defences is necessary.

With the political will and sufficient dedication, efficient defences are possible. In the spring of 2021 Saudi Arabia has weathered an Iran-backed Houthi surge of ballistic missile and drone attacks very well indeed, shooting down most of their targets.[147] In dealing with the latter, the Saudi airborne early warning capacity has been vital – a radar platform looking down high from the skies has an enormous radar horizon and once detected drones are relatively easy to destroy. But these defences have come at a steep price. In the end, the Houthi ability to strike into Saudi territory and the resultant pressure on the Saudi defence budget might very well give the Houthi a decisive edge in any peace negotiations in Yemen.

The attack on Abqaiq and Khurais clearly illustrates the vulnerability of infrastructure against even a small and limited attack

147 Riad Kahwaij, *Saudi Air Defence Stops most Houthi Strikes,* Breaking Defence March 30 2021 https://breakingdefense.com/2021/03/saudi-airdefense-stops-most-houthi-strikes/

4. Actors and scenarios

In the context of integrated air and missile defence (IAMD), European states currently face a great power threat in the form of Russia and increasingly, albeit not in the European theatre itself, China; a regional power threat in the form of Iran; and a variety of non-state actor threats. Non-state actors are primarily a threat at the tactical level Iran and China primarily at the theatre and tactical level; and only Russia can truly threaten European states at the strategic, theatre, and tactical levels. This chapter briefly offers four conceivable scenarios where European states will require air and missile defence against these actors (see Table 2 for an overview). The analysis is based on a review of existing scholarship of the political strategies, concepts, doctrines, and air and missile systems of these actors. It is not intended as a prediction of their actual willingness to engage in conflict. Arguably, impact and likelihood are inversely correlated; with the low impact scenarios more likely and the high impact scenarios less likely to happen.

	Russia	China	Iran	Non-state actor
Levels	Strategic; Theatre; Tactical	Theatre; Tactical	Theatre; Tactical	Tactical
Domain	Land; sea; air; cyber; space	Sea; air; cyber	Sea	Land
Weapons	Ballistic missiles; cruise missiles; aircraft; UAVs; G-RAM	Ballistic missiles; cruise missiles	Cruise; UAVs	UAVs; G-RAM

Table 2. Air and missile threat scenarios

4.1 Russia

Violent, pro-Russian protests erupt in Riga, Latvia, spreading to other parts of the country. As the security situation deteriorates, a group of ethnic Russians announces a shadow government, inviting Russian peacekeepers to restore the peace. Within days, Russia deploys ground force units into the country, supported by artillery, long-range surface-to-air missile systems and tactical aviation,[148] spurring the official Latvian government to invoke NATO Article 5. In response, NATO launches a counteroffensive including ground-, sea-, and air forces.[149] NATO forward-deployed forces and Baltic troops are quickly deployed to Latvia, receiving support from extensive NATO combat air forces (supplied by France and the UK) as well as naval forces arriving through the Baltic Sea. NATO ground forces from Germany and

148 David Ochmanek, *U.S. Military Capabilities and Forces for a Dangerous World: Rethinking the u.s. Approach to Force Planning* (Santa Monica, CA: Rand, 2017).

149 David A. Shlapak and Michael Johnson, "Reinforcing Deterrence on NATO's Eastern Flank: Wargaming the Defense of the Baltics" (RAND, January 29, 2016), https://www.rand.org/pubs/research_reports/RR1253.html.

Poland, meanwhile, seek to cross the Suwalki Gap to reinforce the small number of tripwire forces stationed in the Baltics. Much to NATO's concern, additional Russian forces mobilise at Estonia's border, pushing NATO forces to spread themselves even more thinly. Russia mobilises both its Baltic and Northern Fleet, reinforcing its land- and air-based A2/AD (or "active defence") capabilities. Two weeks after initial protests erupted, Russian forces have reached the outskirts of both Riga and Tallinn.[150]

Russia would look to prevent NATO reinforcements from reaching the Baltics

The Russian attack would take place at all three levels. At the tactical level, NATO ground-, air and sea forces deployed to the Baltic states would come under attack from Russian "active defence" – a combination of defensive actions and offensive strikes including neutralisation and inflicting unacceptable damage – often referred to as anti-access area denial (A2/AD). With its A2/AD capabilities, Russia would look to prevent NATO reinforcements from reaching the Baltics.[151] Rear areas supporting the NATO counteroffensive would become targets too. Military support infrastructure, including airfields, ports, as well as logistic and command and control nodes – targets at the theatre level – would face attacks from long-range air and submarine launched cruise missiles.[152] Moreover, to consolidate its gains, Russia would potentially – or likely – hold targets at the strategic level under threat; these include military infrastructure on the territories of European NATO states, as well as civilian targets. Consequently, there is significant potential for escalation either through nuclear or nonnuclear means.[153] Indeed, Russia's strategy of "active defence" would guarantee escalation to the theatre level and potentially to the strategic level.[154] The limited use of nuclear weapons might be part of such an approach, though not necessarily as an instrument for guaranteeing a *fait accompli*.[155]

Any scenario against Russia would involve attacks in the land-, sea- and air domains, both local and theatre-wide. As part of its moves in the Baltics, Russia would rely on its active defence system that would mix defence against NATO bombers, ballistic missiles, and cruise missiles, with offense against NATO decision-making centres and missile launchers with precision-guided missiles.[156] Russia would rely on submarine-launched cruise missiles

150 Ochmanek, *U.S. Military Capabilities and Forces for a Dangerous World*, 36–38.

151 Eric S. Edelman and Whitney Morgan McNamara, *U.S. Strategy for Maintaining a Europe Whole and Free* (Centre for Strategic and Budgetary Assessments, 2017). David A. Shlapak and Michael Johnson, *Reinforcing Deterrence on NATO's Eastern Flank* (RAND, 2016), https://www.rand.org/pubs/research_reports/RR1253.html.

152 Katarzyna Zysk, "Escalation and Nuclear Weapons in Russia's Military Strategy," *The RUSI Journal* 163, no. 2 (2018): 7; Steve Wills, "'These Aren't the SLOC's You're Looking for': Mirror-Imaging Battles of the Atlantic Won't Solve Current Atlantic Security Needs," *Defense & Security Analysis* 36, no. 1 (2020): 30–41; Maren Garberg Bredesen and Karsten Friis, "Missiles, Vessels and Active Defence: What Potential Threat Do the Russian Armed Forces Represent?," *The RUSI Journal*, 2020, 70–71; Dmitry Dima Adamsky, *Moscow's Aerospace Theory of Victory: Western Assumptions and Russian Reality* (Washington: CNA, 2021), 6.

153 Daniel Flynn, "Russia's Evolving Approach to Deterrenc," in *Russian Strategic Intentions*, Strategic Multilayer Assessment (SMA) White Paper, 2019, https://nsiteam.com/social/wp-content/uploads/2019/05/SMA-Russian-Strategic-Intentions-White-Paper-PDF-compressed.pdf; Bruusgaard, "Russian Nuclear Strategy and Conventional Inferiority."

154 Recently, a variety of experts have argued that the concept of A2/AD has wrongly characterised Russian military strategy. Instead, they argue that "active defence" – presented by Russia's Chief of the General Staff, Valery Gerasimov, in a March 2019 speech – better describes Russian approaches. Adamsky, *Moscow's Aerospace Theory of Victory*, 3–6; Bredesen and Friis, "Missiles, Vessels and Active Defence"; Michael Kofman, "It's Time to Talk About A2/AD: Rethinking the Russian Military Challenge," War on the Rocks, September 5, 2019, https://warontherocks.com/2019/09/its-time-to-talk-about-a2-ad-rethinking-the-russian-military-challenge/.

155 Arguably, Western observers have been wrongly fixated upon Kristin Ven Bruusgaard, "Russian Nuclear Strategy and Conventional Inferiority," *Journal of Strategic Studies* 44, no. 1 (January 2, 2021): 7, https://doi.org/10.1080/01402390.2020.1818070. Andrew S Bowen, "Russian Armed Forces: Military Doctrine and Strategy" (Congressional Research Service, 2020).

156 Adamsky, *Moscow's Aerospace Theory of Victory*, 5; Bredesen and Friis, "Missiles, Vessels and Active Defence," 70–71.

to strike against shore-based military targets and economic infrastructure. Russia's Baltic Fleet operates from Kaliningrad and is reinforced by the Northern Fleet operating from the Kola Peninsula. Beyond active air and missile defence, NATO would thus be engaged in a variety of other missions, including anti-submarine warfare.[157] Simultaneously, NATO air, land and sea operations would be targeted and likely impeded by Russian cyber and electronic warfare, which would affect the confidentiality, availability and integrity of networks.[158] In addition, Russia could conduct a series of cyber strikes against various non-military infrastructures, including hospitals in Latvia, blaming NATO. Other targets might include political and economic infrastructures elsewhere on NATO territory. Furthermore, the conflict could escalate into the space domain, with anti-satellite weapons likely to be used.

NATO would face a wide spectrum of air and missile threats that are deployed in support of Russian military actions in the Baltic states – but also potentially to test the political resolve of NATO allies. Russia would seek to close off the Baltic Sea to surface vessels and air forces, and close off land access via the Suwalki land corridor. It would employ the weapons it has based in the Kaliningrad's enclave, including the S-400 and S-300 surface-to-air missile systems. Denying access of vessels carrying reinforcements through the Baltic Sea would additionally involve the deployment of the K-300 Bastion-P coastal defence system using Oniks anti-ship cruise missiles; the Bal coastal defence systems and ship-based Kalibr anti-ship cruise missiles.[159] These capabilities could be reinforced by the Western District's air forces including Su-27 fighters, Su-24 attack aircraft and Su-35 fighter-bombers, as well as the use of sea mines.[160] Meanwhile, Russian forces would restrict land access by attacking NATO forces crossing the Suwalki Gap through cannon and rocket artillery, including the 2S19 and Smerch, BM-21 and 9A52-2T multiple rocket-launch-systems.[161] Target acquisition would primarily take place through UAVs and special forces. If proven insufficient, Russian ground troops or a proxy force based in Belarus could be deployed to the Suwalki Gap, crossing over Lithuanian territory. In Latvia, Russia would attack the NATO forces by all means, ranging from very small UASs and mortars to large UASs, as well as rocket artillery, fixed- and rotary-wing aircraft and missiles.

The counteroffensive involves the suppression of enemy air defence systems (SEAD) and surface-to-surface fire systems on Russian territory, despite the risk of escalation through targeting Russian territory. NATO's air, land and naval systems would need to be deployed to target Russian A2/AD systems, while defensive systems would be needed to protect against offensive strikes against military and civilian targets in rear areas. Only if SEAD is successful, NATO could move additional airborne troops into Latvia and Estonia. NATO troops that are already in the Baltics – Latvian, Estonian and Lithuanian infantry brigades – as well as Poland, the four forward-deployed multinational battalion battle groups, would rely on NATO combat air patrols for defence against Russian airpower.[162] Anticipating that, over time, NATO reinforcements could burst Russia's A2/AD bubble, Russia would intensify its offensive strikes,

157 Bredesen and Friis, "Missiles, Vessels and Active Defence," 68.

158 "BI-SC-FINAL-REPORT-ON-THE-JOINT-AIRPOWER-STRATEG...-Compressed.Pdf," accessed May 4, 2021, https://www.euroairgroup.org/wp-content/uploads/BI-SC-FINAL-REPORT-ON-THE-JOINT-AIRPOWER-STRATEG...-compressed.pdf.

159 Robert Dalsjö, Michael Jonsson, and Christofer Berglund, "Bursting the Bubble? Russian A2/AD in the Baltic Sea Region: Capabilities, Countermeasures, and Implications" (FOI, March 2019), 26.

160 "Maritime Security Issues in the Baltic Sea Region - Foreign Policy Research Institute," July 22, 2020, https://www.fpri.org/article/2020/07/maritime-security-issues-in-the-baltic-sea-region/; Stephan Frühling and Guillaume Lasconjarias, "NATO, A2/AD and the Kaliningrad Challenge," *Survival* 58, no. 2 (March 3, 2016): 95–116, https://doi.org/10.1080/00396338.2016.1161906.

161 Frühling and Lasconjarias, "NATO, A2/AD and the Kaliningrad Challenge."

162 Shlapak and Johnson, "Reinforcing Deterrence on NATO's Eastern Flank," January 29, 2016.

first primarily against military nodes in rear areas. Once pressure by NATO forces increases, Moscow could decide to carry out various long-range nonnuclear strikes against targets on NATO territory outside the Baltics.

Moscow could potentially threaten to use limited nuclear weapons, the so-called escalate-to-de-escalate strategy.[163] In doing so, Russia would manipulate the risk-averse nature of Western powers, who would likely desist from intervening.[164] That said, this strategy was primarily a response to superior NATO forces. As Russian conventional capabilities advance, Russia's reliance on nuclear escalation would be increasingly questioned.[165] Concerns would be raised over Moscow's potential use of its nonnuclear escalation strategy, which may be employed against strategic targets as part of a de-escalation strategy.[166] Another, perhaps more likely, avenue for nuclear escalation would be inadvertent escalation, given the dual-use nature of various systems, as well as ambiguity in Russian thresholds for escalation.[167] Reinforcements from the Northern Fleet would add to this risk, as NATO antisubmarine warfare assets could mistakenly target Russian nuclear submarines. Similarly, shrinking decision time resulting from modern capabilities including hypersonic weapons could trigger nuclear escalation. Finally, Russia's 2014 military doctrine indicated that the country should be prepared to manage defences against attacks from the air and space, as well as that Russia should prepare the "deployment and maintenance of strategic space area orbital groups of space devices that support the activities of the armed forces".[168] This is perceived as Russia's preparation for space as a future war domain.[169] Russia's June 2020 nuclear doctrine, in turn, picks up on this by writing that the "development and deployment of missile defence means and attack systems in space" should be advanced.[170] In short, there are multiple avenues for inadvertent escalation.

4.2 **China**

The People's Republic of China (PRC) asserts itself in the Western Pacific and expands its territorial waters by building artificial islands in the South China Sea. It not only contests the maritime claims of neighbouring states but uses civilian vessels as paramilitary enforcers to harass civilian and law enforcement activities by those states. The US challenges Chinese claims on international waters by sending its vessels through disputed waters, through so-called Freedom of Navigation Operations (FONOPs), and calls on other states to do the same. In response, a multinational carrier group sets sail for the South China Sea, including a Dutch air defence frigate.[171] A flotilla of paramilitary PRC vessels, officially designated as

163 Viljar Veebel, "Why It Would Be Strategically Rational for Russia to Escalate in Kaliningrad and the Suwalki Corridor," *Comparative Strategy* 38, no. 3 (2019): 182–197. Brad Roberts, "On Adapting Nuclear Deterrence to Reduce Nuclear Risk," *Daedalus* 149, no. 2 (April 2020): 69–83, https://doi.org/10.1162/daed_a_01790. Nikolai Sokov, "Why Russia Calls a Limited Nuclear Strike 'de-Escalation,'" *Bulletin of the Atomic Scientists* (blog), March 13, 2014, https://thebulletin.org/2014/03/why-russia-calls-a-limited-nuclear-strike-de-escalation/.

164 Matthew Kroenig, "A Strategy for Deterring Russian Nuclear De-Escalation Strikes" (Atlantic Council, April 2018), https://doi.org/10.1163/2210-7975_HRD-0128-20180045.

165 Bruusgaard, "Russian Nuclear Strategy and Conventional Inferiority."

166 Flynn, "Russia's Evolving Approach to Deterrenc."

167 Flynn.

168 Daniel Fiott, "The European Space Sector as an Enabler of EU Strategic Autonomy," n.d., 14.

169 "Russia Tests Space-Based Anti-Satellite Weapon," IISS, accessed May 16, 2021, https://www.iiss.org/blogs/analysis/2020/09/mdi-russia-tests-space-based-anti-satellite-weapon.

170 Fiott, "The European Space Sector as an Enabler of EU Strategic Autonomy," 14.

171 See, for example: George Allison, "Dutch Frigate to Join British Carrier Strike Group," March 29, 2021, https://ukdefencejournal.org.uk/dutch-frigate-to-join-british-carrier-strike-group/.

fishing vessels, block the passage near the Spratly Islands. As the China Coast Guard intervenes,[172] a collision leads to one of its ships sinking. The People's Liberation Army (PLA) forces attack from the nearby islands.

The PRC attack on the carrier strike group would involve attacks on surface vessels and the strike group's aircraft. The attack would consist of land-launched ballistic missiles, land-, sea-, and air-launched cruise missiles from bases on the artificial islands, the PLA Navy's submarines and aircraft

The PRC attack would take place at the theatre and tactical level. The PLA would attempt to strike an aircraft carrier, which constitutes a high-value military asset. The PRC attack on the carrier strike group would involve attacks on surface vessels and the strike group's aircraft. The attack would consist of land-launched ballistic missiles, land-, sea-, and air-launched cruise missiles from bases on the artificial islands, the PLA Navy's submarines and aircraft. The PLA has significant infrastructure on the islands, including 3,000m runways, naval berths, hangars, missile silos, munition bunkers, and radar sites.[173] From its islands, it would launch YJ-12B and YJ-62 anti-ship cruise missiles, which would be supported by mainland based longer-range missiles. To destroy the carrier, the main offensive weapon within the strike group, the PLA's Rocket Force fires multiple DF-21D Medium-Range Ballistic Missiles out of the carrier group's range, [174] on the mainland. The PRC has 72 fighter hangars on three airbases in the Spratlys, through which it rotates combat aircraft. The closest ground-based US Air Force aircraft are in Okinawa and Guam. The islands provide radar and UAV support for sensing and tracking the strike group's ships.[175] The PLA would utilise its cyber capabilities and electronic warfare measures during a conflict in the South China Sea. Strike group communications and GPS would be affected. Additional People's Liberation Army Navy (PLAN) ships would join in the initial attack.[176]

Defence and counterattack options are available. The air defence frigate could defend the carrier group against incoming anti-ship cruise missile, though not the ballistic missiles. It has 40 Vertical Launch System cells loaded with SM-2 Block IIIA or Evolved Sea Sparrow missiles to intercept aircraft and cruise missiles directed at the carrier,[177] as well as the other ships in the strike group and itself. To ensure as many successful intercepts, it would fire half of its interceptors.[178] The PLAN could spoof an incoming missile attack with its own cyber and electronic warfare attack, the response to which would further drain the limited number of interceptors the ships carries.[179] Its SMART-L MM/N radar would allow it to sight incoming ballistic missiles at the earliest possible stage but the frigates lack the ability to intercept them. Striking back at the radars and airfields on the islands to interrupt the cruise missile attacks would be preferable. Yet, the facilities on the islands are defended by HQ-9 surface-to-air missiles, and the infrastructure is hardened, including China's missile shelters, larger hangars,

172 "Force Majeure: China's Coast Guard Law in Context," Asia Maritime Transparency Initiative, accessed April 13, 2021, https://amti.csis.org/force-majeure-chinas-coast-guard-law-in-context/.

173 BBC News, "South China Sea: What's China's Plan for Its 'Great Wall of Sand'?," *BBC News*, July 14, 2020, sec. Asia, https://www.bbc.com/news/world-asia-53344449.

174 BBC News.

175 "The Conventional Wisdom on China's Island Bases Is Dangerously Wrong," War on the Rocks, January 10, 2020, https://warontherocks.com/2020/01/the-conventional-wisdom-on-chinas-island-bases-is-dangerously-wrong/.

176 Braden Montgomery, "Contested Primacy in the Western Pacific"; Biddle and Oelrich, "Future Warfare in the Western Pacific."

177 The Evertsen, as all other frigates of its class, carriers: 5 8-cell Mk 41 VLS with SM-2 Block IIIA/RIM-162B ESSM SAM, 2 twin SVTT Mk 32 324mm ASTT with Mk 46 LWT, 1 (one has 2) Goalkeeper CIWS, 1.

178 [Ascertain in interviews what doctrine says about approx.. how many interceptors to fire for likelihood of successful intercept.]

179 Todd South Altman Philip Athey, Diana Stancy Correll, Stephen Losey, Geoff Ziezulewicz, Meghann Myers, Howard, "What War with China Could Look Like," Military Times, September 2, 2020, https://www.militarytimes.com/news/your-army/2020/09/01/what-war-with-china-could-look-like/.

and reinforced buried ammunition depots.[180] The air defence frigate is not carrying SLCMs;[181] these would be suboptimal against airfields in any case. The carrier group would rely on the aircraft for most of these actions.

Should ships of the carrier group survive the initial exchanges, they would quickly deplete their stocks of defensive missiles. The frigate's commander would then face a choice between protecting the carrier or their own ship. The carrier group would pull back as quickly as possible, back to the Sulu and Celebes Seas and probably beyond. As the most high-value asset, the carrier is far too valuable to leave in such an indefensible position.[182] The US Navy would be quickly involved and with it the chance of escalation to higher levels of conflict increases significantly.

It involves an attack on surface vessels and consist of land-launched ballistic missiles, naval mines, submarine-launched missiles and sea-launched shorter-range cruise missiles. In the attack, Iran follows a naval guerrilla-warfare strategy emphasizing speed, mobility and surprise

4.3 **Iran**

Not long after Iran completes the construction of a 1,000 kilometres pipeline along its southern coast, stretching from Goreh to Bandar-e Jask, an oil tanker sailing under an Indian flag is rocked by explosions in the Strait of Hormuz.[183] When an Australian frigate patrolling the Strait approaches the burning vessel, it is being harassed by a multitude of smaller platforms armed with guns and rockets, as well as some surface-launched missiles. The double attack appears to confirm fears that Iran is attempting to close off the Strait, now that the pipeline allows the country's oil exports to bypass the chokepoint. In response, two European frigates patrolling the Strait as part of the European-led Mission for Maritime Awareness in the Strait of Hormuz (EMASoH) rapidly move into action. Additional destroyers, including the Dutch Navy's HNLMS De Ruyter, are being prepared to join.

Iran is attempting to obstruct naval traffic to accomplish the larger purpose of disrupting the global energy market. The attack includes targeting single vessels, larger ships and potentially infrastructure in the region – and thus takes place at the theatre and tactical level. It involves an attack on surface vessels and consist of land-launched ballistic missiles, naval mines, submarine-launched missiles and sea-launched shorter-range cruise missiles. In the attack, Iran follows a naval guerrilla-warfare strategy emphasizing speed, mobility and surprise.[184] The Islamic Revolutionary Guard Corps Navy (IRGCN) would conduct a combined attack including using naval mines; larger Houdong-class and C14-class fast attack boats armed with anti-ship cruise missiles (ASCM) and drones;[185] smaller vessels armed with guns and rockets; and Nahang-, Yono- and Ghadir-class mini submarines armed with torpedoes and the

180 "The Conventional Wisdom on China's Island Bases Is Dangerously Wrong."

181 Jeremy Stöhs, "How High? The Future of European Naval Power and the High-End Challenge" (Djøf Publishing, 2021), 38, https://cms.polsci.ku.dk/publikationer/hvor-hoejt-fremtiden-for-europaeisk-maritim-militaermagt-og-udfordringen-fra-stigende-kapacitetstaerskler/CMS_Report__2021_1_-_How_High_-_The_Future_of_European_Naval_Power__updated_15_FEB_2021_.pdf.

182 "The Conventional Wisdom on China's Island Bases Is Dangerously Wrong."

183 "How Iran's Oil Infrastructure Gambit Could Imperil the Strait of Hormuz," *War on the Rocks*, July 16, 2020, https://warontherocks.com/2020/07/how-irans-oil-infrastructure-gambit-could-imperil-the-strait-of-hormuz/.

184 Anthony H Cordesman, "The Gulf and Iran's Capability for Asymmetric Warfare" (Washington D.C., U.S.: Centre for Strategic and International Studies, 2020).

185 Middle East Eye, "Iranian Press Review: Revolutionary Guard Equips Speed Boats with Suicide Drones," Middle East Eye, accessed April 15, 2021, http://www.middleeasteye.net/news/iranian-press-review-revolutionary-guard-equips-speed-boats-suicide-drones.2021, http://www.middleeasteye.net/news/iranian-press-review-revolutionary-guard-equips-speed-boats-suicide-drones.

Jask-2 ASCM.[186] Additionally, the incident would include Iran's first successful deployment of Unmanned Underwater Vehicles (UUVs).[187] Additionally, non-state proxies in Yemen and Iraq could target vessels in the Strait of Hormuz with anti-ship cruise missiles. The Iranian armed forces could potentially use cyber arms but these are unlikely to be of strategic importance.

A Dutch air defence and command frigate would be sent to reinforce the Australian and European frigates in the Strait of Hormuz. Its arrival would be delayed by a careful demining process as it approaches the combat area. The frigate is capable of targeting ship- and land-based targets at a range of 20 km with its Oto Breda 127mm deck gun[188] and its anti-ship Harpoon Block ID anti-ship missiles (AGM-84). For defence against Iran's ASCMs, it deploys its 40 cell Mark 41 VLS equipped with RIM-162B Evolved Sea Sparrow Missiles (ESSM) and SM-2 Block IIIA missiles. Meanwhile, the frigate's twin Mark 32 Surface Vessel Torpedo Tubes (SVTT), capable of firing 324mm Mark 46 lightweight torpedoes, as well as the NH90 maritime helicopter, are at hand for defence against submarines.[189] Meanwhile, one the Dutch Walrus-class submarines would be deployed too – just months before its planned retirement. It offers defence against submarines with its Mk 48 torpedo, launched by 533mm torpedo tubes and provides target information to the air defence frigate through its various sensors. [190]

European defence and counter-attack efforts to aid the ships would be hampered by Iranian A2/AD capabilities, notably its Coastal Defence Cruise Missiles, including the Noor, 200km range Ghader and the 300km range Ghadir ASCMs. Moreover, Iran steps up efforts with anti-ship ballistic missiles including the Khalij and Hormuz 2.[191] NATO would rapidly send in combat air forces (supplied by France, the UK and US) to target Iranian military infrastructure and one or two economic targets, such as ports. If proven insufficient to end the conflict, it could threaten to target civilian targets. Insofar it exists, the Iranian nuclear program is far from complete. There would thus be little to no risk of escalation to the nuclear level. However, US involvement would be certain, given its presence in the region through the 7th Fleet.

4.4 Non-state actors

As the security situation in Mali continues to disintegrate, an EU military mission assists the Malian government in securing the country against several competing non-state-actor groups. Dutch forces are deployed to Mali, consisting of one battlegroup that includes

186 Sebastien Roblin, "Iran's Submarines Could Be Unstoppable in the Persian Gulf," *The National Interest* (The Centre for the National Interest, January 9, 2021), https://nationalinterest.org/blog/reboot/iran%E2%80%99s-submarines-could-be-unstoppable-persian-gulf-176066; Joseph Trevithick, "Iran Claims It Tested A Submarine Launched Anti-Ship Missile Capable Of Standoff Strikes," The Drive, accessed April 15, 2021, https://www.thedrive.com/the-war-zone/26629/iran-claims-it-tested-a-submarine-launched-anti-ship-missile-capable-of-standoff-strikes.

187 H. I. Sutton, "Mystery Submarine May Reveal A Major New Capability For Iran," Forbes, accessed April 15, 2021, https://www.forbes.com/sites/hisutton/2020/05/29/mystery-submarine-may-reveal-a-major-new-capability-for-iran/; "Did Iranian Navy Just Receive an Underwater Drone?," accessed April 15, 2021, https://www.defenseworld.net/news/27098/Did_Iranian_Navy_Just_Receive_an_Underwater_Drone_#.YHg1YegzaUk.

188 In the near future, the Vulcano gun could have an extended range up to 100km. "Leonardo Confirms Selection of Its 127mm Naval Gun for Spain's F-110 Bonifaz-Class Frigates - Naval News," accessed August 11, 2021, https://www.navalnews.com/naval-news/2020/05/leonardo-confirms-selection-of-its-127mm-naval-gun-for-spains-f-110-bonifaz-class-frigates/.

189 Ministerie van Defensie, "Luchtverdedigings- en commandofregat (LCF) - Materieel - Defensie.nl," onderwerp (Ministerie van Defensie, September 20, 2016), https://www.defensie.nl/onderwerpen/materieel/schepen/luchtverdedigings--en-commandofregatten-lcf.

190 "Walrus Class," Weaponsystems.net, accessed January 6, 2021, https://weaponsystems.net/system/509-Walrus+class.

191 Cordesman, "The Gulf and Iran's Capability for Asymmetric Warfare."

While firing suppressing artillery rockets on the base, the group attacks the patrol by all kind of UASs and mortar fire. The group films the attack on the patrol to be used later in propaganda

engineers, artillery, air defence and other miscellaneous units. Looking to undermine the government and raise the costs for the foreign forces, the non-state actor *Jama'a Nusrat ul-Islam wa al-Muslimin* conducts simultaneous attacks on a company size patrol and on the main Dutch military base, which also hosts other states participating in the EU military mission. While firing suppressing artillery rockets on the base, the group attacks the patrol by all kind of UASs and mortar fire. The group films the attack on the patrol to be used later in propaganda.

The attack would be at the tactical level. However, while the lethal fight is at the tactical level, the information fight has a greater purpose: persuade the Dutch government to withdraw Dutch troops from Mali. The defender would defend against attacks on land, however, both sides would use aerial weapons too. The non-state actor would use small commercial UAVs, modified to be used as a platform for intelligence, surveillance and reconnaissance (ISR) and as a carrier of small explosives. The group is sponsored by a Gulf State which supplies low tech medium UAVs. The group could then overrun Malian army bases acquiring mortars and BM-21 rocket artillery systems.[192] The non-state actor is not expected to be able to effectively use cyber arms to interfere with the command and control systems of the Dutch forces. The risk of further escalation is almost fully absent.[193]

192 5th of March 2017: JNIM attacked a Boulikessi military base in central Mali, close to the Burkina Faso border. JNIM militants killed 11 Malian soldiers, burned vehicles, and stole arms. "Mali : l'attaque contre la base militaire de Boulikessi revendiquée par l'organisation jihadiste d'Iyad Ag Ghali – Jeune Afrique," *JeuneAfrique.com* (blog), March 10, 2017, https://www.jeuneafrique.com/411287/politique/mali-lattaque-contre-base-militaire-de-boulikessi-revendiquee-lorganisation-jihadiste-diyad-ag-ghali/. In April 2000, the Liberation Tigers of Tamil Eelam (LTTE) overran the Elephant Pass, which links the Jaffna Peninsular to the rest of the island. In so doing, a significant amount of military materiel, including long-range artillery, was captured, which the LTTE continues to use and maintain to effect. "Weapon Transfers to Non-State Armed Groups," 48, accessed April 28, 2021, https://www.peacepalacelibrary.nl/ebooks/files/UNIDIR_pdf-art2711.pdf.

193 A capable non-state-actor might use Radiological dispersal weapons, meaning explosives mixed with nuclear material. These weapons serve political or psychological purposes instead of military ones. Anthony H Cordesman, "Radiological Weapons as Means of Attack," accessed April 28, 2021, https://www.csis.org/analysis/radiological-weapons-means-attack.

Vignette 2: Gaza Strip and Southern Israel, May 10th to 21st 2021

All too familiar violence in Eastern Jerusalem escalated further when Hamas issued an ultimatum to Israel to remove its troops and police from the Sheikh Jarrah neighbourhood and the Haram al Sharif Mosque at 6PM of the 10th of May or face the consequences. When this ultimatum passed without an Israeli answer, Hamas attacked minutes after its expiration. An initial massive salvo of 150 rockets was launched at various targets. According to Israeli sources, seven of them were aimed at Jerusalem, crossing a new threshold in the Israeli-Hamas conflict. Israel activated its missile defences and retaliated with air and artillery strikes on Palestinian targets. After the first round, both sides entered a gruesomely familiar pattern of attrition warfare.

'Hamas' strong point was the vast quantity of cheap rockets it could fire. To complicate the picture for the defenders, Hamas further added small amounts of primitive drones, although their relatively limited capabilities restricted their utility – for now. Tactically, this use of mass gave Hamas a shot at overwhelming the advanced Israeli defences with sheer numbers. A good example is their retaliatory attack on Tel Aviv with 137 missiles fired in five minutes in response to the destruction of the Hanadi Tower by Israeli aircraft.[194] If enough interceptions were forced on the Iron Dome system (seen in action in Figure 5), its launchers could run out of rockets and the following weapons would get through. Strategically, the goal was to deplete Israel's limited stock of *Tamir* missiles. If a point could be reached where not enough interceptor missiles were available, the damage Hamas's rockets could inflict and the political clout this would give them would grow exponentially. This would also illustrate to Israel the enormous cost that a conflict with Hamas could cause.

Figure 5. Iron Dome missile defense in action, 2021

194 Al Jazeera, *Rockets fired towards Tel Aviv after Gaza tower block destroyed,* May 11 2021 https://www.aljazeera.com/news/2021/5/11/israel-strikes-down-tower-in-gaza-prompting-hamas-response

Israel had the advantage of overwhelming military superiority and was fully prepared to wage this battle. The Iron Dome systems were ready and ample missile stocks were available. Passive air defence measures were taken in the threatened zones (which became quite large with the extending range of Hamas's rockets). Constant monitoring of the Gaza strip with drone and ground mounted sensors provided Israel with intelligence, surveillance and reconnaissance (ISR). Preventive and reactive air and artillery strikes were aimed at Palestinian infrastructure and rocket teams – with fixed wing aircraft also joining the fight to intercept drones.

The fighting ended rather inconclusively with a familiar cease-fire. Both sides had made their point. Hamas and Palestinian Jihad had fired 4,360 rockets and mortar shells at Israel. The Iron Dome system used 1,428 missiles to intercept rockets threatening inhabited areas and destroyed 95% of these – only 60 to 70 rockets came through. These few rockets were enough to kill 13 Israelis and wound another 117. Israeli strikes on Gaza killed in their turn at least 128 civilians and an unknown number of Palestinian militants and wounded many more.

Tactical Drivers

***Qassam* rocket**: It is hard to imagine a less sophisticated weapon than the *Qassam* rocket. Nothing more than a simple steel tube filled with a propellant based on sugar and fertiliser and a warhead made of smuggled or scavenged TNT, fertiliser and ball bearings or iron scrap with no guidance or even stabilisation to speak off. With a range of up to 16 kilometres and no precision to speak of, a *Qassam* rocket's military effectiveness is nihil. But they can be produced in vast numbers in the Gaza strip for no more than $500 to $800 per rocket and have sufficient range and precision to be used on civilian area targets close to the Gaza strip. Hamas had created enormous stocks of these rockets and had managed to add limited numbers of more advanced longer ranged weapons. Altogether, this formed a fearsome arsenal with which it could hold at ransom an ever-growing part of Israel.[195]

The fighting ended rather inconclusively with a familiar cease-fire

Iron Dome: Specifically designed to counter the Palestinian rocket threat, the Iron Dome system is an advanced integrated air and missile defence system. It consists in its most basic form of a radar system to detect and track the targets, a control centre and several missile launchers with the *Tamir* interceptor missiles. Intercepting a rocket is in essence the equivalent feat of hitting a bullet with a bullet. This is a great technical challenge and demands a very sophisticated and therefore expensive interceptor missile. These unavoidable costs of complexity are further compounded by the fact that to achieve a high percentage chance of interception two missiles must be fired at each target. Luckily for Israel, the missile expenditure can be partially mitigated by determining the probable impact area of the target and only attacking rockets that threaten inhabited areas. But all together the estimated cost of an Iron Dome interception is about $100,000 to $150,000.

Salient Facts

This small conflict is a case study of attrition warfare in a limited asymmetric conflict. Hamas needed to fire massive amounts of primitive rockets to get even a few of them through. To counter this, Israel needed to launch very sizeable numbers of advanced interceptors to destroy those rockets that were threatening inhabited areas. Additionally, Israel conducted intensive but careful strikes on targets in the Gaza strip – although the casualty rate remains lopsided, Israel is very much aware of the political implications of civilian casualties and does it best to avoid them

195 Isabel Debre, *How Hamas amassed thousands of rockets to strike at Israel*, Los Angeles Times May 20 2021 https://www.latimes.com/world-nation/story/2021-05-20/hamas-amass-arsenal-rockets-strike-israel

– but while these undoubtedly had their impact on the fighting power of Hamas these could not stop the rocket campaign. Even with the impressive situational awareness offered by Israel's ISR capability and the awesome firepower of its air force and army, the small and mobile rocket teams operating in the complex build-up environment offered only fleeting targets. These were impossible to take out in sufficient numbers to change the dynamic of the battle. This meant that the brunt of the responsibility of defending Israel rested squarely on the Air Defences.

In the future we can expect to see a definite increase of Hamas's capabilities. Their *Qassam* rocket arsenal will be reinforced by more advanced missiles with a far greater precision, range and possibly enough manoeuvrability and countermeasures to challenge the effectiveness of the Iron Dome system. These will be combined to use mass to overwhelm Israeli defences, probably in conjunction with drones once these become available in sufficient numbers. A combined salvo of rockets followed by more precise missiles will be far harder to defend against.

To counter this, Israel will also need numbers. The increasing range of Hamas's rockets and missiles places an ever-increasing part of Israel in the danger zone and although the 150 square kilometre footprint of an Iron Dome battery sounds impressive, many batteries are needed to cover every twelve-kilometre by twelve-kilometre block of vulnerable territory. Israel will also need vast missile stocks to keep up such a battle. The rate at which air defence systems can expend ammunition is profligate and, considering the cost of missiles, potentially unsustainable. Taking the offense won't solve this problem either. The potential of air attacks on small mobile targets in a build-up environment is limited and will likely remain so. Ground troops would offer a more realistic way of supressing missile attacks but the political, economic and military cost of invading the Gaza strip would create bigger problems than it would solve. A possible solution to the interceptor missile attrition might be the introduction of directed energy systems – lasers. Although these futuristic weapons are still in their infancy and are expensive to deploy, they have the inherent advantage that their ammunition cost is negligible – you just need enough electricity. This cheap and endless "deep ammo" capability might give them a crucial edge in attrition warfare.[196]

Hamas needed to fire massive amounts of primitive rockets to get even a few of them through. To counter this, Israel needed to launch very sizeable numbers of advanced interceptors to destroy those rockets that were threatening inhabited areas

196 Henry Trey Obering, *Directed Energy Weapons Are Real...And Disruptive, https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Obering_36-46.pdf*

5. Shifts in the Offense-Defence Balance at the Strategic, Theatre, and Tactical Levels

The various air and missile systems discussed in chapter 3 and in the scenarios in chapter 4 pose an assortment of threats to targets at the strategic, the theatre and the tactical level. Depending on the characteristics of these systems, as well as the configuration in which they are used, defenders can develop counterstrategies and concomitant capabilities. Such counterstrategies encompass active air defence, passive air defence and various forms of prevention, which will be discussed in the next chapter.

If the balance favours the attacker –the offense - the argument goes, the greater the likelihood that states will launch an attack and the higher the chances of armed conflict between states

5.1 The offense-defence balance

The offense-defence balance (ODB) in the broadest sense can be defined as the costs (operationalised in various ways) for the attacker, relative to the defender, for the attack to succeed. The ODB, a concept from the international relations and security studies literature, has been used to account for variation in peace and war through its effect on the cost calculus of attackers and defenders. If the balance favours the attacker –the offense - the argument goes, the greater the likelihood that states will launch an attack and the higher the chances of armed conflict between states. In the basic form of the ODB, it is technological developments that ensure the ODB is not static but changes over time.[197] Yet definitions of the ODB vary in focus and scope. The ODB has been defined strictly as the ease of taking territory based on the nature of military technology and geography.[198] It has also been defined as the relative costs for the attacker and the defender[199] and as the investment ratio in between attackers and defenders for the attacker to win.[200] A better understanding of the impact of air and missile threats on the ODB clarifies the return on investment of defensive measures.

197 Charles L. Glaser and Chairn Kaufmann, "What Is the Offense-Defense Balance and How Can We Measure It?," *International Security* 22, no. 4 (1998): 44–82; Stephen Van Evera, *Causes of War: Power and the Roots of Conflict* (Cornell University Press, 1999), 191-245 https://www.jstor.org/stable/10.7591/j.ctt24hg70.

198 Robert Jervis, "Cooperation under the Security Dilemma," *World Politics: A Quarterly Journal of International Relations*, 1978, 167–214.

199 Glaser and Kaufmann, "What Is the Offense-Defense Balance and How Can We Measure It?," 46.

200 Sean M. Lynn-Jones, "Offense-Defense Theory and Its Critics," *Security Studies* 4, no. 4 (1995): 660–691.

As a concept, the ODB is not uncontroversial. The ODB risks being technologically determinative, whereas it is concepts and doctrine that shape whether and how technologies are developed and employed.[201] Another criticism of the concept concerns whether states can successfully distinguish between offensive and defensive technologies and thus in fact signal offensive or defensive intentions. Moreover, organisational biases within the armed forces can drive preferences for the offense.[202] At the same time, the real-world costs of wrongly assessing the relative ease of offense or defence are costly.[203] Therefore, as Glaser and Kaufmann note, the difficulty of distinguishability should not be conflated with the actual offense-defence balance.[204]

Despite these criticisms of the ODB as a concept and its utility in explaining variation in peace and war, we seize upon the concept here because it offers a valuable analytical prism to gauge the impact of air and missile threats and consider defensive measures. Three broad ways of measuring the ODB exist: (1) the resources invested by the attacker relative to the defender needed to gain victory; (2) as the capabilities invested; and (3) the utility lost through investments into the conflict.[205] An inherent problem of these existing approaches to the ODB is that it is assumed that the ODB ratio remains constant regardless of the level of investment of the attackers and defenders, as Ben Garfinkel and Allan Dafoe note. In other words, if the ODB is 3:1, then it is assumed that that ratio holds at both 1bn$ and 100bn$ investments.[206] Yet the ODB scales, meaning that it changes as investment levels grow. For example, tactical breakthroughs with ground forces – measured as Armoured Division Equivalents (ADEs) - become more difficult as the defender increases its spending. In turn, Garfinkel and Dafoe argue that there is a general pattern where growth in investments will favour offense when investment levels are sufficiently low and favour defence when investment levels are sufficiently high.[207] Their argument harks back to earlier understandings of the cost-exchange ratio in missile defence, namely the ratio of the incremental cost to the aggressor of getting an additional warhead through the active defensive measures, divided by the incremental cost to the defender of defending against that additional missile. In the 1960s the costs of the defender were estimated to be anywhere from 3:1 to 10:1 in favour of the attacker; in the 1980s, this ratio had further shifted in a favourable direction for the attacker.[208] The arms race in missiles had outpaced investments in defences.

201 For a critique on the technological determinism, see Biddle, *Military Power: Explaining Defeat and Victory in Modern Battle*, 15–17.Of the major states on the eve of WWII, only Germany successfully adopted a suitable doctrine for armour, air support, and communications. Britain and France failed to do so, while having access to the same or qualitatively better versions of these technologies. Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*, 1st ed. (Cornell University Press, 1984), https://www.jstor.org/stable/10.7591/j.ctt1287fp3; The ease of territorial conquest is ill-fitted for other key domains of military competition. For example, at sea offense and defense centre around the relative ability to destroy the enemies capabilities rather than seizing territory. Jonathan D. Caverley and Peter Dombrowski, "Cruising for a Bruising: Maritime Competition in an Anti-Access Age," *Security Studies* 29, no. 4 (2020): 671–700. Within the cyber domain the notion centres around access and destruction as well.

202 Caverley and Dombrowski, "Cruising for a Bruising," 680.

203 In the first half of the twentieth century, most of the major states got it wrong twice: before WWI when they believed offensive was dominant, then before WWII when they failed to see the new offensive possibilities of combined arms. Posen, *The Sources of Military Doctrine*.

204 Glaser and Kaufmann, "What Is the Offense-Defense Balance and How Can We Measure It?," 79–80.

205 Ben Garfinkel and Allan Dafoe, "How Does the Offense-Defense Balance Scale?," *Journal of Strategic Studies* 42, no. 6 (2019): 740.

206 Garfinkel and Dafoe, 741.

207 Garfinkel and Dafoe, "How Does the Offense-Defense Balance Scale?"

208 Alexander Flax, "Ballistic Missile Defense: Concepts and History," *Daedalus*, 1985, 40.

The ODB should be understood as the relative efficacy of the two actors' investments on a dynamic shifting scale.[209] Initial investments increase the attacker's ability to exploit points on an attack surface where the defender has relatively less coverage (*gap exploitation*); beyond a certain level, the defender can saturate the attack surface, reducing the opportunities the attacker derives from differences in the two rivals' patterns of coverage (*defensive saturation*). Defining the problem as the exploitation of the attack surface, opens a more comprehensive understanding of where gains may or may not be realised – or realised at differential rates.

The opportunities for the attacker and defender are not the same when it comes to the various air and missile threats

The implication for the ODB vary per weapon system. The opportunities for the attacker and defender are not the same when it comes to the various air and missile threats: ballistic missiles; hypersonic cruise missiles; manned aircraft; unmanned aircraft and loitering munitions; and guided rockets and artillery. Each has different possibilities for gap exploitation and defensive saturation in favour of respectively the attacker and the defender. Garfinkel and Dafoe find evidence that scaling up investments first benefits the attacker and then benefits the defender, when it comes to land operations, cyber operations, as well as unmanned aerial systems (UAS) operations. However, they believe defence saturation – meaning covering the entire attack surface with intercepts against incoming missiles – is not possible for missile defence.[210] The ODB is not a universal feature within the international system as a whole. It cannot be divorced from the geographic and strategic context in which a particular competition between two or a limited number of actors is taking place.[211] That being said, what are the implications at the three different levels – strategic, theatre, and tactical – regarding the weapon systems most relevant to those levels?

5.2 The offense-defence balance across the three levels

5.2.1 Strategic level

Defence against strategic threats from ballistic missiles and hypersonic weapons with nonconventional warheads will remain incredible difficult, if not impossible, due to their extreme speeds and ranges. Interception in the boost phase of the ballistic missile may be indistinguishable from offensive action against the attacker's home territory, or more dangerously, a first strike. Midcourse interception is difficult because the attacker can throw the defender off through decoys, chaff and other means. Terminal phase interception for both ballistic missiles and hypersonic glide vehicles must take place at such excessive speeds that there is little to no room for error.[212] Moreover, current and next generation Multiple Independent Re-entry Vehicles (MIRV) can carry over a dozen warheads which can easily overwhelm defences because the warheads themselves can follow their own, independent trajectories following the initial boost phase; not to mention Manoeuvrable Re-entry Vehicles (MARV) that allow for in-flight course corrections. According to Garfinkel and Dafoe, missile

209 Their argument draws upon the concept of a contest success function which refers to relate the expected outcome of an attack to investment made by the attacker and defender.

210 Garfinkel and Dafoe, "How Does the Offense-Defense Balance Scale?," 742.

211 David Blagden, "When Does Competition Become Conflict? Technology, Geography, and the Offense-Defense Balance," *Journal of Global Security Studies*, 2021.

212 George N. Lewis, "Ballistic Missile Defense Effectiveness," in *AIP Conference Proceedings*, vol. 1898 (AIP Publishing LLC, 2017), 030007; Dean A. Wilkening, "The National Research Council Study:" Making Sense of Ballistic Missile Defense"," in *AIP Conference Proceedings*, vol. 1596 (American Institute of Physics, 2014), 123–134.

defence is arguably a domain where the defender cannot invest sufficiently to gain an advantage over the attacker. Unlike defensive lines in surface warfare, it is not plausible to achieve defensive saturation with interceptors against the attacker's missiles. Even ignoring the highly unfavourable, if not prohibitively expensive, cost-exchange ratio of missile defence, an essentially unlimited supply of interceptors would be hampered by the need to avoid blue-on-blue fratricide between interceptors.[213] Nevertheless, certain targets may be too valuable to accept their vulnerability – a higher likelihood of effective defence is its own kind of deterrent against aggression. Overall, however, the return on investment for the defender is lower than for the attacker and this has consequences for strategy.

Hypersonic missiles add to the defender's misery, but arguably only in degrees

Defences against non-conventional warheads with weapons of mass destruction (WMD) payloads are unlike what would be considered successful defences against conventional surface attacks. A failure to intercept 100% of the missile attack might as well be functionally equivalent to an interception rate of 0%. Moreover, the very attempt to defend against ballistic missile (or hypersonic missile) attacks might be uniquely destabilising itself, as it suggests a willingness to engage in the retaliation-free first use of nuclear weapons.[214] Hypersonic missiles add to the defender's misery, but arguably only in degrees. Bluntly put, if it was difficult - if not impossible - to successfully defend civilian targets against a nuclear attack with ballistic missiles, the addition of hypersonic weapons changes little within that overall calculus. Little in the overall ODB is likely to shift here, when we assume the balance applies to states and alliances each armed with similar strategic weapons. Strategic bombers remain a threat as a platform to deliver strategic weapons, yet stealth remains difficult to achieve, especially as sensors become more sophisticated individually, and as a system.

5.2.2 **Theatre level**

The extreme speeds and ranges of ballistic missiles (and hypersonic missiles) armed with conventional warheads are also a near-impossible problem for any defence of military targets from conventional attacks at the theatre level. However, the same logic does not entirely apply for the defender when the targets are military. First, losses are more acceptable, and lower success rates of interception become more manageable from a crisis escalation standpoint (provided the launch platforms allow for discrimination). Second, military infrastructure is easier to protect through active and passive measures than so-called soft civilian targets.

From the attacker's point of view, the risk of escalation is also more manageable, but the possible gains are large. Damaging or destroying military infrastructure, command and control centres, airfields, ports and so on, through air and missile systems could enable the success of larger-scale theatre-wide deterrence, defence and offense. An attack with conventionally armed ballistic missiles on major military targets is likely to be particularly effective when simultaneously combined with cruise missiles and UAVs. The latter can be used in both an offensive form – such as loitering munitions – with which it can disable key systems of the defender, such as command and control centres or communication networks essential to air and missile defence – and as a remote sensor that can relay information back to the attacker and improve the accuracy and efficiency of other weapons. The relatively lower per unit costs of those systems – along with their increasingly widespread prevalence due to proliferation and dual-use technology, their ability to be moved undetected, and to be used in an integrated way – makes them a more dangerous threat for the offensive than simply the sum of the parts.

213 Garfinkel and Dafoe, "How Does the Offense-Defense Balance Scale?," 756–57.

214 Jeffrey Lewis, "The Nuclear Option," February 22, 2021, https://www.foreignaffairs.com/articles/china/2021-02-22/nuclear-option.

Such salvo attacks are likely to be difficult to stop and provide real advantages to an attacker who relies on numbers. Without sufficient investments in defences, the attacker may exploit this offensive advantage.

Aircraft remain a threat at the theatre level as well. For an extended period since the late 1980s, since the introduction of stealth technology and electronic warfare, next-generation aircraft had an offensive advantage over air defence systems.[215] However, the battle between hiders and seekers is constantly moving away from the hiders. While multiple states are developing stealth capabilities, the successful implementation is difficult. In contrast, advances with remote sensing capabilities and with ground-based radars switching between multiple frequencies, the chances of detection and interception increase.[216]

However, while such developments also apply to cruise missiles and unmanned aerial vehicles (UAVs), their costs per unit are much lower, they rely on a much smaller logistical tail, and, without onboard humans piloting them, they are expendable. UAVs are hardly invincible but they do require adaptations of active air defence networks that have been designed for larger, faster moving and more advanced systems. Their key advantage lies in their lower costs per unit. Most kinetic interceptors are highly cost-ineffective against UAVs. Directed energy weapons, electronic warfare and other weapons are likelier to be effective.

If local air superiority is not assured through the exploitation of combined air and missile threats, ground attacks are extremely costly to the attacker

5.2.3 Tactical level

The possibilities of cost-effectively exploiting UAVs at both the tactical and at the theatre level is great, specifically in combination with guided rockets, artillery and mortars (G-RAM). Their cheaper intelligence, surveillance and reconnaissance (ISR) capabilities, combined with near-instantaneous communications, ensure a transparent and lethal battleground with small windows of decision-making – particularly because UAVs can disable complex defensive systems, swinging air superiority in the favour of the attacker. In turn, they can increase the effectiveness of air-to-ground attacks, provided the attacker has first disabled core defensive systems. UAVs are therefore conceivably a game changing weapon because of quality as a force multiplier for more destructive, but also more exquisite, other weapon systems such as ballistic missiles or cruise missiles, or manned aircraft, and for readily available G-RAM. Their successful exploitation through proper doctrine and employment can swing the advantage to the attacker at both levels of conventional conflict. Though UAVs suggest the tactical possibility of using large swarms of expendable drones to overwhelm the defences, defenders can feasibly saturate the airspace around a target with defensive drones.[217]

The crux is the following: if local air superiority is not assured through the exploitation of combined air and missile threats, ground attacks are extremely costly to the attacker. Innovations in remote sensing and the integration of networks of weapon systems has created and will increasingly create an essentially transparent battlefield without any cover for advancing or defending forces.

215 Meilinger, *The Paths Of Heaven*, 24–25.

216 Mike Pietrucha, "Stuck on Denial Part I: The U.S. Air Force and Stealth," *War on the Rocks*, March 24, 2016, https://warontherocks.com/2016/03/stuck-on-denial-part-i-the-u-s-airforce-and-stealth/.

217 Garfinkel and Dafoe, "How Does the Offense-Defense Balance Scale?," 757–58.

5.3 **Summary:** Weapon systems and shifts in the offense-defence balance

The core message of the chapter's analysis is that current trends in technological innovation and in innovation of concepts and doctrine as well as supplies of weapons offer significant advantages to attackers. As noted in chapters 2 and 4, various potential adversaries have invested in air and missile capabilities in all three dimensions of technology, concepts and doctrine, and numbers to overwhelm defences. Moreover, the investment in defensive measures against air and missile threats varies in success across the strategic, theatre and tactical levels when attackers and defenders invest equivalent amounts in respectively offense and defence. While defences against cruise missiles, manned and unmanned aircraft, and rockets and artillery can be successful given sufficient investments, defences against ballistic missiles and hypersonic weapons armed is unlikely to be sufficient to protect vital targets. At the theatre and tactical levels, however, the advantages that aggressors arguably currently enjoy can be rebalanced towards defenders with an appropriate investment in technology, conceptual and doctrinal innovation, and numbers of defensive systems. The inability to sufficiently protect key civilian and military infrastructure, or to ensure the access of military units to and within the theatre, would undermine European deterrence.

Vignette 3: Nagorno-Karabakh, September 27th to November 10th 2020

In the morning of the 27th of September, fighting along the border between Nagorno-Karabakh and Azerbaijan started with both sides unleashing heavy artillery fire on each other's positions. Tensions had been running high during the last weeks and each side blamed the other for opening fire first. The first days of the conflict saw relatively limited ground movement as both sides were mobilising their troops and developing their situational awareness. Azeri troops launched limited attacks on the Armenian positions but did not make noticeable gains. Most of the fighting was done with artillery and the occasional ballistic missiles strike. But during this time Azerbaijan conducted a classic counter-air defence campaign by first focusing the attention of its unmanned aerial vehicles (UAVs) on the Armenian Air Defences using both direct attacks by armed drones and its artillery. This allowed Azeri UAVs in their turn to build up a telling intelligence, surveillance and reconnaissance (ISR) advantage over the Armenian forces which could in its turn be converted in a decisive firepower advantage.

The decisive superiority in firepower granted by superior battle-field intelligence allowed the Azeri ground forces to slowly but certainly advance in the south where the terrain was slightly better than in the north. In a series of local battles, the Azeri troops ground their way forward, all the time ably supported by artillery fire that not only supported their tactical advances but was also deliberately used to create an operational advantage by attacking crucial Armenian targets in the rear. This remorse-less pressure started to cave in the Armenian lines and threaten the vital communications along the Lachin corridor between Artsakh and Armenia proper. While this fighting was taking place, further missile and artillery fire exchanges kept taking place all over the front and deep beyond with both sides juggling with the questions of how to use their limited stocks of ballistic missiles to their maximum advantage while keeping the potential impact on (international) public opinion to a minimum.[218]

Figure 6. Azeri UAV targeting Armenian tank

218 Shaan Shaikh and Wes Rumbaugh, *The Air and Missile War in Nagorno Karabakh: Lessons for the Future of Strike and Defense*, Center for Strategic & International Studies December 8 2020 https://www.csis.org/analysis/airand-missile-war-nagorno-karabakh-lessons-future-strike-and-defense

In the end, the relentless Azeri advance in the south resulted in the conclusive attack on the strategic mountain town of Shusha. This natural fortress controlled the communications between Nagorno-Karabakh and Armenia. The battle for its control started at the end of October and raged on until its capture by the Azeri army on the 8th of November, sealing the Armenian defeat. At that point both sides were willing to agree with Russian mediation. On the 10th of November the Second Nagorno-Karabakh ended with a resounding victory for Azerbaijan.

Tactical Drivers

Unmanned Aircraft: Unmanned Aircraft are ideal "eyes in the sky" and a crucial part of the ISR operations of any modern army. Azerbaijan further augmented this classic function by deploying armed UAVs. Figure 6 shows an Azeri UAV targeting an Armenian tank. The Turkish made *Bayraktar TB2* can be armed with light precision weapons like infrared guided anti-tank missiles or small guided glide bombs. This gives them the ability to attack small targets like air defence systems, artillery and even armoured vehicles. The Israeli made *Sky-Striker* follows a different concept and is an autonomous loitering munition which can independently attack targets deep in the enemy hinterland. As important as the capabilities of the armed and unarmed UAV is how these capabilities are used and the Azeri showed great skill in these. The focus of their armed UAV was the Armenian Air Defence, even knocking out advanced *S-300* missile systems.

However, these spectacular successes should not make us overlook that the main success of the Azeri "eyes in the sky" were the impressive results gained by the domination of the information battle. Especially once this was leveraged by conventional military operations.

Indirect Fire: In any high-intensity war between peer opponents indirect fire by artillery is the main killer, far surpassing the damage done by aircraft, armour or infantry weapons. Modern artillery systems are either tubed (guns and mortars) or use rockets and missiles. A good example of the latter is the *BM-30 Smerch* 300 mm rocket launcher which was in use with both the Armenian and Azeri armed forces. Developed by the USSR at the end of the Cold War, each launch vehicle carries twelve rocket tubes that can fire their projectiles up to 90 kilometres away where they rain down high explosives or cluster munitions on their target. Operated in batteries of multiple launchers the amount of firepower such weapons can deliver in a short terrible burst is devastating.[219]

But what makes indirect fire truly destructive is the speed which with it can be delivered on an identified target. What is needed is a spotter that timely passes reliable targeting information to the artillery far in the rear. If this process goes fast enough, fire can be brought to bear before a foe moves. If the process is too slow or your target moves swiftly, you will only churn up dust – and might catch a few unlucky civilians in the ensuing storm of destruction. The Azeri army was fast. Its UAV provided it with great battlefield transparency but the crux was that their command, control and communications and artillery were swift enough on the uptake to follow up on that battlefield intelligence with overwhelming firepower.

219 Amos Chapple, *The Smerch Rocket: A Fearsome Symbol of the Nagorno-Karabakh War,* Radio Free Europe November 9 2020 https://www.rferl.org/a/smerch-rockets-fearsome-symbol-of-nagorno-karabakh-war/30937010.html

Salient Facts

First and foremost, this was a well-fought war by Azerbaijan. The Azeri forces showed professionalism and slowly but steadily managed to conquer enough strategic terrain to force the Armenians to admit their defeat. It illustrates the impressive level of competence that can be achieved by even the armed forces of a small and relatively underdeveloped country, although ably supported by a regional power. This is a clear warning: not all countries in the developing world will be so militarily inept as Iraq.

Particularly impressive was the Azeri use of UAVs. The novel use of armed drones has been quite understandably given much attention, but the ISR missions were even more decisive. The superior and timely battlefield intelligence provided by their UAVs allowed the Azeri armed forces to create a transparent battlefield which they could then exploit with firepower and manoeuvre. The skill with which the Azeri forces have been used becomes even more spectacular if one considers the terrain in which this war was fought. According to conventional wisdom, the mountains of the Caucasus should have provided the defending Armenians with a decisive advantage.[220] But while the Armenian forces were reasonably well provided with classic air defence systems, they lacked the capacity to deal efficiently with the drone threat. This doomed them in the end to defeat and severe losses due to artillery fire. Like the First Nagorno-Karabakh War, this was not a clean fight and the extensive use of indirect firepower resulted in widespread devastation and serious non-combatant casualties. In this context the limited role played by the ballistic missiles from both sides must be noted. Both sides refrained from large scale attacks and seem to have hoarded their finite stocks which neither side could independently replenish.

The Second Nagorno-Karabakh War illustrates the importance of battlefield transparency and preventing the other side from achieving the same. However, battlefield transparency is useless without good command, control and communications and the classic firepower and manoeuvre forces, without which you cannot exploit this enormous advantage. In the end, this war was won by hard and skilful fighting.

What makes indirect fire truly destructive is the speed which with it can be delivered on an identified target. What is needed is a spotter that timely passes reliable targeting information to the artillery far in the rear

220 Steven Aftergood, *The Tactical Challenges of Mountain Warfare,* Federation of American Scientists April 4 2011 https://fas.org/blogs/secrecy/2011/04/mountain_warfare/

6. Solution Set: Prevention, Passive Defence and Active Defence

The different impacts of air and missile weapon systems on the offense-defence balance (ODB) inform different sets of counterstrategies. Simply put, if higher levels of investment lead to a shift in favour of the defence, it seems sensible to invest in various forms of defensive capabilities. If higher levels of investment tilt the ODB towards the offensive, then from an integrated air and missile defence (IAMD) perspective, pursuing other counterstrategies may be more advisable.

This chapter discusses three categories of countermeasures with which defenders can protect themselves against air and missile threats: (1) prevention; (2) passive defence; and (3) active defence. Preventive measures range from bilateral, minilateral or multilateral arms control and non-proliferation agreements, including those with commercial producers; deterrence by denial through conventional means; deterrence by punishment through non-conventional means; or pre-emptive offensive action against the source of the threat. Passive defence includes measures that focus on avoiding or blunting the attacker such as hardening, concealments, mobility and dispersion. Active defence protects targets by intercepting the threat and is particularly relevant to those targets for which passive measures are insufficient, unfeasible or cost inefficient.

6.1 **Do not start:** Prevention

The interception of ballistic missiles and hypersonic weapons (as soon as these are fully operational) is likely to remain only intermittently successful (see 3.2.1. and 3.2.3), though the European Phased Adaptive Approach (EPAA) have made advances towards increasing the likelihood of interception. At best, only a handful of carefully selected targets stand a chance at effective protection. Given the difficulty of sufficient successful interception of more than a handful of ballistic missiles and hypersonic weapons, should these be armed with nuclear or other non-conventional warheads, active defence is not a suitable measure to protect "soft" targets such as cities or civilian infrastructure. In the case of missiles armed with weapons of mass destruction (WMDs), anything less than a perfect success rate of interception would for all intents and purposes be indistinguishable from total failure. Nor are passive defence measures such as concealment, hardening, mobility, and dispersion conceivable for civilian targets. They are likely to have only limited benefits for populations given the precision and destructive capacity of current-day weapons.[221] Active and passive measures might only be feasible for specific infrastructural targets, such as port facilities or energy storage. As a result, for defence against the possibility of attacks with large numbers of ballistic missiles, both at the strategic and theatre level, and hypersonic weapons, preventive measures provide an essential component of air and missile defence in the true sense of the word.

Arms control measures and agreements are likely to be the most effective instrument, if not in all cases to prevent the acquisition – or proliferation – of a long-range missile capability together with non-conventional warheads, then at least to manage strategic stability.

6.1.1 Arms control and non-proliferation

Arms control measures and agreements are likely to be the most effective instrument, if not in all cases to prevent the acquisition – or proliferation – of a long-range missile capability together with non-conventional warheads, then at least to manage strategic stability. Since the Intermediate-Range and Shorter-Range Missiles (INF) Treaty expired in 2019, New START, which was renewed in February 2021, is the last nuclear arms control treaty left standing between the US and Russia.[222] Informal arrangements and initiatives aimed at limiting the proliferation of missile technology persist.[223] Other agreements seek to limit the export of various weapon systems, particularly to non-state actors.[224] These arms control measures are not binding, however, and are limited in both geographical scope and implementation.[225] The erosion of arms control is underpinned by the emerging nuclear and conventional precision-strike multipolarity and the proliferation of lower-level weapon systems.[226] Specifically for dual-use technologies with commercial applications, arms control will likely prove an insufficient measure to safeguard stability at the tactical and theatre level.

6.1.2 Deterrence by denial, deterrence by punishment

When it is too difficult to prevent weapons from falling into the hands of an adversary, the next preventive measure is for the defender to raise the cost of the attacker using a weapon. The threat of retaliation with weapons with non-conventional warheads is likely to be the most effective instrument to prevent an attack at the strategic level once a potential adversary is already in possession of the weapon. Known as deterrence by punishment, this is a threat to impose costs after the aggression. Deterrence by denial strategies, in contrast, raise the costs for the attacker during the attack, to deny the objective the attacker is seeking even if an actual defence fails.[227] Deterrence by punishment is the most familiar and apparently effective measure to protect against the threat of strategic weapons. Due to their high costs,

221 Point also made in interview with Dutch defence officials, June 2021. Hardening certain civilian infrastructure, such as fuel supplies, would, however, have some benefits.

222 "Joe Biden's Arms Control Ambitions Are Welcome—but Delivering on Them Will Not Be Easy," SIPRI | Stockholm International Peace Research Institute, January 19, 2021, https://www.sipri.org/commentary/essay/2021/joe-bidens-arms-control-ambitions-are-welcome-delivering-them-will-not-be-easy.

223 These include the Missile Technology Control Regime (MTCR) and the Hague Code of Conduct Against Ballistic Missile Proliferation

224 These include the Wassenaar Arrangement, the United Nations Security Council Resolution 1540, and the Joint Declaration for the Export and Subsequent Use of Armed or Strike-Enabled UAS,

225 Peter van Ham, "The MTCR at 30: Ideas to Strengthen the Missile Technology Control Norm" (Clingendael | Netherlands Institute of International Relations, 2017), https://www.clingendael.org/sites/default/files/2017-11/PB_The_MCTR_at_30.pdf.

226 Jürgen Altmann and Frank Sauer, "Autonomous Weapon Systems and Strategic Stability," *Survival* 59, no. 5 (September 3, 2017): 117–42, https://doi.org/10.1080/00396338.2017.1375263; Todd S. Sechser, Neil Narang, and Caitlin Talmadge, "Emerging Technologies and Strategic Stability in Peacetime, Crisis, and War," *Journal of Strategic Studies* 42, no. 6 (September 19, 2019): 727–35, https://doi.org/10.1080/01402390.2019.1626725; Michael C. Horowitz, "When Speed Kills: Lethal Autonomous Weapon Systems, Deterrence and Stability," *Journal of Strategic Studies* 42, no. 6 (September 19, 2019): 764–88, https://doi.org/10.1080/01402390.2019.1621174.

227 Mazarr et al., "What Deters and Why"; Glenn Snyder, "Deterrence by Punishment and Denial," *Number Research Monograph*, no. 1 (1959).

long-range ballistic missiles, cruise missiles, and possible hypersonic missiles, are primarily the providence of major powers, such as Russia, China, India, France, the United Kingdom, and the US, with minor powers such as Pakistan, North Korea, and Iran having only minimal access to them. Major powers have a great deal to lose and little to gain by using these capabilities against each other's high-value targets. However, an increasingly multipolar world also makes calibrating such strategies more difficult and leads to greater risks associated both with inadvertent escalation and nuclear accidents. Moreover, beyond the normative question, the threat of punishment is more effective when it is proportionate to the offense. The presence of strategic weapons is therefore not an entirely fungible deterrent at lower levels of conflict, including at the theatre level.[228]

6.1.3 **Pre-emptive offensive action**

Pre-emptive solutions should be used only with the greatest caution, to avoid the risk of inadvertent escalation by striking command and control systems or launchers used for both conventional and nuclear weapons

At the strategic level, first strikes against the strategic weapons of major powers are incredibly dangerous, if not outright suicidal. As soon as nuclear-armed states perceive their deterrence as under attack, whether or not intended, they are likely to consider themselves in a use-it-or-lose-it dilemma. At the theatre level, pre-emptive solutions should be used only with the greatest caution, to avoid the risk of inadvertent escalation by striking command and control systems or launchers used for both conventional and nuclear weapons.[229] Careful target selection should take place in advance, though during the conflict phase, responses should not necessarily be considered as escalatory. Pre-emptive offensive actions are conceivable against minor states, which do not have an equivalent ability to escalate. However, at the tactical level, where guided rockets, artillery and mortars (G-RAM) capabilities such as mortars are a serious concern, offensive solutions that aim at debilitating launchers or operators are likely to be more effective and cheaper than active defence options, while avoiding the risk of escalation of the conflict to more dangerous levels. There are a whole set of left-of-launch measures that a state can take to disable the sensors, command and control, or launchers of the adversary. These range from kinetic attacks – from land, sea, or air – or non-kinetic attacks, such as cyber operations. The risk of cyber operations is that it could lead to inadvertent escalation due to the difficulty in distinguishing the purpose of the attack.

6.2 **Duck, cover, hide:** Passive defence

Passive defence measures seek to improve the survivability of assets and personnel by avoiding detection or by limiting the collateral effects of an attack that cannot be avoided.[230] The modern system of warfare that has been in use since the end of the 19th century has relied on using terrain features for protection and avoidance.[231] Attack avoidance techniques can be either concealment, whereby targeted platforms are hid either through blending, disguising, or hiding, while taking advantage of the natural terrain and surroundings;[232] or camouflage,

228 Robert J. Art, "American Foreign Policy and the Fungibility of Force," *Security Studies* 5, no. 4 (June 1996): 7–42, https://doi.org/10.1080/09636419608429287; Krepon, "The Stability-Instability Paradox, Misperception, and Escalation Control in South Asia"; Lawrence D. Freedman, *The Evolution of Nuclear Strategy: New, Updated and Completely Revised*, 4th ed. (Palgrave Macmillan, 2019), https://doi.org/10.1057/978-1-137-57350-6.2019

229 Talmadge, "Would China Go Nuclear?"; Joshua Rovner, "Two Kinds of Catastrophe: Nuclear Escalation and Protracted War in Asia," *Journal of Strategic Studies* 40, no. 5 (July 29, 2017): 696–730, https://doi.org/10.1080/01402390.2017.1293532; Barry R. Posen, *Inadvertent Escalation: Conventional War and Nuclear Risks* (Cornell University Press, 1991), https://www.jstor.org/stable/10.7591/j.ctt1xx51d.

230 "ATP 3-01 - Techniques for Combined Arms for Air Defense," 2016, 3–1.

231 Biddle, *Military Power: Explaining Defeat and Victory in Modern Battle*.

232 "ATP 3-01 - Techniques for Combined Arms for Air Defense," 3–2.

which relies on manmade elements to protect targeted platforms.[233] Damage-limiting techniques include hardening, whereby valuable assets and shelters are reinforced or moved underground to limit damage;[234] distribution whereby assets are scattered to raise the costs for an attacker;[235] redundancy, whereby principal systems – (such as command and control (C2) systems and communication networks, antennas, and fixed sites – are duplicated to preserve combat power; [236] and recovery and reconstitution, whereby a swift post-attack recovery is ensured to dissuade an enemy from lengthy attacks.[237]

Passive measures, like preventive measures, can diminish the defender's dependency on complex active defence systems

Diverse geographical conditions and technological developments influence the efficacy of passive defence. At sea, passive defence is arguably more difficult, at least on the surface given there are no terrain features on the surface to use the passive measures mentioned above.[238] The navy, with the exception of submarines, therefore generally relies less on passive defence techniques as their application is more difficult at sea, compared to the air force and particularly the army.[239] Recently, the introduction of remote-sensing devices that use multi-spectrum sensors has further undermined the efficacy of concealment and camouflage.[240] Yet technological advancements in offensive methods also increase the importance of passive defence: for one, the effectiveness of combined or salvo attacks renders active defence increasingly inefficient. Dispersing infrastructure, increasing mobility, hardening immobile targets like ports, airfields, energy storage units, or C2 -nodes has real value in this heightened threat environment. Thus, passive measures, like preventive measures, can diminish the defender's dependency on complex active defence systems that do not have a 100% success rate though they are less likely to be effective for "soft" civilian targets.

6.3 **Shooting bullets with bullets (or lasers):** Active defence

Efficient active defence relies on seeing a threat as soon as possible, tracking and acquiring, and then shooting it on its path towards the target. It requires that the capabilities involved in these tasks can seamlessly communicate with each other. In short, active defence consists of an effective combination of sensors, interceptors, and C2 centres. For each of the levels – strategic, theatre, and tactical – distinct types of active air defence systems are available, including some that cover multiple threats at multiple levels.

At the strategic level, where ballistic missiles (and potentially hypersonic glide vehicles) are the primary threat, the difficulty of sensing and interception is particularly complex. Interception in the boost-phase is difficult due to possible escalation or entangling of non-combatant, neighbouring states; in the mid-course phase because missiles have multiple

233 "ATP 3-01 - Techniques for Combined Arms for Air Defense," 3–3.

234 "Joint Publication 3-01 - Countering Air and Missile Threats," 2017, V–17.

235 Eric Heginbotham and Richard J. Samuels, "Active Denial: Redesigning Japan's Response to China's Military Challenge," *International Security* 42, no. 4 (2018): 128–69; "ATP 3-01 - Techniques for Combined Arms for Air Defense." 3-3.

236 "ATP 3-01 - Techniques for Combined Arms for Air Defense," 3–3.

237 Alan Vick et al., *Air Base Defense: Rethinking Army and Air Force Roles and Functions* (RAND Corporation, 2020), https://doi.org/10.7249/RR4368; "Joint Publication 3-01 - Countering Air and Missile Threats," V–18.

238 CAPT Wayne P. Hughes Jr, *Fleet Tactics and Naval Operations* (Naval Institute Press, 2018); Caverley and Dombrowski, "Cruising for a Bruising."

239 "Joint Publication 3-01 - Countering Air and Missile Threats."

240 Vick et al., *Air Base Defense*, 49.

means of confusing sensors; and in the terminal phase due to the extreme speeds that leave little room for error.[241] Given the variety of threats and vulnerabilities of the current network, effective defence requires a more layered and resilient sensor network, such as through introducing or adding space-, land- and air-based sensors.[242]

For interception of theatre threats, which include short-range ballistic missiles, cruise missiles, aircraft and unmanned aerial vehicles (UAVs), Europeans operate various endo-atmospheric low tier air defence systems as well as aircraft. Interception takes place close to targets due to these systems' shorter range, hence they are in proximity to potential targets – notably military infrastructure, C2 centres, airfields, ports, and so on.[243] Aircraft fulfil multiple roles here, includes adding sensors to tracking threats, possibly electronic warfare capabilities to confuse the threat, and their weapons to intercept the threat.

Defence against tactical threats such as fixed, but also rotary wing aircraft, cruise missiles, UAVs, loitering munitions, and G-RAM relies on short and very short-range air defence systems, ranging from the longer-range MIM-23 Hawk to man-portable systems (MANPADS), such as the Stinger which launches the LeFlaSys. Such systems were essential in operations in Afghanistan and Iraq. The development of counter UAV technology (C-UAS) is crucial, not so much because of the technology's lethality but because of its supporting role in crucial combat functions such as target acquisition – thereby increasing the effectiveness of other weapon systems including ballistic and cruise missiles. Countering small unmanned aerial systems (UAS) poses distinct challenges, thanks to the technology's various and wide-ranging features including reduced radar cross section, manoeuvrability, speed and altitude making them harder to detect and classify. Larger UAS present the existing challenges and well-honed solutions used for manned aircraft.[244] Rapid technological developments in this domain make it particularly hard to keep counter-technology up to date.

Active IAMD also includes (non-kinetic) directed energy weapons (DEW)[245], which can be high power lasers and high-power microwave transmitters. Given the difficulty of "shooting bullets with bullets", these technologies present a promising avenue of research. High energy lasers (HELs) are particularly effective to disrupt missiles' guidance systems by dazzling their sensors or overheating vital components of the missiles. Once the technology has matured, HELs could potentially be used for ground-based defence against UAVs, fixed-wing aircrafts, cruise and ballistic missiles and airborne defence against MANPADS.[246] High power microwave weapons (HPMs) have the ability of saturating sensitive and wear out electronic components.[247] Their beams are less tightly focused than lasers' and for this reason they have a

241 Lewis, "Ballistic Missile Defense Effectiveness"; Wilkening, "The National Research Council Study."

242 European NATO members are currently dependent on US-deployed Aegis systems, combining land- and sea-based SM-3 interceptors and a forward-based AN/TPY-2 radar, as well as recently acquired SMART-L Extended Long Range radars.

243 Ground-based systems currently deployed in Europe include the US-made Patriot PAC-3 and European-made SAMP/T, while ship-based-systems include the US-made Aegis system and European-made PAAMS.

244 Lt Col Andreas Schmidt and Lt Col Berry Pronk, "Defensive Counter-Air Operations," in *A Comprehensive Approach to Countering Unmanned Aircraft Systems* (Joint Air power Competence Centre (JAPCC)), accessed January 19, 2021, https://www.japcc.org/c-uas-defensive-counter-airoperations/.

245 DEWs are defined as "systems that produce a beam of concentrated electromagnetic energy or atomic or subatomic particles, which is used as a direct means to incapacitate, injure or kill people, or to incapacitate, degrade, damage or destroy objects," Anna de Courcy Wheeler and Maya Brehm, "Directed Energy Weapons," 2017.

246 Andrew Feickert, "U.S. Army Weapons-Related Directed Energy (DE) Programs: Background and Potential Issues for Congress," CRS Report (Congressional Research Service, February 12, 2018).

247 Dave Adamy, "Directed-Energy Weapons," 2015, 2.

shorter range.[248] HPMs are employed mainly for airborne defeat of electronic systems.[249] While still in development, DEWs may prove highly effective and cost-efficient tools in defence against the whole range of air and missile threats. [250] Finally, DEWs are not only efficient and cost-effective, but they also allow ballistic missile interception in the boost-phase, that is before eventual decoys and warheads are released.[251] Of course, deployment close to the launch of the weapons could in many circumstances be considered an offensive operation.

Active defence is not only a question of sensors and interceptors, but vitally depends on C2 systems. These provide interconnectivity between sensors, targeting systems and shooters, for instance, performing functions to "collect and communicate data from various sensors, radars, satellites, and combat systems, relaying information to commanders for decision-making and assessment."[252] While C2 allows for the intertwining of AMD networks, communication is indispensable to guarantee the effectiveness of operations. An attack on communications assets would greatly hinder the functionality of C2. Command, control, and communications (C3) are hence inseparable and fundamental to air and missile defence.[253] The developments of technologies such as tactical data links has changed the structure of C2, reducing the role of human operators by integrating machine systems. At present, tactical data links are crucial to C3 systems, in that they transmit and receive information and encrypted data almost in real-time and simultaneously across different platforms.[254] While technological progress in the C3 field is undeniable, many of these systems stay vulnerable to cyber- and electronic attacks. Resilience to these kinds of attacks should be enhanced in the future.[255] Shooting bullets with bullets (or lasers) remains inherently difficult, therefore mixing active and passive measures becomes even more important.

6.4 **Summary:** Counterstrategies against air and missile threats

The focus of the report is on active defence measures but these sit within a larger set of preventive and passive measures that should be considered for the threats at the various levels. As IAMD is particularly difficult against strategic weapons like ballistic missiles and hypersonic weapons that can threaten civilian targets with non-conventional warheads, preventive measures like arms control, but also deterrence, are arguably a more effective solution. Kinetic and non-kinetic left-of-launch actions against adversaries to pre-empt an attack are also possibility for theatre-level threats, but one that is particularly risky against nuclear-armed adversaries because C2 and launch systems are often mixed and pre-emptive

248 Feickert, "U.S. Army Weapons-Related Directed Energy (DE) Programs: Background and Potential Issues for Congress," 25.

249 Feickert, 27.

250 Feickert, 3.

251 John Knowles, "Non-Kinetic Thinking Creates New Possibilities for Air and Missile Defense," 2016, 30.

252 "Command and Control," Missile Defense Advocacy Alliance, accessed April 6, 2021, https://missiledefenseadvocacy.org/missile-defense-systems-2/missile-defense-systems/deployed-command-and-control/.

253 Yasmin Afina, Calum Inverarity, and Beyza Unal, "Ensuring Cyber Resilience in NATO's Command, Control and Communication Systems" (Chatham House, July 17, 2020), 7, https://www.chathamhouse.org/2020/07/ensuring-cyber-resilience-natos-command-control-and-communication-systems-0/2-command.

254 Afina, Inverarity, and Unal, 9.

255 Afina, Inverarity, and Unal, "Ensuring Cyber Resilience in NATO's Command, Control and Communication Systems."

actions could be difficult to distinguish from a first strike. At the theatre and tactical level, given the risk of combination and saturation attacks, passive measures – including dispersion, mobility, concealment, camouflage and hardening – would lighten the load for active defence systems. Figure 7 visualises the relationships between the preventive, passive, and active defence measures.

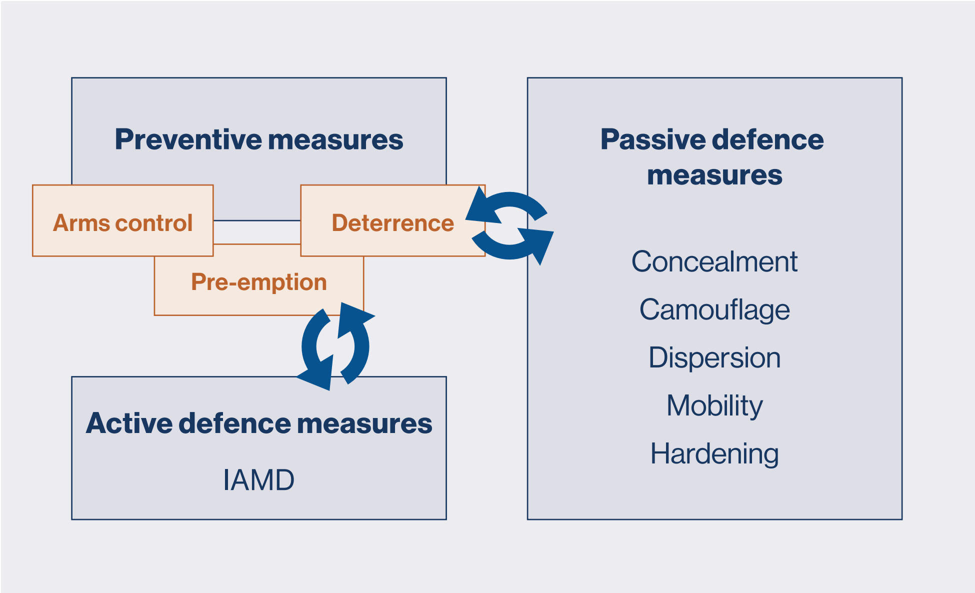


Figure 7. Relation between preventive, passive, and active defence measures

7. Active Air and Missile Defence Within Europe

7.1 Existing IAMD capabilities in Europe and shortcomings

The technological trends centre on the increasing availabilities of platforms, increased speed and manoeuvrability, growing precision and the ability to combine weapons to overwhelm the defender

To what extent do existing European air and missile defences address the key current geopolitical and technological trends and developments in the international system? The geopolitical trends include the return of competition between the great powers, their investments in missile and other technologies, and the continuing attraction of these technologies to minor actors. The technological trends centre on the increasing availabilities of platforms, increased speed and manoeuvrability, growing precision and the ability to combine weapons to overwhelm the defender.

Our analysis places these trends and developments across three levels of threat: the strategic, theatre and tactical levels. The strategic level of threat concerns potential attacks against Europe's population, territory or vital interests. Concretely, the primary threat at this level consists of intercontinental, medium- and intermediate range ballistic missiles and now possibly also hypersonic missiles, from Russia, and possibly ballistic missiles from Iran. Active defence against these threats requires long-range systems that detect and begin tracking missiles early in the boost phase, to intercept them outside the atmosphere with mid-course interceptors or, more likely, during their terminal phase descent towards their target. Theatre level threats include medium- and intermediate range and short-range ballistic missiles, cruise missiles, aircraft and UAVs that may target Europe's critical military infrastructures including bases, airfields, command and control (C2) centres, logistics hubs, and high-value military forces and platforms. The Russian threat to NATO has grown particularly on the theatre level; China and Iran can present serious theatre threats as well to European ships in the Western Pacific and the Persian Gulf. These threats are typically countered in the terminal phase, through shorter range interceptors in proximity of the targets. Tactical level threats that can strike forward bases and sea-or land-based units with predominantly aircraft, cruise missiles, unmanned aerial vehicles (UAVs), loitering munitions, guided rockets, artillery and mortars (G-RAM) and, at times, short-range ballistic missiles. These systems are short-range and less costly to provide a proportional response to – at least if using the right equipment. At the tactical level, European forces are threatened within the NATO treaty area by Russia, and further afield, whether maritime forces across the world's oceans, or land forces by non-state actors.

The impact and likelihood of threats move in opposite directions. Threats at the strategic and theatre level are less likely, but vastly more impactful. Threats at the tactical level are more likely but generally speaking less impactful. However, developments at the tactical level will interact with those at the theatre level. For example, if military units can be more easily overwhelmed at the tactical level, secure lines of communication to deliver reinforcements and munitions become more important.[256] Critical C2 and logistics nodes are also more easily threatened. Attacks at multiple levels would primarily be executed by near-peer competitors; though they are improbable, their likelihood has been increasing gradually over the past decade plus.

The political and technological challenges vary significantly across these levels and thus require an integrated complex set of responses. In the following sections we discuss European air and missile defence capabilities and to what extent they meet the geopolitical and technological challenges at the strategic, theatre and tactical levels. We argue that existing integrated air and missile defence (IAMD) capabilities in Europe are unevenly distributed, both in terms of the level of threats they address and which states own them. Overall, as noted in chapter three, European states have primarily focused on limited ballistic missile threats and low-intensity threats to military forces at the tactical level. As a result – and this is our core argument here – European air and missile defence capabilities are insufficient for near-peer campaigns at both the theatre level and at the tactical level. Uneven also describes the European dependency on the United States and US systems, particularly at the strategic level. Ballistic missile defence for the European cities and major civilian and military infrastructure would not be possible without US systems. Nor is integration between the various systems well-developed, meaning that, with or without the US, European states cannot even make full use of the capabilities they possess.

In the following section, we discuss strategic threats, with a focus on ballistic missiles, before discussing theatre and then tactical level threats. Note that defensive systems are generally not single-purpose; they overlap in the range of threats they cover. However, it is crucial to clarify the different strengths and weaknesses of the available systems for the various threat levels.

7.2 Defence against Strategic Level Threats

At the strategic level of threat, Europe's population and territory can be attacked by sea-, land-, or air-launched intercontinental, medium, and intermediate range ballistic missiles; hypersonic weapons; and certain types of cruise missiles, all of which could be fitted with either nuclear or conventional warheads. Defences focus on both the weapon systems and the platforms that can deliver them. Defence against ballistic missiles is particularly difficult due to their trajectory and speed, even if predictable flight paths reduce somewhat of the complexity of interception. That is why the next subsection focusses on ballistic missile defence (BMD).

7.2.1 Ballistic missile defence

Given their speed and trajectory, active defence against ballistic missiles requires early warning sea- or land-based radars or space sensors that detect and begin tracking missiles early on in the boost phase, in order to intercept them during the terminal phase – or possibly

256 The same assessment was given in interviews with French defence official, American industry expert, June 2021.

mid-course – of their trajectory.[257] Alternatively, forward deployed radars cue sensors in closer proximity of the intended targets which can discriminate the nature of the threat before deciding on the appropriate response. Forward deployment of radars is thus as much part of the solution as improvements in technological capabilities.

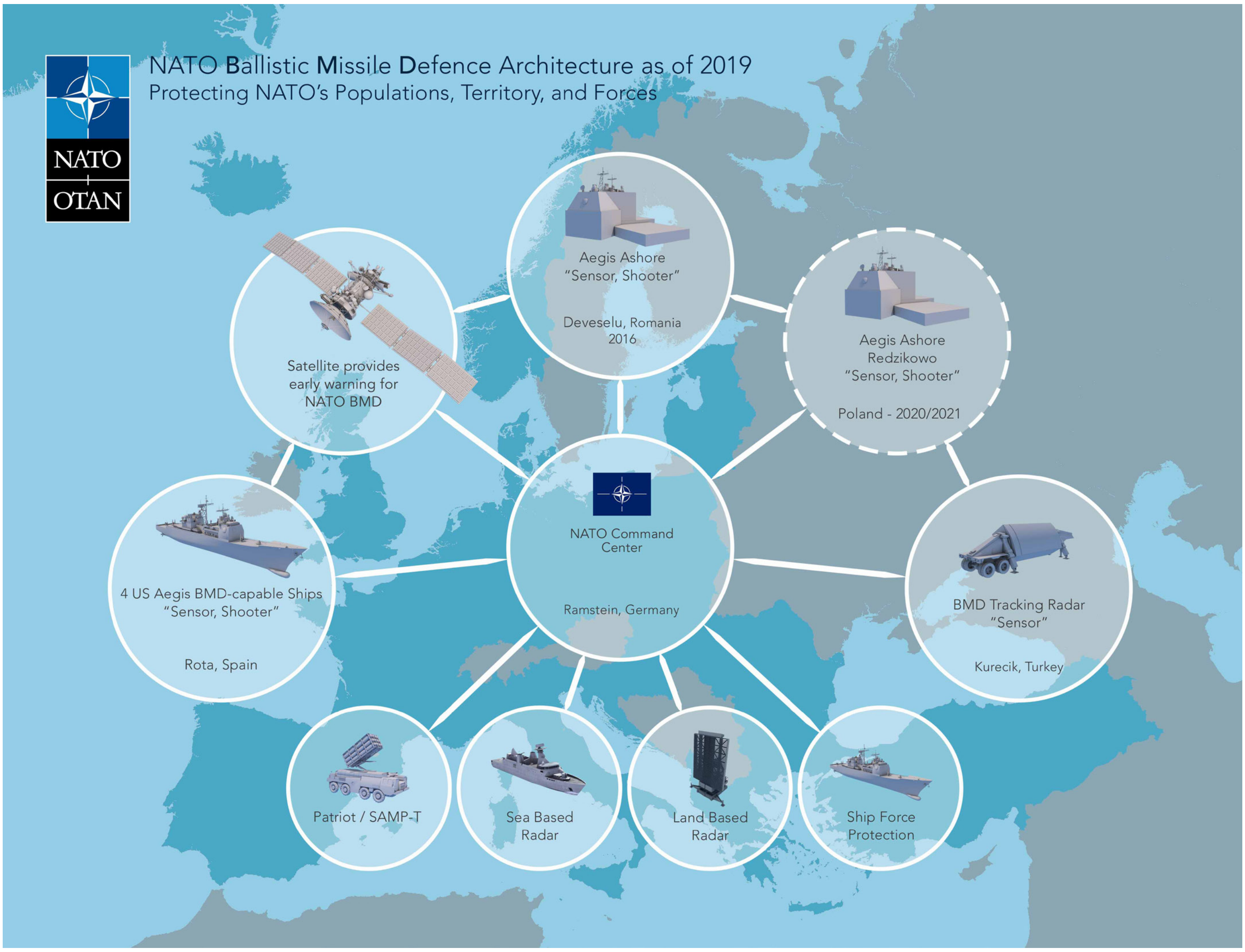


Figure 8: US assets under European Phased Adaptive Approach. Source: NATO

Europe's current BMD defence architecture makes use of a phased and layered approach that combines forward deployed land-based radars with naval assets. It dates to the 2010 Lisbon Summit, when NATO allies agreed on the need to defend European territory against medium- or intermediate range ballistic missiles from the Middle East. This NATO BMD capability has been advanced through the European Phased Adaptive Approach (EPAA), a US program that consists of the deployment of sea-and land-based configurations of the Aegis missile defence system that was introduced in and around Europe in three phases (see Figure 8).[258] More specifically, EPAA includes a land-based AN/TPY-2 radar in Turkey, four

257 Hypersonic weapons present many of the same problems to defenders as ballistic missiles; infrared sensors are particularly useful to track the heat signatures of hypersonic missiles.

258 Phase 4, which was to deploy SM-3 IIB interceptors in Redzikowo, Poland from 2020 onwards, was cancelled in 2013, partly in response to mounting concerns in Moscow."Missile Defense Review" (Office of the Secretary of Defence, 2019).

US multi-mission Aegis ships stationed in the Mediterranean Sea,[259] two Aegis Ashore sites in Romania and Poland – the latter of which is still under construction,[260] and a C2 centre in Germany. Crucial to note is that this BMD architecture provides territorial protection of Europe against ballistic missile threats from outside the Euro-Atlantic area. Its mid-course interceptors are not directed against potential ballistic missiles from Russia.

Beyond hosting US assets, European efforts have been made to contribute to BMD also in terms of equipment. For example, the Netherlands is currently enhancing its four *De Zeven Provinciën*-class air defence frigates with the SMART-L MM/N radar, which is capable of surveillance and tracking ballistic missiles up to an distance of 2,000 km and can thus contribute to NATO's overall early warning capability.[261] Earlier this year, a launch-on-remote test with a US SM-3 interceptor was successfully conducted using data provided by the first SMART-L MM/N radar delivered to the Netherlands.[262] Germany is similarly planning to replace its first generation SMART-L radars with longer range radars capable of exo-atmospheric detection and tracking as it introduces a new generation of frigates.[263] Meanwhile, Denmark expressed intent to upgrade at least one of its Iver Huitfeldt-class frigates to provide BMD capacity to NATO,[264] and the UK announced its investment in a land-based BMD radar in its 2015 Strategic Defence and Security Review.[265]

Despite these developments, European defence against aircraft is more comprehensive, especially when it comes to the Russian threat. Air defence radars can track incoming fighter-bomber aircraft, and European air forces would be able to intercept these. However, Russia is equipping its aircraft with air launched ballistic missiles and cruise missiles. Should these be able to fire, the difficulties of interception are significant. Strategic weapons could be launched from Strategic Ballistic Missile Submarines (SSBN) as well as strategic bombers, the first of which requiring Anti-Submarine Warfare (ASW) capabilities for tracking and interception, the latter integrated air defences.

259 The four *Arleigh Burke*-class destroyers Ross (DDG-71), Donald Cook (DDG-75) Carney (DDG-64) and Porter (DDG-78) are equipped with onboard SPY-1 tracking radars, SM-3 Block IA interceptors and multimissile, eight-cell launchers, the Mark 41 (Mk 41) Vertical Launch System (VLS). The ships are based Rota naval base, Spain.

260 The Aegis Ashore site in Deveselu, Romania (operational since mid-2016) deploys a SM-3 Block IB interceptor and a land-based SPY-1 radar. The Aegis Ashore site in Redzikowo, Poland, was initially scheduled for 2018 but has been delayed until 2022. This site is to deploy a SM-3 Block IIA interceptor and a land-based SPY-1 radar. Jen Judson, "Poland's Aegis Ashore Delayed to 2022 with New Way Forward Coming Soon," Defense News, February 19, 2020, https://www.defensenews.com/smr/federal-budget/2020/02/18/polands-aegis-ashore-delayed-to-2022-with-new-way-forward-coming-soon/.

261 "SMART-L Early Warning Capability (EWC) – Missile Defense Advocacy Alliance," accessed January 19, 2021, https://missiledefenseadvocacy.org/defense-systems/smart-l-early-warning-capability-ewc/.

262 "US Navy Destroyer Uses Thales' Radar for SM-3 Launch on Remote Test," accessed July 14, 2021, https://www.naval-technology.com/news/us-navy-destroyer-uses-thales-radar-for-sm-3-launch-on-remote-test/.

263 Jaime Karremann, "Nederland En Duitsland Willen Samenwerken, Maar Ook Niet Helemaal," Marineschepen.nl, accessed August 10, 2021, https://marineschepen.nl/nieuws/Nederland-en-Duitsland-willen-samenwerken-maar-ook-niet-helemaal-180121.html.

264 "Denmark Progresses in NATO Ballistic Missile Defense Role," Defense News, August 8, 2017, https://www.defensenews.com/air/2016/04/22/denmark-progresses-in-nato-ballistic-missile-defense-role/; "Royal Danish Navy Orders SM-2 Block IIIA for Iver Huitfeldt-Class Frigates," Navy Recognition, accessed August 10, 2021, https://www.navyrecognition.com/index.php/naval-news/naval-news-archive/2018/october-2018-navy-naval-defense-news/6551-royal-danish-navy-orders-sm-2-block-iiia-for-iver-huitfeldt-class-frigates.html.

265 Great Britain and Cabinet Office, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, 2015, 25.

7.2.2 Shortfalls in European strategic defence

We note multiple shortfalls in European defence against strategic level air and missile threats, including a high reliance on US assets, the vulnerability of a forward-deployed radar system and the limited capacity against certain actors and missile technologies.

Dependency on the United States. At the strategic level, European states remain highly dependent on the US. EPAA is a US project in every single way: initiative, technology and funding. Crucially, the US naval capability in Europe is limited and demand could easily exceed supply should the Aegis forces based in Spain be asked to contribute to, for example, a contingency in the Middle East involving Israel.[266] Overall, European countries are thus dependent on the US security guarantee for upper layer BMD, even if European allies participate and contribute to the EPAA architecture, with Spain providing a naval base for the four Aegis ships, Romania and Poland hosting Aegis Ashore sites and Germany hosting NATO BMD's headquarters in Ramstein.

European states should address these dependencies by adding more of their own capabilities to this infrastructure of systems. The Dutch SMART-L MM update and planned procurements of longer-range radars by countries like Germany and the UK are first steps to decrease this dependency. In terms of space-based sensors, the EU does not yet have its own sensors network for BMD, such as the US space-based infrared system (SBIRS) in Low Earth Orbit (LEO) and geosynchronous equatorial orbit (GEO).[267] European space situational awareness sensors seem to be insufficiently developed for missile and air defence purposes yet. The European Military Space Surveillance Awareness Network could in principle be used for these purposes but is only in its early stages.

Placement, vulnerabilities and politics. Effective early warning not only depends on the quality of sensors but also on their placement, which may cause political and practical strategic problems. A crucial component of EPAA is its early warning 'engage on remote' approach. The Aegis Ashore systems rely for their target information not just on their own SPY-1 radar but also on the forward-deployed TPY-2 radar in Turkey. The latter radar's reach and proximity allows it to detect a potential missile launch much sooner and cue other radars rapidly. In contrast, the more limited range of the Aegis ships' and ashore sites' SPY-1 radars may detect missiles too late, or not at all, if they fly over the radar's range when heading for Western Europe – thus leaving a variety of military bases and cities across Europe unprotected. The SMART-L MM radars could partly compensate for this dependency (see §8.3).

Because of the TPY-2 radar's strategic value and proximity to the Middle East – 560 km from the Iranian border and 160 km from the Syrian border – it may be a potential target. In particular, Iran's demonstrated appetite for complex integrated attacks could be a cause for concern.[268] Should the TPY-2 radar drop out, Europe's defence against medium- and intermediate-range missiles would be vastly weaker. It is unclear to what extent the TPY-2 radar site in Turkey is protected by a lower tier air defence system that is capable of resisting a complex combined attack.[269] This vulnerability underlines the new era of air and missile threats where mixing high- and low-end threats has become easier.

266 Interview with US defence industry expert, June 2021.

267 Since the French Space Defence Strategy paper refers to the SPIRALE early warning demonstrator that was used in orbit between 2009 and 2011 but to no other early-warning system that is based on space-based capabilities. In some papers SPIRALE is still listed among the NATO satellite capabilities under "Integral Tactical Warning and Threat Assessment" for force protection, attribution, and missile defence. 'Europe's Missile Defence and Italy: Capabilities and Cooperation', 2021.

268 The UAV attack against Saudi Patriot radars in 2019 serves as a case in point.

269 "Achilles' Heel: Adding Resilience to NATO's Fragile Missile Shield," accessed January 11, 2021, https://www.csis.org/analysis/achilles-heel-adding-resilience-natos-fragile-missile-shield.

Political problems of other kinds further add to NATO BMD's weakness. In 2019, Turkey received the Russian-built S-400 Triumf air defence system, providing highly advanced defence against medium-range ballistic missiles, cruise missiles, stealth aircraft – and in theory UAVs.[270] Political tensions over this purchase could undermine EPAA's resilience. Moreover, what this means in terms of Russian intelligence-gathering for the radar signatures of NATO aircraft is as of yet unclear.[271] Certainly it did cause the US to remove Turkey from its F-35 program.[272] Another political sensitivity is that the Aegis ashore radar sites in Poland and Romania are potential targets, yet, arguably, their contribution to EPAA primarily benefits Western European NATO members. The placement of radars and interceptors underlines uneven exposures to risks, costs, and benefits, underlining dependencies within the alliance and the potential for exploitation through direct threats or subversion.

Limited capacity. Finally, Europe's ballistic missile defence system is limited in its intercept capacity, as it was designed for the limited threat from Iran. It would be inadequate during a potential crisis with Russia, yet still also present an obvious target for an initial Russian attack. Nor was the system designed with a varied 360-degree threat environment in mind once missiles are out of the radar's range, the Aegis system relies on calculations to guide its interceptors. Similarly, manoeuvring ballistic missiles pose a potential threat to the TPY-2-dependent system too. To monitor such manoeuvres, the system would require continued observation that is beyond the TPY-2's capacity and requires additional radars.

The placement of radars and interceptors underlines uneven exposures to risks, costs, and benefits, underlining dependencies within the alliance and the potential for exploitation through direct threats or subversion

7.2.3 **Why it matters**

At the strategic level, threats to populations and civilian infrastructure are newly relevant due to geopolitical developments. Arguably, the newest technological developments – precision and speed (hypersonic weapons) – do little to change the balance of terror per se. The same states that utilise hypersonic weapons – or will expect to – already possess nuclear-tipped intercontinental ballistic missiles.[273] However, the risk of Russia holding European capitals at risk could dampen the willingness of NATO members to come to each other's aid. In that aspect, the strategic level, while less affected by technological trends, itself affects the developments at the theatre and tactical levels.

We think it important to note that we expect the American, British, and French nuclear deterrents to be sufficient to dissuade Russia from attacking major European population centres with either nuclear or conventional warheads. Far less dangerous in terms of missile capability but marginally more likely to exploit its ability to blackmail Europe, would be Iran. That said, multiple targets that are valuable to Russia from a military point of view are located in Western Europe and serve both civilian and military roles – for example, the ports of Rotterdam, Antwerp, and Bremen would be essential for moving forces and material from the US to Europe – which are likely to be considered legitimate targets by Russia in the case of conflict escalation [see section 4.1.].

270 Laura Pitel, Henry Foy, and Aime Williams, "Turkey Receives First Shipment of Russian Missile System," *Financial Times*, July 12, 2019, https://www.ft.com/content/e71a9f5a-a479-11e9-a282-2df48f366f7d.

271 "Turkey's S-400 could give F-35s and F-22s a major advantage in a fight with Russia," Business Insider Nederland, July 18, 2019, https://www.businessinsider.nl/turkeys-s400-f-35s-f-22s-a-boost-against-russia-2019-7/.

272 Aaron Mehta, "Turkey Officially Kicked out of F-35 Program, Costing US Half a Billion Dollars," Defense News, July 17, 2019, https://www.defensenews.com/air/2019/07/17/turkey-officially-kicked-out-of-f-35-program/.

273 See our discussion in §3.2.3. It was also a point reiterated in interviews with US defence industry expert, a French defence official, and Dutch defence officials, June 2021.

7.3 Defence against Theatre Level Threats

A consistent theme of this report is that the theatre level threat of a near-peer competitor engaging in a sustained campaign of air and missile attacks against major military infrastructure and major assets has been underrated. Major powers can use their persistent sensing capabilities to improve transparency and precision for ballistic, cruise and potentially hypersonic missiles. These threats can be combined with UAVs and loitering munitions to disable high-value military targets. The key challenge here lies in the potential for mixing mass with more exquisite systems in combined attacks to overwhelm and saturate the sensing, C2, and interception capabilities of the defender. For Europe, that particular threat has been covered in the Russian scenario [see §4.1], but elements of this threat are also present for Europe's naval forces in the Persian Gulf [see §4.3] and in the Western Pacific [see §4.2].

7.3.1 Theatre defence

The theatre level of threat is presented by short-range ballistic missiles, cruise missiles and aircraft requires shorter range air defence systems. NATO Allies launched the Active Layered Theatre Ballistic Missile Defence (ALTBMD) in 2005 in an effort to integrate national capabilities directed at short- and medium-range threats into a common battle management system. ALTBMD later became part of NATO BMD, a key pillar of which is the EPAA. EPAA radar infrastructure is technically capable of cueing these shorter-range systems.[274]

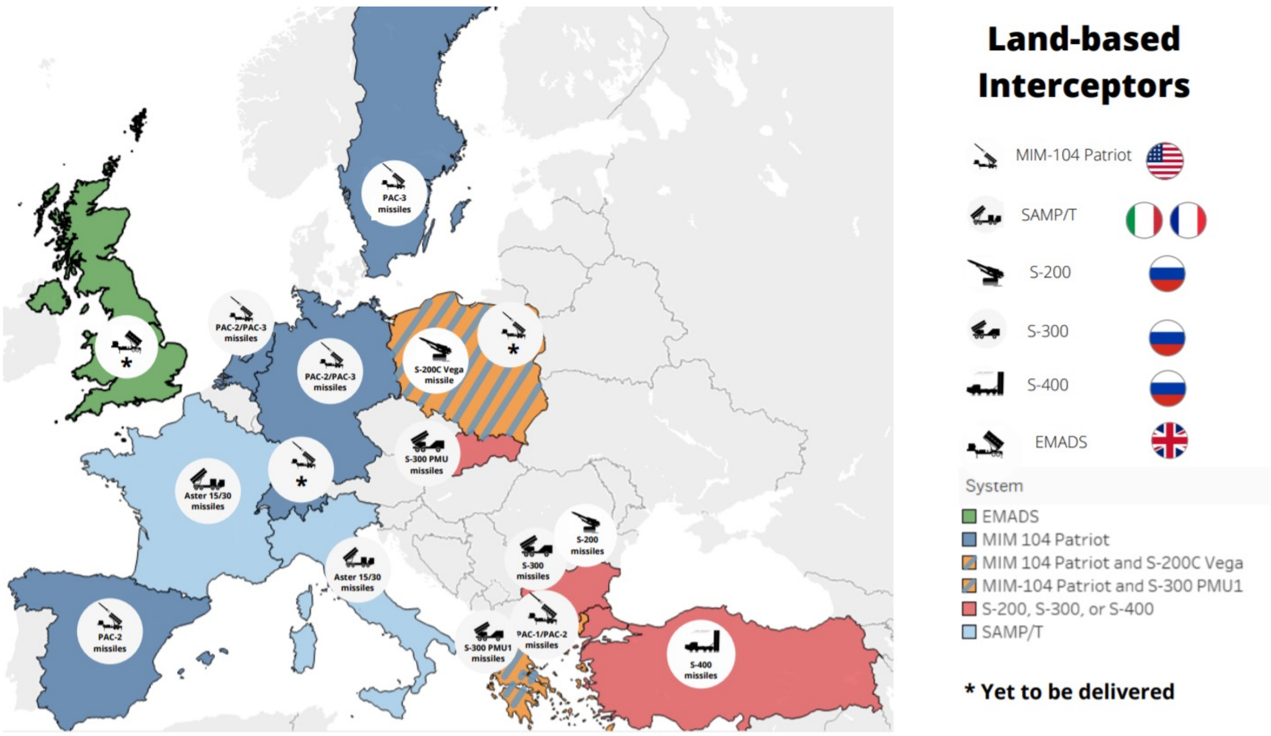


Figure 9. Overview of medium/long range land-based air- and missile defence systems in Europe[275]

274 "MDA, Army Test Interoperability of THAAD, Patriot Missile Defence systems; Jon Hill Quoted," Executive Gov, October 2, 2020, https://www.executivegov.com/2020/10/mda-army-test-interoperability-of-thaad-patriot-missile-defense-systems-jon-hill-quoted/.

275 This figure gives an indication of current and upcoming systems; systems are constantly updated or replaced.

In Europe, the ground-based, mobile defence systems Patriot (American) and SAMP/T (French-Italian) defend critical (military) infrastructures against short-range ballistic missiles, cruise missiles, aircraft, rockets, UAVs such as medium-altitude long-endurance (MALE) and high-altitude long-endurance (HALE), and possibly smaller types (see Figure 9 and Table 3 for an overview).[276] The UK is soon to acquire EMADS, a ground-based system comparable to Patriot and SAMP/T.[277] The Russian-made S-300 are also still in use by a number of European NATO allies.[278] These systems are used for point defence: their geographical coverage is limited and batteries must therefore be located in proximity of potential targets. These mobile systems can be used with flexibility, whether to protect assets both on the national territory and outside. For instance during the Syrian conflict, various NATO allies deployed Patriot and SAMP/T batteries to Turkey for the protection of three cities.[279] Figure 9 offers an overview of the systems currently in use in Europe.

Users	System	Planned upgrades/innovations	Producers (company – state)
	MIM-104 Patriot	Poland to receive the first elements of Patriot (delivery date: early 2022); Switzerland to receive Patriot system (delivery date: TBA)	Lockheed Martin 
	SAMP/T	Aster Block I; upgraded launcher; multi-function rotating active electronically scanned array; (delivery date: TBA)	Eurosam 
	EMADS	Has yet to be delivered	
	s-200, s-300, s-400		NPO Almaz 

Table 3. Overview of land-based air- and missile defence systems in Europe[280]

When it comes to sea-based theatre defence, a total of nine navies currently deploy guided missile destroyers capable of air defence (see Table 4).[281] Again, American systems dominate: the majority of European navies operate US effectors such as the SM-2 and Evolved Sea

276 Germany, Greece, the Netherlands, Spain, Romania, and most recently Sweden operate Patriot Batteries, while Poland is soon to receive its first shipment. The system consists of an AN/MPQ-53 C-band phased array radar system with a 100km range, the MSQ-104 control station, missile launchers and Patriot missiles, including PAC-2, PAC-2 GEM, PAC-2 GEM-T, PAC-3, and PAC-3 MSE variations. SAMP/T systems operate a C2 vehicle, Arabel radar and up to six transporter erector launcher (TEL) vehicles, each equipped with eight Aster interceptors

277 "Enhanced Modular Air Defense Solutions (EMADS)," Missile Defense Advocacy Alliance, accessed December 22, 2020, https://missiledefenseadvocacy.org/defense-systems/enhanced-modular-air-defense-solutions-emads/.

278 These include Greece, Cyprus, and Slovakia.

279 The US, Germany, the Netherlands, Spain, France and Italy alternately deployed Patriot and SAMP/T batteries. See for instance: "Amid S-400 Crisis, France Deploys Missile Defense Battery to Turkey," Arab News, July 26, 2019, https://www.arabnews.com/node/1531306/middle-east; Tom Kington, "Italy to Remove Its AirDefense Assets from Turkey by Year's End," Defense News, October 25, 2019, https://www.defensenews.com/global/europe/2019/10/25/italy-to-remove-its-airdefense-assets-from-turkey-by-years-end/.

280 This table gives an indication of current and upcoming systems; systems are constantly updated or replaced.

281 France (3), Italy (6), Germany (7), Spain (5), the Netherlands (4), Denmark (3), Norway (4), the United Kingdom (6), and Turkey (4).

Sparrow Missiles (ESSM) missiles,[282] which intercept aircraft and missiles, including supersonic manoeuvring anti-ship cruise missiles.[283] These European vessels can be used for point defence or layered defence of higher-tier Aegis systems deployed under EPAA. They can do with SM-6, SM-2, or ESSM missiles, though this varies per state. The U.K. counterpart to the US-made Aegis Combat System is the Principal Anti-Air Missile System (PAAMS).[284] Both systems are integrated into NATO air and missile defence architecture but the interceptors used in the Aegis and PAAMS systems are not interchangeable though proposals are in place to address this problem.[285]

Country	Class	Interceptors[286]
	De Zeven Provinciën-class	ESSM and SM-2 Block IIIA 5 8-cell Mk 41 VLS with SM-2 Block IIIA and RIM-162B ESSM SAM
	Brandenburg-class (F-123)	2 8-cell Mk 41 VLS with RIM-7P *Sea Sparrow* SAM
	Sachsen-class (F-124)	4 8-cell Mk 41 VLS with SM-2 Block IIIA SAM/ RIM-162B ESSM SAM
	Iver Huitfeldt-class	2 12-cell Mk 56 VLS with RIM-162B ESSM SAM
	Fridtjof Nansen-class	1 8-cell Mk 41 VLS with RIM-162A ESSM SAM
	Álvaro de Bazán-class	6 8-cell Mk 41 VLS with SM-2 Block IIIA and RIM-162B ESSM SAM
	Daring-class (Type-45)	6 8-cell *Sylver* A50 VLS with *Aster* 15/30
	Cassard-class	1 Mk 13 GMLS with SM-1MR Block VI SAM
	Horizon-class	4 8-cell *Sylver* A50 VLS with *Aster* 30 SAM, 2 8-cell *Sylver* A50 VLS with *Aster* 15 SAM
	Horizon-class	6 8-cell *Sylver* A50 VLS with *Aster* 15/*Aster* 30 SAM
	Durand de la Penne-class	1 Mk 13 mod 4 GMLS with SM-1MR Block VI SAM and 1 octuple *Albatros* with *Aspide* SAM
	Bergamini-class	2 8-cell *Sylver* A50 VLS with *Aster* 15/*Aster* 30 SAM
	On the 28th September 2021, Greece signed a memorandum of understanding with France for the supply of three FDI frigates (delivery date: 2025-2027)	TBA, Aster 30

Table 4. Overview of air defence frigates in Europe[287]

282 European Aegis-equipped vessels include Denmark's three *Iver Huitfeldt*-class destroyers (to be fitted with SAM); Germany's four *Brandenburg*-class destroyers (F-123) equipped with SAM as well as three *Sachsen*-class (F-124) destroyers fitted with SAM *and* SM-2 Block IIIA; the Netherlands' four *De Zeven Provinciën*-class destroyers fitted with SAM *and* SM-2 Block IIIA; Norway's four *Fridtjof Nansen*-class destroyers equipped with Aegis C2 and Mk 41 VLS for SAM; Spain's five Álvaro de *Bazán*-class destroyers with equipped Aegis Baseline 5 C2 and Mk 41 VLS fitted with SM-2 Block IIIA and SAM; and Turkey's four *Barbaros*- and *Gabya*-class destroyers fitted with SAM."IISS Military Balance 2020.Pdf," n.d.

283 Agnes Katona, "NATO Territorial Ballistic Missile Defense and Its Implications for Arms Control," *The Nonproliferation Review,* 22, no. 2 (2015): 253–72.

284 Currently, two French and two Italian Horizon-class frigates as well as six British Type 45 destroyers are equipped with PAAMS. The highly mobile, ship-based system deploys Aster 15 and Aster 30 interceptors in combination with the long-range S1850M radar and the shorter-range British SAMPSON radar and French-Italian EMPAR radars, as well as configurations of the Sylver VLS – either the shorter range A-35 and A-43 or longer-range A-50 and A-70 VLS. The ASPER is known in the U.K. as Sea Viper.

285 Reportedly proposals were developed to adapt PAAMS vertical launch systems, the Sylver A70, to allow SM-3 missiles, or replace them with the MK 41 VLS which allow for more types of missiles. Agnes Katona, "NATO Territorial Ballistic Missile Defense and Its Implications for Arms Control."

286 For the purposes of this section, anti-ship cruise missiles and short range defense systems and guns are not included.

287 This table gives an indication of current and upcoming systems; systems are constantly updated or replaced.

Finally, European air forces play a key role in finding, confusing through electronic counter-warfare (ECW), and intercepting air and missile attacks. Air-to-air missiles (AAMs) of aircraft are an effective measure to counter highly manoeuvrable air and missile threats, including cruise missiles, aircraft such fighter jets, and UAVs. European deployed systems include the IRIS-T, Meteor BVRAAM, MICA, PYTHON-5, AIM-120 AMRAAM and A-Darter.[288] The counter-air task of the air forces are central to traditional understanding of air defence.

7.3.2 Shortfalls in European theatre defence

Multiple shortfalls in European defence against theatre level air and missile threats. These range from limitations in quantities of both batteries and missiles, to limitations in qualities, whereby current systems are not up to today's and future threats

We note multiple shortfalls in European defence against theatre level air and missile threats. These range from limitations in quantities of both batteries and missiles, to limitations in qualities, whereby current systems are not up to today's and future threats. Threats to which current systems fall short include combined or salvo attacks, newer technologies such as hypersonic weapons and a 360° threat environment. Even if current systems protect against newer threats such as UAVs, cost-effectiveness is an issue. Finally, integration of systems and defence against network attacks proves challenging.

Shortage of endo-atmospheric defence. Defences have been weighted toward defending against a limited number of high-end threats. Designed for exo-atmospheric midcourse intercept, EPAA's SM-3 interceptors do not defend against Russian short-range ballistic missiles or cruise missiles such as *Iskanders* or *Kalibrs*. Additional lower-tier, endo-atmospheric defence capabilities are needed in Europe to protect critical infrastructures and sites in Europe. [289]

Overwhelmed by combined attacks. Despite subsequent upgrades, the air defence radars currently in possession of Europe were built primarily in the Cold War and intended to be deployed as part of the "ring of steel" directed towards the East. The primary threat they were designed to counter was Warsaw Pact air forces and missiles moving in large numbers from a predictable direction and at great speed. They were pertinently not designed for slow-moving and potentially static threats such as intelligence, surveillance and reconnaissance (ISR) UAVs or loitering munitions. At its core, this is why low-end weapons could be combined with more high-end weapons to potentially great effect; the defensive systems were not designed with them in mind.

New technologies. Technological innovations such as hypersonic weapons allow attackers to strike critical infrastructure. While we discount the risks of hypersonic weapons as substantially affecting defences at the strategic level [see our discussion in §3.2.3], we see greater risks of their use against carrier groups, C2 centres, mobile missile launchers, or air defence radars.[290] Existing sensors cannot defend against hypersonic weapons, nor is it likely that interceptors can accomplish successful interceptions. Moreover, current NATO sensor capabilities are not fully prepared to provide full coverage, which is for instance problematic with regard to the cruise missile threat.[291]

Lack of mass and cost-effectiveness against threats. The theatre level defences were reduced in numbers after the end of the Cold War and are no longer ready to defend against large numbers of incoming missiles that a near-peer competitor like Russia would use.

288 "The World's Most Effective Airto-Air Missiles," accessed March 30, 2021, https://www.airforce-technology.com/features/featurethe-worlds-most-effective-airto-airmissiles-4167934/.

289 Thomas Karako, "European Air and Missile Defense after Warsaw," n.d., 10.

290 Interview with French defence official, June 2021.

291 E-mail exchange with NATO defence official, June 2021.

European states have limited numbers of Patriot and SAMP/T systems, the most commonly used medium- and longer-range systems, and limited numbers of interceptor stocks. In the more benign threat environment that followed the Cold War, given the costs of Patriot PAC-3 interceptors at multiple millions each,[292] building large stocks of interceptors seemed exorbitant. During a large-scale attack, defensive options would be highly limited. [293] This provides a hard ceiling on the ability to defend targets but also signals that the systems are not cost-effective against certain weapons. While SAMP/T and Patriot could intercept UAVs, for example, using them in this manner would be highly expensive (NASAMS would be preferable for UAVs).

The limited number of defensive systems at the theatre level means that hard choices will have to be made by individual European states and within NATO on what to defend. The mobility of these systems means they can be deployed to protect different targets. Should defensive systems be deployed to protect civilian or military targets? Should they protect targets on the national territory or those of allies? Assessments on the likelihood of attacks must be weighed against alliance commitments and responsibilities to citizens. [294]

Lack of integration. The multiple systems within Europe are not well-integrated, or not at all. The US and NATO use mostly Tactical Data Link 16 to ensure interoperability in IAMD, as Link 16 enables C2 centres to create a Common Operating Picture and allows them to "electronically observe the battlespace, identify threats, and acquire targets".[295] Different air and missile defence platforms, such as aircrafts, UAVs and missiles, are guided by different types of C2. For example, the US employs the Forward Area Air Defence Command and Control (FAAD C2) system to provide C2 for countering UAVs and other short range air defences.[296] FAAD C2 "enables easy integration with available sensors, effectors and warning systems to launch rapid, real-time defence against short range and manoeuvring threats."[297] Another C2 system used by the US is the Command and Control, Battle Management and Communications (C2BMC). This type of system integrates individual ballistic missile defence systems, generating a layered missile defence apparatus with identification, tracking and interception capabilities.[298] These kinds of C2 systems integrate sensors, shooters, and defence systems within specific domains, such as the one of UAVs or ballistic missiles.

However, these systems are not integrated, as they often use different codes and protocols. That is a definite problem with sensors, interceptors and C2 systems produced by different national defence industries. For reasons of national security and commercial interests,

292 The costs of PAC-3s significantly fluctuate as the price changes depending on the amounts ordered, the timing of other orders made at the same time, and so on.

293 The working assumption is that Dutch forces would be able to rely on the supplies of allies, as they do not expect to work outside of a multinational military operations. This assumption has not been formalised. Nor does that address potential shortages that would emerge if the Netherlands would decide to use its PATRIOT capability to protect potential targets on its national territory. Interview with Dutch defence officials, May 2021.

294 For example, the three Patriot units in the Netherlands are sufficient only to defend *one* city, or *one* port, as all three would be needed to ensure successful coverage. Interview with Dutch defence officials, May 2021.

295 "Link 16," Missile Defense Advocacy Alliance, accessed April 6, 2021, https://missiledefenseadvocacy.org/defense-systems/link-16/.

296 Mike Ball, "U.S. DOD Selects New Counter-UAS Command & Control System," Unmanned Systems Technology, July 10, 2020, https://www.unmannedsystemstechnology.com/2020/07/u-s-dod-selects-new-counter-uas-command-control-system/.

297 Ball.

298 "Command and Control, Battle Management and Communications (C2BMC)," Missile Defense Advocacy Alliance, accessed April 6, 2021, https://missiledefenseadvocacy.org/defense-systems/command-and-control-battle-management-and-communications-system-c2bmc/.

producers supply their systems as 'black box'.[299] However, even with a single producer and a single type of system, these problems exist and interoperability is often improvised.[300] Complicating affairs further is the prevalence of legacy systems from the Warsaw Pact era among Central and Eastern European NATO member states, including Russian surface-to-air systems for BMD, the Soviet-era S-200 (NATO designation SA-5 Gammon) used by Poland and Greece and the S-300 (SA-20 Gargoyle) operated by Greece, Bulgaria, and Slovakia.[301]

The lack of integration means that a great deal of potential air and missile defence capacity is not close to being fully realised. If systems are well-integrated, sensors can cue other sensors and interceptors can attempt interceptions at different ranges against a single weapon or against combined attacks with different weapons. For example, Patriot and NASAMS supplement the other's coverage.

Attacks on the networks. Paradoxically, integrating systems carry their own set of problems as the networks are vulnerable to disruption through electronic warfare or cyberattacks Offensive electronic warfare (EW) technologies are in constant evolution, with improvements in range, survivability and integration with other elements. The latest jammers are effective from distances up to 300 km, EW equipment is increasingly miniaturised and employed by UAVs, and new cyber and optical technologies are in the development.[302]

The importance of EW for air and missile defence cannot be overstated. When it comes to missiles, EW is able to disturb and/or neutralise search and tracking radars' signals, heat-seeking systems, laser designators, satellite guidance signals and communication signals relying on radio frequency, such as spread spectrum signals.[303] For the attacker, EW represents the possibility to deceive the defender and carry on the attack without being intercepted. Through jamming and deception, the attacker can avoid detection by luring the defender's infrared and radar-guided missiles away from the intended target and by interrupting the defender's communication and radar signals.[304]

The combat management and satellite datalinks systems could also be attacked by cyber weapons. As the networks become more complicated, the number of potential weak spots to attack increases.[305]

7.3.3 Why it matters

The limited defensive capacity against threats at the theatre level leaves military infrastructure vulnerable. Impediments to access to and movement within the theatre can cripple efforts to mount a successful defence and, by implication, weaken conventional deterrence. If US and Western European forces cannot quickly reach member states that are potentially under

299 Interviews with Dutch defence officials, May and June 2021, interview with French defence official, American defence industry expert, June 2021.

300 Interview with US defence industry official, June 2021.

301 "The Challenge of Defending European Airspace," IISS, accessed November 26, 2020, https://www.iiss.org/blogs/military-balance/2020/02/defending-european-airspace.

302 Subhasis Das, "Electronic Warfare: Emerging Trends in Technology," *Indian Defence Review* (blog), January 14, 2018, http://www.indiandefencereview.com/news/electronic-warfare-emerging-trends-in-technology/.

303 David Adamy, "EW 102 : A Second Course in Electronic Warfare," 2004, http://web.b.ebscohost.com.ezproxy.leidenuniv.nl:2048/ehost/ebookviewer/ebook/ZTAwMHh3d19fMTIxNzY2X19BTg2?sid=8d8595d3-20c7-4f71-9bdb-d4e83f2bb9ff@pdc-v-sessmgr04&vid=0&format=EB&rid=1.

304 Andrea De Martino, *Introduction to Modern EW Systems*, 2018, 3, http://web.a.ebscohost.com.ezproxy.leidenuniv.nl:2048/ehost/ebookviewer/ebook/ZTAwMHh3d19fMTkwNDM4MV9fQU41?sid=a-9d5752a-b619-4942-a722-babfc5029310@sessionmgr4006&vid=0&format=EB&rid=1.

305 Interview with Dutch defence officials, June 2021.

attack on NATO's eastern flank, their commitments of assistance significantly lose credibility. Moreover, the vulnerability of ships to various missiles is arguably growing[306] and the limited numbers of defences therefore present European navies with real vulnerabilities.

7.4 Defence against Tactical Level Threats

At the tactical level, short and very short-range systems should protect forward bases and sea- or land units against UAVs primarily, while their secondary role includes defence against fixed wing and rotary wing targets.[307] In reality, this is often the other way around. Systems within these range include (Extended) Short Range Air Defence (SHORAD)[308] and V-SHORAD (very short-range defence) systems,[309] of which MANPADS[310] are a subtype.

Generally, short-range air and missile defence systems have long been overlooked in favour of their more sophisticated cousins that defend against ballistic missiles.[311] However, they have become more and more essential again as battlefield transparency has increased, alongside the ability to integrate high-end and low-end threats. This new sense of urgency translates into renewed initiatives both within national and multinational frameworks in Europe, with a variety of tenders ongoing for enhanced SHORAD and VSHORAD capabilities, such as in Germany and Poland.[312]

Especially counter UAV (C-UAS) capabilities have recently received attention, not just because they provide a novel air threat accessible to a myriad of state and non-state actors, but also because of their coordinated use with more sophisticated systems. UAVs can guide rockets, artillery and munitions, or be used as loitering munitions to destroy C2-nodes as well as radars that are essential for the defence against more sophisticated threats. Short-range air defences against UAVs are less expensive and can be used for both land- and sea-based assets. They should consequently be developed on a joint basis. Table 5 offers an overview of short-range air defence systems in use in Europe.

306 Caverley and Dombrowski, "Cruising for a Bruising."

307 NATO Industrial Advisory Group (NIAG), "GBAD Operations in the 21st Century," November 5, 2019.

308 The MIM-23 *Hawk* is the only Extended SHORAD system (with a 20-50 km range) operated by NATO Allies (Sweden, Turkey, Spain, Romania and Greece) – excluding some legacy Soviet-era systems in Cyprus, Czech Republic and Romania. Ground-based SHORAD (<25 km) systems include NASAMS (II/III), SA-6, and SPADA SAM 2000, as well as the shorter-range (<10 km) CROTALE NG, and Rapier. NASAMS is a popular system fit to engage fixed and rotary-wing aircraft, cruise missiles, and UAVs. Built in response to Russian air threats, its use extends much further. In Europe, the system is operated by Norway, the Netherlands, Spain, Finland, and Lithuania. "National Advanced Surface-to-Air Missile System (NASAMS) – Missile Defense Advocacy Alliance," accessed February 25, 2021, https://missiledefenseadvocacy.org/defense-systems/national-advanced-surface-to-airmissile-system-nasams/.

309 Ground-based V-SHORAD systems operated in Europe include AVENGER, LeFlasys, MISTRAL, SA-13, STARSTREAK and RBS70 NG; Guns operated in Europe include MANTIS and Oerlikon.

310 MANPADS (man-portable air defence systems) are short-range surface-to-air missiles that can be carried by individuals or small groups of individuals, to protect troops or facilities. Types include infrared, command line-of-sight (CLOS) and Laser Beam Riders (LBR) systems. MANPADS are capable of striking aircraft up to 15,000 feet at a range of up to 5 kilometres and at a speed of about twice the speed of sound. European-deployed systems include the GROM, FIM-92 Stinger, MISTRAL, RBS-70 NG and STARSTREAK. "MANPADS: Combating the Threat to Global Aviation," accessed February 25, 2021, https://2009-2017.state.gov/t/pm/wra/c62623.htm.

311 Christian Mölling, Torben Schütz, and Zoe Stanley-Lockman, "A New Dimension of AirBased Threats," 2019, 5.

312 "Europe's Missile Defence and Italy: Capabilities and Cooperation," 2021, 117.

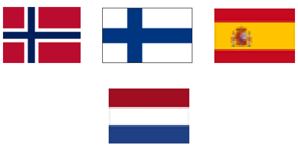
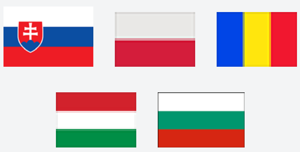
Users	System	Producer (company-state)
	MIM-23 Hawk[313]	Raytheon Co. 
	CROTALE NG	Thales 
	Sky Sabre	MBDA 
	Rapier	MBDA 
	Gepard	Krauss-Maffei Wegmann 
	Skyshield 35	Rheinmetall Defence 
	RBS 23 Bamse	Saab 
	SPADA SAM 2000	MBDA 
	NASAMS II/III	Kongsberg Defence & Aerospace 
	SA-6	Ulyanovsk Mechanical Plant and ZiK 
	GROM	Zakłady Metalowe Mesko 

Table 5. Overview of short-range air defence systems in use in Europe

313 The MIM-23 Hawk is actually an extended SHORAD system (with a 20-50 km range)

Users	System	Producer (company-state)
	FIM-92 Stinger	Raytheon Co. 
	AVENGER[314]	Boeing 
	LeFlasys	Rheinmetall Defense Electronics and Krauss Maffei Wegmann 
	MISTRAL	MBDA 
	CROTALE NG	Thales 
	SA-13	Degtyaryov Plant 
	STARSTREAK	Thales 
	RBS70 NG	Saab 
	MANTIS	Rheinmetall Air Defence 
	Oerlikon	Oerlikon Contraves 

Table 6: Overview of very short-range air defence systems in use in Europe

314 Avenger systems are used by a US division deployed in Germany

European militaries have grown increasingly wary of the UAV threat and have begun directing resources to the development of counter UAV (C-UAS) capabilities. Research and development programs are in full swing, at both national and European level, including a C-UAS project under PESCO led by Italy.[315] While technologies currently in use in Europe primarily rely on radio-frequency and GPS jamming,[316] a considerable number of programs are focusing on the development laser technology.[317] Overall, defence against drones is clearly gathering momentum, as illustrated by Germany's recent decision to redirect resources towards drone defence.[318] Table 6 offers an overview of these systems in Europe.

7.4.1 Shortfalls in European tactical defence

We note multiple shortfalls in European defence against tactical level air and missile threats, which consists of an overall shortage VSHORAD and SHORAD systems across Europe, a shortage of counter-UAV systems, especially when it comes to countering loitering munitions, short-range air defences against aircraft, and against rockets, artillery and munitions.

Insufficient defence against UAVs, including loitering munitions. The proliferation of UAVs has created major shortcomings in existing approaches towards air defence. The response has been significant: the number of dedicated counter-UAV systems has increased from a dozen in 2015 to more than 500 in 2020.[319] Whether that makes interoperability more effective is questionable. The problem is technological in part but also one of cost-effectiveness. While in theory many regular interceptors ranging from long-range Patriot to very short-range MANTIS can be used to counter most of the UAV threats, specific UAV features (such as manoeuvrability) and the issue of proportionality have spurred demand for dedicated systems. That said, higher-tier systems such as Patriot are well suited to counter HALE and MALE UAVs, as they fly generally high, relatively slow, and are not very agile. Medium-range interceptors such as NASAMS can target MALE but not all HALE systems. Line-of-sight interceptors can target UAVs but were designed to counter targets with steady flight paths. Loitering munitions specifically make use of these weaknesses. While perhaps not equipped with the same destructive power as more sophisticated weapons, they can be used against C2-nodes and radars to knock out the defences against those more sophisticated weapons and aircraft.

7.4.2 Why it matters

The inability to successfully defend military units against more precise attacks could be exploited by adversaries to such an extent that current estimates of friendly troop levels needed to defend and deter geographically important locations are insufficient. Using the

315 "Counter Unmanned Aerial System (C-UAS) | PESCO," January 20, 2021, https://pesco.europa.eu/project/counter-unmanned-aerial-system-c-uas/.

316 "CSD-CUAS-2nd-Edition-Web.Pdf," accessed February 8, 2021, https://dronecentre.bard.edu/files/2019/12/CSD-CUAS-2nd-Edition-Web.pdf.

317 For instance Tom Kington, "Italian Air Force Eyes Microwaves and Lasers to Defeat Drones," Defense News, May 24, 2021, https://www.defensenews.com/unmanned/2021/05/24/italian-airforce-eyes-microwaves-and-lasers-to-defeat-drones/; Philip Butterworth-Hayes, "France Trials C-UAS Laser Defence System Planned for 2024 Olympics," *Unmanned Airspace* (blog), July 9, 2021, https://www.unmannedairspace.info/latest-news-and-information/france-trials-c-uas-laser-defence-system-planned-for-2024-olympics/.July 9, 2021, https://www.unmannedairspace.info/latest-news-and-information/france-trials-c-uas-laser-defence-system-planned-for-2024-olympics/.

318 Sebastian Sprenger, "Germany Shelves New Anti-Missile Weapon and Turns to Drone Defense," Defense News, March 23, 2021, https://www.defensenews.com/global/europe/2021/03/23/germany-shelves-new-anti-missile-weapon-and-turns-to-drone-defense/.

319 "CSD-CUAS-2nd-Edition-Web.Pdf."

UAVs to overwhelm or bypass defences to target weak spots in the defence infrastructure could quickly upset the local military balance. Such early losses by the defender could then be further exploited with simultaneous attacks on logistical nodes and lines of communication at the theatre level. Without additional resources and reinforcements, tactical losses would be even more difficult to sustain.

Using the UAVs to overwhelm or bypass defences to target weak spots in the defence infrastructure could quickly upset the local military balance

8. Recommendations for European air and missile defences

How actors employ new and existing technologies is decisive, particularly their ability to utilise mixed attacks with multiple weapon systems that benefit from saturation with large numbers

Why should European states invest in more effectively integrated air and missile defences? Our study highlights multiple intersecting geopolitical and technological trends in the threat environment with consequences for the short-to-medium term of the next five to ten years and the medium-to-long term of ten to fifteen years. These threats will have varying consequences on the strategic, theatre and tactical levels, as vulnerabilities vary across each of them. They affect both the societal and economic security of European, as well as their military security. We underline that vulnerabilities are not just a question of technological developments, whether it be advances on the side of the attacker or shortcomings on the part of the defender. *How* actors employ new and existing technologies is decisive, particularly their ability to utilise mixed attacks with multiple weapon systems that benefit from saturation with large numbers. Current trends suggest potential aggressors would have offensive advantages against current European capabilities, as well as conceptual and doctrinal employment practices.

Unless the defender takes action, the offense-defence balance at both the theatre and tactical levels is shifting to the advantage of the attacker. Our study emphasises the increased vulnerability of military or dual-use civilian-military infrastructure at the theatre level and of military forces at the tactical level.[320] The return of Russia as a revisionist power in Europe ensures that at least one actor has the ability, and may be inclined, given the right circumstances, to use air and missile weapons against Europe at the strategic, theatre and tactical levels. Other major and regional powers can threaten sea lines of communication at the theatre and tactical levels. Additionally, minor powers and non-state actors can use relatively unsophisticated weapons in sophisticated manners to pose a serious, if less encompassing, threat as well.

What does this mean for Europe? The consequences for deterrence in Europe are significant. If European states, or the United States, have their access within the theatre significantly impeded, the fundamental logic that the Enhanced Forward Presence's tripwire forces would trigger large-scale reinforcements is broken. Ports and airfields, command and control (C2) nodes and staging areas are essential to theatre-wide operations. Moreover, the potential ability to rapidly exploit tactical successes will not remain constrained at a local level but reverberate to consequence at the theatre level. Specifically, possible tactical weaknesses make the importance of theatre level operations even more important. Especially, as in the case

320 We do not mean that there is no threat at the strategic level to civilian populations and infrastructure in Europe, rather that the situation there has not changed to as significant a degree as at the theatre and tactical levels.

of Russia, if a potential adversary has the ability to threaten civilian and economic security through conventional and non-conventional means.

Are there solutions? Simply put, the systems of the defenders should be similarly integrated to those of the attackers, equally taking into account technology, concepts and doctrine, as well as numbers. The chapter offers multiple recommendations for European states, while the next chapters offers more specific recommendations for the Netherlands.

8.1 Denying the adversary the benefits of aggression: Building European A2/AD

For Europeans, air and missile defence sits at the centre of effective conventional deterrence through denial

For Europeans, air and missile defence sits at the centre of effective conventional deterrence through denial. This means that European states can raise the costs of aggression sufficiently to dissuade an adversary from pursuing aggression. In effect, European states would be creating their own Anti-Access Area Denial (A2/AD) capabilities. Similar measures have been proposed for the Asian allies and partners of the US.[321] The motives for European states would be the same. In the current era, European allies cannot expect the US to protect and reinforce Europe as easily as it did in the past. China has been the pacing threat for the past three US administrations, a fact which the Biden administration reiterated.[322] The focus for US planning is thus on the broader Indo-Pacific,[323] and not on Europe. Effectively this has made Europe the secondary theatre.[324] The constraints on US power have increased in the meantime and are putting significant pressure on the US to choose between regions.[325] Force planning constructs are reflecting these changes[326] and highlight especially the limits of US naval capabilities, as these become crucial to the Indo-Pacific theatre.[327]

What this means is that Europeans will need to think about how to protect military infrastructure and lines of communication, and not only about how best to protect individual military units. At its core, this is needed to ensure that US reinforcements can arrive quickly in Europe through ports and airports in the European theatre and that Western European forces can move quickly to the Eastern flank. The US Navy may not be able to cover the sea lines of communication when the US is already engaged in the Indo-Pacific for a crisis there - a

321 James R. Holmes, "Defeating China's Fortress Fleet and A2/AD Strategy: Lessons for the United States and Her Allies," accessed August 11, 2021, https://thediplomat.com/2016/06/defeating-chinas-fortress-fleet-and-a2ad-strategy-lessons-for-the-united-states-and-her-allies/; Michael Beckley, "The Emerging Military Balance in East Asia: How China's Neighbors Can Check Chinese Naval Expansion," *International Security* 42, no. 2 (2017): 78–119; Caroline Dorminey and Eric Gomez, *America's Nuclear Crossroads: A Forward-Looking Anthology* (Cato Institute, 2019); Patrick Porter, "Advice for a Dark Age: Managing Great Power Competition," *The Washington Quarterly* 42, no. 1 (2019): 7–25.

322 Joseph R. Biden, "Interim National Security Strategic Guidance," March 3, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/03/interim-national-security-strategic-guidance/.

323 "Pentagon Rebrands PACOM as 'Indo-Pacific Command,'" Defense One, accessed October 24, 2018, https://www.defenseone.com/threats/2018/05/pentagon-rebrands-pacom-indo-pacific-command/148612/.

324 Luis Simón, Linde Desmaele, and Jordan Becker, "Europe as a Secondary Theater? Competition with China and the Future of America's European Strategy," *Strategic Studies Quarterly* 15, no. 1 (2021): 90–115.

325 See, for example, the discussion in: Hal Brands and Evan Braden Montgomery, "One War Is Not Enough: Strategy and Force Planning for Great Power Competition," *Texas National Security Review* 2, no. 3 (2020).

326 Mattis, "National Defense Strategy of the United States of America."

327 Paul Van Hooft, "All-in or All-out: Why Insularity Pushes and Pulls American Grand Strategy to Extremes," *Security Studies*, 2020; Paul Van Hooft, "Don't Knock Yourself Out: How America Can Turn the Tables on China by Giving up the Fight for Command of the Seas," *War on the Rocks*, February 23, 2021.

fact that Russia could take advantage of.[328] It also means that the European navies should become more capable in protecting themselves and commercial vessels that move across the sea lines of communication through the Mediterranean, Red Sea, Gulf and Indian Ocean. Air and missile defence ensures sufficient political manoeuvre room and diminishes the opportunities for blackmail against allies.

The defence of civilian and military targets from air and missile threats also cannot be disengaged from the larger deterrence-related questions. European states must think more about how to manage the steps on the escalation ladder, and this may include thinking about deterrence by punishment – the latter not necessarily nuclear. Moreover, they also must be willing to explore offensive actions that pre-empt an adversary's use of air and missile weapons against European interests. These could include cyberattacks on non-nuclear opponents where the risk of inadvertent nuclear escalation is absent. However, such aspects are beyond the scope of the project.

European policymakers need to be aware and make clear that they face important choices regarding which targets to protect with limited resources. Should the national territory be given priority over alliance commitments? Policymakers and the wider public must then acknowledge and even accept vulnerabilities: given current capabilities, many valued targets will remain undefended. Other deterrent measures should hopefully suffice there but a reappraisal of current deterrent as related to these threats is needed.

More actors are capable of delivering more firepower with greater precision, continuing a trend that has been ongoing for more than a century

Below we discuss a number of active and passive defence strategies to address the gaps identified in chapter 7. As current geopolitical and technological trends overlap and interact, so do our recommendations. In line with the rest of our analysis, we emphasise the importance of addressing the shortcoming specifically at the tactical and theatre levels.

8.2 Keep it moving: Combining active and passive defence measures

Combining active and passive defence measures is needed as a counter to the new potential for combined attacks. We noted that defenders run the risk of being overwhelmed. As the time windows to actively defend against air and missile threats are shrinking, current capabilities do not suffice in dealing with multiple high-speed, or variable speed, attacks. Simply put, more actors are capable of delivering more firepower with greater precision, continuing a trend that has been ongoing for more than a century. As firepower increased together with the possibility to acquire targets through aircraft, military forces became more and more vulnerable. Because they allow for persistent sensing, satellites and unmanned aerial vehicles (UAVs) have further increased that challenge for the defender. Surface based forces are therefore increasingly vulnerable to missile- and air attacks from major power, minor powers, and non-state actors.[329]

At the theatre and at the tactical level, passive defence measures are part of the solution against greater transparency and precision. Greater mobility and dispersion dampen the

328 Hal Brands and Evan Braden Montgomery, "Opportunistic Aggression in the Twenty-First Century," *Survival* 62, no. 4 (2020): 157–182.

329 The 2020 conflict in Nagorno-Karabakh between Azerbaijan and Armenia underlined that even a small state like Azerbaijan can be highly effective by creatively utilizing the possibilities of technological advances.

cost-effectiveness of attacks despite greater precision and firepower. In terms of the concepts and doctrine required, Europe's military forces must thus renew their attention to operational concepts.[330] They can do so through intelligent operating concepts that combine active and passive defences.[331] This is not easy. Passive defensive measures will require more delegation to the unit level and increase the overall complexity of operations. Yet, the costs of failure are significant.[332] At the technical level, the importance of integrating defensive systems into networks becomes greater. Networking sensors and interceptors requires a robust C2 architecture, and an acknowledgment of other vulnerabilities. At the conceptual and doctrinal level, getting it right requires persistent attention to simulations as well as life exercises.

Preventive solutions, whether kinetic in the form of missile or air attacks, or non-kinetic in the form of cyber operations, remain an option. But it is an option that should be carefully considered during the pre-conflict and conflict stages, at least at the strategic and theatre levels when facing major powers, to avoid rapid inadvertent escalation. At the tactical level, striking first is an obvious component of defence.

8.3 Mixing it up, but more is more: High-end and low-end mixes, redundancy

Defenders risk being overwhelmed by combined attacks and their systems being saturated with an attacker's weapons. Possible attacks that combine sophisticated and unsophisticated weapon systems require parallel high-end and low-end defensive responses.[333] Point defences around key nodes are essential. High-end interceptors have limited availability and their small stocks will deplete quickly. They are consequently not effective at intercepting the newer slow-moving UAVs or loitering munitions. Because basic systems such as a 76 mm gun can protect against UAVs and loitering munitions, it is low-hanging fruit for acquisition.[334] For European states, investments on the low-end of sensing and interceptors would therefore have relatively high returns.

European states could consider schemes such as common stocks or interceptors pools near areas likely to be attacked in case of a conflict

European states have underinvested in interceptor stocks. The cliché that less is more definitely does not apply here. Trading effectiveness for efficiency leaves too many military forces and infrastructure insufficiently protected. Despite the exorbitant costs of interceptors, the value of almost any high-value target that they protect vastly exceeds those costs in human, financial and strategic terms. If they can ensure their systems are more interoperable (see §8.4), European states could consider schemes such as common stocks or interceptors pools near areas likely to be attacked in case of a conflict. Collectively, Europeans could enhance defence capacity through clever burden-sharing, whereby militaries focus on

330 As political scientist Stephen Biddle notes, the modern system of warfare relies on a tightly interrelated complex of cover, concealment, dispersion, suppression, independent manoeuvre, and combines arms, and in-depth reserves, and differential concentration at the theatre level, to mitigate the costs and risks of exposure to the destruction of firepower. Stephen D. Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton University Press, 2004), 3, 28–51.

331 See for multiple ideas along these lines: Karako and Rumbaugh, *Distributed Defense*.

332 For example, see Biddle's discussion of the failure of the Iraqi army to implement the modern system in the 1991 Gulf War. Biddle, *Military Power*, 132–49.

333 Interviews with US defence industry expert, with French defence official, June 2021.

334 The possibility for automatisation of these defences against UAVs should be seriously considered, as this would provide a less labour-intensive solution for European armed forces struggling to fill their personnel levels.

different capabilities according to their budgets, manpower and technological expertise. Capital injections could help certain countries focus on low-hanging fruit, while Europe's larger military powers could direct their attention to capital- and expertise-intensive systems. Naturally, the same goes for the development of new systems such as counter unmanned aerial system (C-UAS) technology.

On both high and low ends of the spectrum, efforts are ongoing. NATO members have launched several initiatives to fill the short-range defence gap. In 2018, the US activated the 5th Battalion, 4th Air Defence Artillery Regiment (5-4th ADAR) in Germany. Initially equipped with Avengers, in FY2021 this battalion is planned to transition to the M-SHORAD, providing defence against UAVs as well as rotary- and fixed-wing aircraft. Nine more battalions that are part of the European Deterrence Initiative (EDI) should be added – four of which are planned to arrive by 2024.[335] Initiatives are being undertaken by European allies, too: during a NATO meeting in October 2020, the defence ministers of Belgium, Denmark, Germany, Hungary, Italy, Latvia, the Netherlands, Slovenia, Spain and the United Kingdom launched an initiative for the development of very short-, short-, and medium-range ground-based air defence (GBAD) capabilities.[336]

As counter UAV poses distinct challenges to C2 that can have repercussions on the theatre, tactical, and even strategic level, an EU PESCO project led by Italy and with participation by Poland is currently developing an "advanced and efficient system of systems with C2 dedicated architecture, modular, integrated and interoperable with C2 info-structure, able to counter the threat posed by mini and micro Unmanned Aerial Systems".[337] Non-kinetic options, such as electronic warfare (EW) should also be explored. EW attacks can hinder and disrupt C2 and positioning, navigation and timing (PNT) services, destroy the C2 link between the UAV and its remote control,[338] as well as disrupt satellite signals, radar signals and digital data links communication signals.[339] Laser weapons could also be effective against UAVs: they might require too much energy to protect mobile units but they could be deployed to protect static or less mobile C2-nodes and radar installations.[340] Once technology of ground- and ship-based lasers against smaller targets (such as UAVs) has matured and proven its worth, efforts should be focus on air-based defensive lasers that potentially target larger threats such as missiles.[341] Finally, high power microwave (HPM) technology is promising, especially in the defence against groups of drones, but challenges including harm to a defender's own systems remain unsolved for now. Doubling down on research and development here could prove valuable. Against high-end threats, creative alternative measures could also yield successes.[342]

335 Andrew Feickert, "U.S. Army Short-Range Air Defense Force Structure and Selected Programs: Background and Issues for Congress," n.d., 30.

336 NATO, "Modular Solution for Very Short Range, Short Range, and Medium Range Ground Based Air Defence Capabilities (Modular GBAD)," October 2020, https://www.nato.int/nato_static_fl2014/assets/pdf/2020/10/pdf/2010-factsheet-mod-gbad.pdf.

337 "Counter Unmanned Aerial System (C-UAS) | PESCO," accessed January 20, 2021, https://pesco.europa.eu/project/counter-unmanned-aerial-system-c-uas/.

338 André Haider, "A Comprehensive Approach to Countering Unmanned Aircraft Systems," *Joint Air Power Competence Centre* (blog), August 16, 2019, https://www.japcc.org/portfolio/a-comprehensive-approach-to-countering-unmanned-aircraft-systems/.

339 Adamy, "EW 102 : A Second Course in Electronic Warfare."

340 Interview with Dutch defence official, July 2021.

341 "Directed Energy Weapons: An Overview of the Current State of Technology and Systems" (NLR, n.d.).

342 Though still far off, using a grouping of UAVs with or without chaff against a hypersonic weapon could use the glide vehicle's extreme speeds against it. Given the difficulties in designing the glide vehicle materials, due to the sensitivities of resistance at high speeds, an approximate collision with material could transform the glide vehicles into a ball of molten slag.

Finally, it could be argued that gaps exist between the various levels of defence with, for example, few European capabilities existing above the theatre level (such as Patriots and SAMP/Ts) but below the strategic level (that is currently covered by US-deployed SM-3s). Investments in systems such as THAAD could fill this gap.

8.4 Getting more out of what is already there: Building systems of systems through integration, interoperability, and artificial intelligence

Because many systems are so expensive, it is not feasible for European NATO or EU member states to defend themselves against the entire spectrum of threats on an individual basis

The air and missile defence systems in Europe often cannot interoperate with each other directly for both technological reasons as well as conceptual, doctrinal and organisational reasons. At the technological level, the various defensive systems are unable to directly communicate with each other. That inability applies not only to systems manufactured by different weapons producers but also the systems of one producer deployed by different states (see 7.3.2).[343] Beyond difficulties in communicating with other systems directly, launchers generally cannot exchange interceptors between each other. The limited European capabilities are therefore further hampered by their inability to access the potential that is already theoretically available. That is a missed opportunity. Because many systems are so expensive, it is not feasible for European NATO or EU member states to defend themselves against the entire spectrum of threats on an individual basis. Cross-national integration of sensing and interceptor systems would therefore have high returns on investment.

Interoperability also requires greater conceptual and doctrinal coordination. It is not only a question of protocols and communication systems, but also of understanding the weaknesses of the partners' systems in terms of how these are employed.[344]Increased simulations and testing provide insight into the so-called error budget through the entire kill chain from sensors to C2 to the interceptors. Without understanding the other's error budget, planners will need to make the safest, worst-case assumptions about each step. Interoperability is therefore not an ICT discussion but a behavioural one.[345]

On the technical end, artificial intelligence (AI) can play a key role in improving speed and accuracy, and shortening the C2-cycle, specifically to capitalise on better integrated systems.[346] AI-augmented air defence systems can process data coming from drones, satellites and radars, for example, in a fraction of the time needed by human operators, then pool them to obtain a picture of the threat and thus "automatically sense and detect targets and fire upon them."[347] Due to its capacity to synthesise large volumes of data, the addition of AI to early warning missile systems could exponentially accelerate the decision-making timeframe,

343 The lack of integration even exists within the services. Apparently, West Coast and East Coast based US Navy vessels have difficulties talking to each other. Interview with US defence industry expert, June 2021.

344 Interview with US defence industry expert, June 2021.

345 The error budgets would be determined by thousands of non-deterministic Monte Carlo simulations to model the system's behaviour from end to end and determine its error budget; life fire exercises are not where the main demand is (though they are good for military personnel's confidence). Interview with US defence industry expert, June 2021, also interview with Dutch defence official, June 2021.

346 Daniele Frisoni, "Potential Impact of Artificial Intelligence to C2 Systems," Joint Air Power Competence Centre, June 16, 2020, https://www.japcc.org/potential-impact-of-artificial-intelligence-to-c2-systems/.

347 Watts and Bode, "Meaning-Less Human Control: Lessons from Air Defence Systems for LAWS," 27.

allowing for a much faster response to hostile missile threats.[348] AI could also help to spoil the enemy's efforts to damage its communications networks and GPS and satellite signals by ranking incoming data rapidly and precisely to eliminate the less important signals.[349]

Integration may have to take place at varying speeds. Political and commercial interests hampered effective integration. European governments should push coordination between defence industries. Fortunately, some success has already been had in terms of integrating US and European systems.[350] Finally, beyond maximising the realisation of existing potential, European states still need to invest in stocks of interceptors.

8.5 Europe: Need to be resilient, robust, and space is the place

At the highest level of ambition, European states should invest in their own systems, pursue integration and build up stocks of interceptors. To lessen European dependencies within missile defence, within the current EU frameworks – EDA's Coordinated Annual Review on Defence (CARD), Permanent Structured Cooperation (PESCO) or European Defence Funds projects – several projects aim to improve European capabilities (see Table 7 for an overview of PESCO projects that relate to IAMD). One PESCO project would improve radio navigation, the EU Radio Navigation Solution (EURAS). EURAS aims to advance military PNT capabilities in the EU, is related to the Galileo satellite constellation and would feed into the wider missile defence architecture in Europe.[351] These systems aim to create "persistent ISR (intelligence, surveillance and reconnaissance), network centric operations, and future navigation technology".[352] Another PESCO project would build space-based early warning and defence – the Timely Warning and Interception with Space-based Theatre surveillance capability project (TWISTER). TWISTER aims to provide improved capabilities for space-based early warning systems and endo-atmospheric interceptors. While still in a very early phase, current plans foresee introducing the system in 2030, with the goal to contribute to NATO Ballistic-Missile Defence (BMD).[353] It certainly would also increase the EU's level of strategic autonomy in

348 James Johnson, "Artificial Intelligence & Future Warfare: Implications for International Security," *Defense & Security Analysis* 35, no. 2 (April 3, 2019): 152, https://doi.org/10.1080/14751798.2019.1600800. There have also been reports of a prototypical 'missile hunting' AI-driven system under development in the US that draws information, among other sources, from satellite imagery and sophisticated radars. Stewart, "Deep in the Pentagon, a Secret AI Program to Find Hidden Nuclear Missiles." Other AI AMD systems based on UAVs, such as the US-developed Project Maven, analyse data through the incorporation of "computer vision and machine learning algorithms into intelligence collection cells that would comb through Remotely Piloted Aircraft (RPA) footage and automatically identify hostile activity for targeting." Hoadley and Lucas, "Artificial Intelligence and National Security," 9.

349 Purabi Sharma, Kandarpa Kumar Sarma, and Nikos E. Mastorakis, "Artificial Intelligence Aided Electronic Warfare Systems- Recent Trends and Evolving Applications," *IEEE Access* 8 (2020): 74, https://doi.org/10.1109/ACCESS.2020.3044453.

350 There are initiatives such as the Maritime Integration Forum. Moreover, in May 2021, a US AEGIS operating vessel was cued by a Dutch air defence frigate operating a SMART-L radar. Dorian Archus, "USS Paul Ignatius Intercepts Ballistic Missile in Cooperation with the Dutch Frigate's SMART-L MM Radar," *Naval Post* (blog), May 31, 2021, https://navalpost.com/uss-paul-ignatius-intercepts-bm-smart-l-assistance/.

351 Fiott, "The European Space Sector as an Enabler of EU Strategic Autonomy," 36.

352 "Europe's Missile Defence and Italy: Capabilities and Cooperation," 2021, 40.

353 The TWISTER project was initiated by France, Finland, Italy, Spain and the Netherlands, while Germany is also a member since 2020. "Timely Warning and Interception with Space-Based TheatER Surveillance (TWISTER) | PESCO," accessed April 16, 2021, https://pesco.europa.eu/project/timely-warning-and-intercep-tion-with-space-based-theater-surveillance-twister/.

missile defence.[354] Through the combination of space-based early warning systems and the endo-atmospheric interceptors, TWISTER could offer great opportunities "against a broad range of threats, particularly concerning hypersonic missiles and gliders".[355] That said, it should be noted that projects like TWISTER are extremely costly and have a high risk of failure, leading some to point out that European investments in existing US-made systems would already be a significant improvement in European autonomy in the short-term.

Europeans could also consider investing in longer range interceptors to decrease their BMD dependency on the US. European procurement of missile defence capabilities that fall in the range above Patriot and SAMP/T but below SM-3, such as THAAD which covers about a surface half the size of the Netherlands, could be considered.

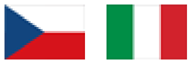
Project	Country Participant	Scope of project
Timely Warning And Interception With Space-Based Theatre Surveillance (TWISTER)		Defence against missile threats
EU Radio Navigation Solution		Development of EU military positioning, navigation and timing (PNT) capabilities and future coopera-tion taking advantage of Galileo
Counter Unmanned Aerial System (C-UAS)		Defence against mini and micro Unmanned Aerial Systems
Airborne Electronic Attack (AEA)		Design, development and testing of an interoper-able multi-jamming capability
European Military Space Surveillance Awareness Network (EU-SSA-N)		Protection of European MS Space assets and services
European High Atmosphere Airship Platform (EHAAP) – Persistent Intelligence, Surveillance and Reconnaissance (ISR) Capability		Development of cost-efficient and innovative ISR platform
EU Collaborative Warfare Capabilities (ECOWAR)		Allow interconnections between diverse current and future warfare platform
Strategic C2 System for CSDP Missions and Operations (EUMILCOM)		Improve the C2 systems of EU missions

Table 7: Selected PESCO projects

354 Fiott, "The European Space Sector as an Enabler of EU Strategic Autonomy," 35–36."Europe's Missile Defence and Italy: Capabilities and Cooperation," 2021, 39.

355 "Europe's Missile Defence and Italy: Capabilities and Cooperation," 2021, 38. "The EU's PESCO: Here to Stay?," IISS, accessed April 16, 2021, https://www.iiss.org/blogs/military-balance/2019/12/eu-pesco-hurdles.

9. Recommendations for the Netherlands

Which specific air and missile defence policies make the most sense for the Netherlands to pursue? This chapter takes the broader conceptual assessments of chapter 8 and applies these to more concrete policy recommendations for the Netherlands.

International cooperation and systems integration. Effective air and missile defences of national civilian and military infrastructure will be difficult without making use of the defensive systems of European partners and the United States, especially as the complexity of attacks is likely to increase. Unsurprisingly, our study underlines that the Netherlands should continue to focus on collaborating with European partners and the US – but also be aware of trade-offs in sovereignty when it comes to dealing with the latter.

Addressing Europe-wide gaps. The Netherlands should play a more proactive role in building a collective European response to continent-wide gaps in their integrated air and missile defence (IAMD) postures in the broadest sense, thus also pertaining to offensive postures including left-of-launch capabilities. European satellite-based intelligence, surveillance and reconnaissance (ISR) capabilities are currently poor but EU space projects such as TWISTER, the military use of the Galileo global navigation satellite system (GNSS) through the EU Radio Navigation Solution (EURAS) and the European Military Space Surveillance Awareness Network (EU-SSA-N) are set to change this. Obtaining more intelligence about capabilities at an early stage, long before a crisis, allows for more effective defensive solutions at a later stage – or to prevent their need. The 2011 Libya intervention demonstrated basic shortfalls by European states against a minor state. Prestige-driven prioritisation is questionable at a time when Europeans need to be smarter about their defence investments. Coordination at EU level is key.

Synchronising European efforts. The Netherlands should also play a more proactive role in synchronising capability development and procurement processes.[356] These continue to be largely separate among the different European states and among military units. European countries may want to consider buying stocks or capabilities in a coordinated manner to reduce order prices and increase leverage over sellers. In addition, the benefits of single source supply of various missile sizes to reduce maintenance costs should be considered against trade-offs such as monopoly risks. Synchronising capability and procurement processes, between the respective services as well as the separate European states, is key, such as in the procurement of missiles or the development of counter drone technology. European synchronisation could solve capability gaps and make those solutions more cost-effective but European cooperation should not be abused as a cost-cutting option. There is no more slack in the defensive system a whole.

356 The Netherlands is already cooperating with Germany through the Apollo project. Ministerie van Defensie, "Apollo - International Cooperation - Defensie.Nl," onderwerp (Ministerie van Defensie, February 26, 2016), https://english.defensie.nl/topics/international-cooperation/other-countries/apollo.

Rethinking stocks. The Netherlands, like other European countries, needs to address stock weaknesses. As the defence industry has largely come to rely on just-in-time supply, it is not only vulnerable to disruption but also poorly prepared if demand would spike in times of conflict. In this case, efficiency is not effectiveness. Creating redundancies in stock supplies, but also pushing for greater standardisation of missile launchers, even if opposed by suppliers, are options that need to be considered.

Netherlands as radar country. The Netherlands is positioning itself as a radar country. For a state with limited resources, this provides the Netherlands with a technological, industrial and operational niche within Europe. Research and development efforts have resulted in the production of the GM200 MM/C (Multi Mission Radar/MMR), which is able to detect and track targets simultaneously at various altitudes and cue very short range air defence (VSHORAD) up to short range air defence (SHORAD) systems.[357] The radars provide a solid 360-degree coverage for land-based units that need to defend themselves against the growing threats at the tactical level including rockets, artillery and munitions (RAM), unmanned aerial vehicles (UAVs), rotary-wing aircraft and fighters. It could go a long way towards addressing the changing threat environment the study has underlined at both the tactical and possibly the theatre level. Meanwhile, the SMART-L MM radar update allows for missile detection and tracking outside the atmosphere and enables communication with Aegis systems operating SM-3 missiles.[358] As such, the Netherlands is able to contribute to NATO BMD, adding redundancy, but also play a role in lower tier air defence. It is advisable that the Netherlands continues its efforts in the development of next generation radars to detect future threats (such as hypersonic missiles) and increase efforts on integration with international sensor networks, provide distributed effectors with queues for fire control solutions and develop smart solutions for a system to support IAMD.

The Netherlands is positioning itself as a radar country. For a state with limited resources, this provides the Netherlands with a technological, industrial and operational niche within Europe

Deterrence through sensing. Strengthening Europe's sensing capability is itself a valuable component of more effective deterrence, as it diminishes the benefits for aggressors to attempt a *fait accompli* surprise attack. The Netherlands is thus well-positioned to play a strong role in this European and allied capability.

Focusing on the low-end threat. The Netherlands should double down on short range air defence capabilities at the tactical level of IAMD. Currently, the Netherlands does not possess any dedicated capability to defend against loitering munitions (even if some systems such as Stinger and NASAMS have limited capacity in this direction), despite their relatively low costs. Further, investing in the development of counter unmanned aerial system (C-UAS) solid-state laser technology is another avenue worth exploring, before upscaling the technology to higher end threats. Another option to consider at the lower end of the capability spectrum is deepening cooperation with more vulnerable NATO partners that have fewer resources available, such as the Baltic States, for instance through working groups focusing on short range capability needs and capital injections.

In short, effective air and missile defence is not just matter of technology. Better defences of Dutch infrastructure and military units will not just be a matter of technology – and neither is the threat. Instead, both defenders and attackers are engaged in a competition to leverage technological innovations, with conceptual and doctrinal adaptation, as well investments in stocks to create redundancy. As the size and variety of the threats from the skies increase over the next decades, no single solution will suffice to protect Dutch population, infrastructure and military forces.

357 "Nieuwe radar voor landmacht," De Ingenieur, February 11, 2019, https://www.deingenieur.nl/artikel/nieuwe-radar-voor-landmacht.

358 "SMART-L Early Warning Capability (EWC) – Missile Defense Advocacy Alliance."

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