



NATO Parliamentary Assembly

SCIENCE AND TECHNOLOGY
COMMITTEE

MAINTAINING
NATO'S TECHNOLOGICAL EDGE:
STRATEGIC ADAPTATION AND DEFENCE
RESEARCH & DEVELOPMENT

GENERAL REPORT

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I. INTRODUCTION

1. The transatlantic Alliance finds itself in a new and dynamic strategic reality that is markedly different from the post-Cold War era. Russia has decided to position itself as a strategic competitor to NATO again. China is rising as a great power. And both are challenging the established international order in a number of ways. Moreover, other emerging economies are gaining greater clout, and the terrorist threat continues unabated. Global trends, such as demographic and economic shifts, the proliferation of advanced conventional and unconventional weapons, pressure on scarce resources and the changing nature of conflict, add to the complex geopolitical and operational environment for future NATO actions.

2. At the same time, the world is entering a new age of innovation, which will likely have profound effects on the armed forces as well. On the one hand, a multitude of emerging technologies could potentially disrupt the global strategic balance (see also the annex). In recent years, the Committee has focused extensively on such technologies, and this report complements its activities on the subject.¹ On the other hand, the way innovation in science and technology (S&T) takes place has greatly changed. Today, innovation in many sectors is predominantly driven by the private sector. Gone are the days when advanced technologies almost exclusively emerged from efforts sponsored by governments – and often by militaries. As a result, armed forces often struggle to keep up with the pace of private-sector innovation or to leverage such innovation effectively and quickly. One reason is that small- and medium-sized enterprises (SMEs), start-ups and even individuals are driving important discoveries and innovation to a larger degree than before – a trend some have dubbed “the democratization of science” (Boustead, 2008). Finally, advanced economies no longer hold a monopoly on high-end technologies and innovation. More and more states have access to strategic technologies and, in some cases, are beginning to outpace traditional leaders in S&T.

3. These developments present the transatlantic community with novel challenges. It is imperative that NATO and its member states adapt to them. Investing in defence is a crucial element for successful adaptation. Regrettably, after the financial crisis of 2007/2008, defence budgets have declined or, at best, stagnated. The picture for defence research and development (R&D) is even bleaker, as this report shows. In addition, the transatlantic community has been engaged in expensive asymmetric military operations for over 15 years. Meanwhile, other states have used and increased their resources to make serious progress in potentially game-changing defence R&D. In particular, Russia and China are trying very hard to close the technological gap with the United States – the global defence technology leader. Put bluntly, NATO’s technological edge is eroding. Therefore, to safeguard our freedom and shared values, strategic defence R&D policy decisions are necessary and urgent.

4. If NATO is to remain credible as an Alliance, there can never be any doubt about its ability to fulfil its three essential core tasks: collective defence, crisis management and cooperative security. Defence R&D is crucial to all of them. However, to live up to the promise of collective defence under Article 5, it is essential the Alliance maintains the full spectrum of capabilities to deter and defend against any threat. Thus, many Allies have come to realise there is a need to both increase investment in defence R&D and to rethink how they approach and organise their defence R&D.

5. As this report shows, defence R&D budgets are indeed rising in many NATO member states. However, it is perhaps more important that North America and Europe are engaging in initiatives to change their approaches to defence R&D. The United States is engaged in a Defense Innovation

¹ The [Science and Technology Committee](#) has focused on emerging technologies through reports on select topics, during Committee meetings and visits, but also a small-scale expert survey. In 2017, the Sub-Committee on Technology Trends and Security (STCTTS) continues this work with a report on [The Internet of Things \[175 STCTTS 17 E\]](#).

Initiative/Third Offset Strategy; other Allies have embarked on their own innovation efforts; and the European Union (EU) is discussing a European Defence Fund to reinvigorate European defence R&D. Despite these efforts, NATO member states must do more – at the national level, via bi- and multilateral collaboration, through the EU and also as an Alliance.

6. Reinvigorating defence R&D is only one, albeit crucial, element of adapting the Alliance for the current and future strategic environment. Organizational adaptation, force modernization, strengthening the defence industrial base, acquisition reform and other elements must be pursued as well. The NATO PA and its Committees scrutinise all of these lines of effort on a continuing basis. In 2017, the [Defence and Security Committee](#) examined NATO-EU Cooperation after Warsaw and the [Economics and Security Committee](#) examined The State of Europe's Defence Industrial Base.

7. This report first evaluates if NATO's technological edge is indeed eroding through an analysis of defence R&D trends and spending in the Alliance as well as Chinese and Russian efforts. Then, it takes a closer look at:

- the US Defense Innovation Initiative/Third Offset Strategy;
- other examples of national initiatives within the Alliance;
- European efforts; and
- scientific and technological collaboration within NATO.

8. The report should be viewed as the beginning of the Committee's engagement to support a much-needed drive to maintain NATO's technological edge. Nevertheless, the report closes with initial recommendations aimed at strengthening the transatlantic approach to defence R&D. These recommendations serve as the basis for a resolution to be adopted at the NATO Parliamentary Assembly Annual Session in Bucharest, Romania, in early October.

II. IS NATO LOSING ITS EDGE IN DEFENCE TECHNOLOGY?

A. DEFENCE R&D TRENDS IN THE ALLIANCE

9. In recent years, it has become clear that the transatlantic advantage in defence technology is indeed eroding. Three root-causes can be identified:

- First, defence spending, including on R&D, in the rest of the world, most notably in China and Russia, has been rising at substantial rates, as compared to spending trends within the Alliance (see Figure 1).
- Second, advanced military and dual-use high-end technologies are proliferating and accessible to an ever-growing number of states across the globe – and even non-state actors (International Institute for Strategic Studies, 2016).
- Third, the rate in which technological progress takes place outpaces the Alliance's ability to introduce and adapt to those technologies in a timely manner (Carter, 2015).

10. The United States has held the global defence technological edge since the end of the Second World War. However, the United States has come to the conclusion that non-allied states are catching up and thereby potentially undermining its technological advantage. In 2015, then-US Secretary of Defense Ashton Carter warned "It's evident that nations like Russia and China have been pursuing military modernization programs to close the technology gap with the United States. They're developing platforms designed to thwart our traditional advantages of power projection and freedom of movement" (Carter, 2015). While the United States remains ahead, he added that the lead was endangered by slow innovation and a lack of consistent budgets.

11. The relationship of overall defence expenditures between the Allies from North America and Europe has been unbalanced for many years (see Figure 2), with the United States accounting for 67.3% of overall defence expenditures (2017 estimate; NATO, 2017). The European Commission, for its part, has recognized that the member states of the EU lag far behind the United States and that other states, like China, Russia and Saudi Arabia, “have been upgrading their defence sectors on an unprecedented scale” (European Commission, 2016). The European Commission thus argues that “Without a sustained investment in defence, the European industry risks lacking the technological ability to build the next generation of critical defence capabilities. Ultimately, this will affect the strategic autonomy of the Union and its ability to act as a security provider” (European Commission, 2016).

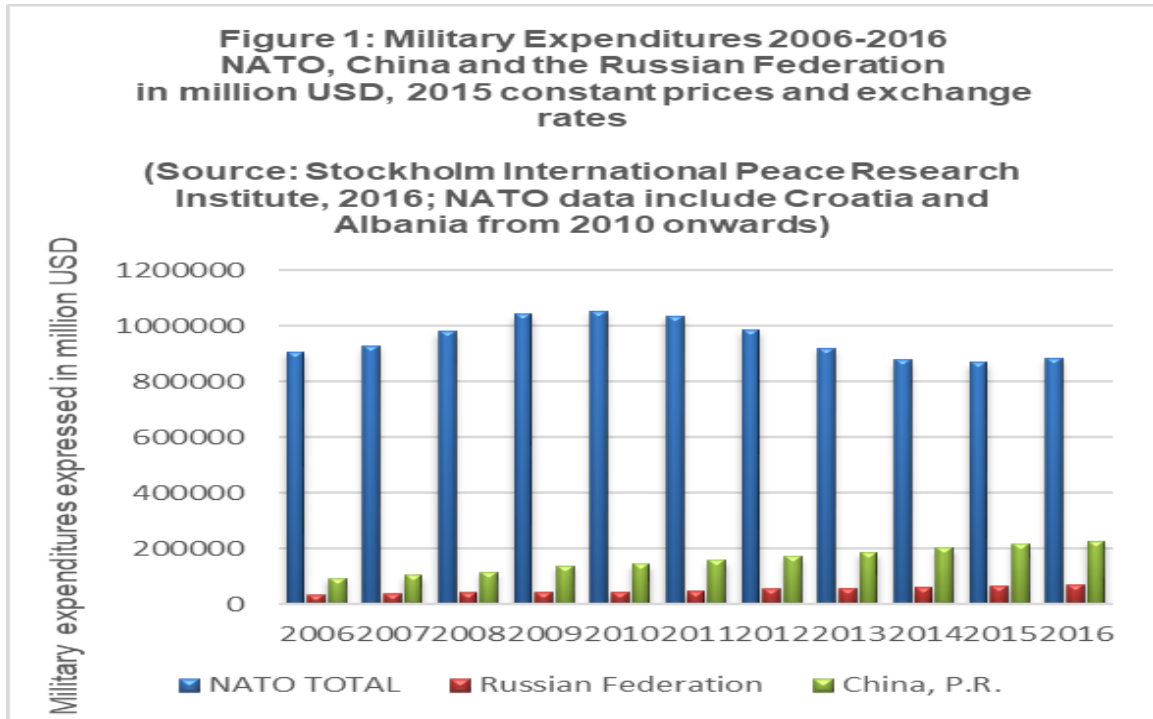
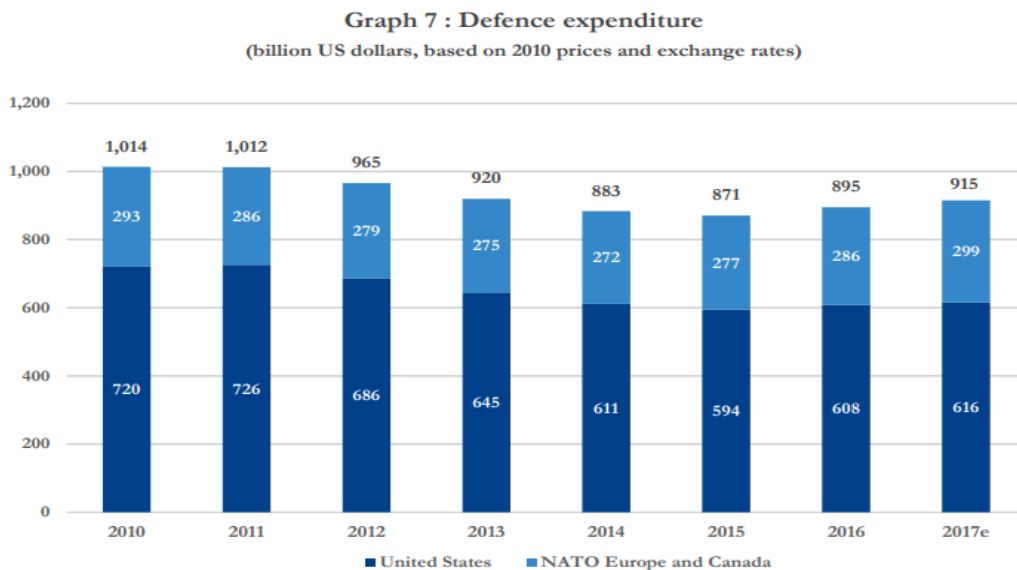


Figure 2: NATO Defence Expenditures 2009-2017e; source: NATO, 2017



12. NATO's publicly released data on defence expenditure does not include an exclusive category on defence R&D. Instead, the Alliance publishes data on equipment expenditure, which is defined as major equipment expenditure and R&D devoted to major equipment. Allies have committed themselves to move, by 2024, towards spending 20% of their annual defence spending on this category. Figure 3 shows that only nine member states reached that goal. In other words, much work needs to be done.

Figure 3: Equipment expenditure as percentages of total defence expenditure 2010-2017e (source: NATO, 2017)

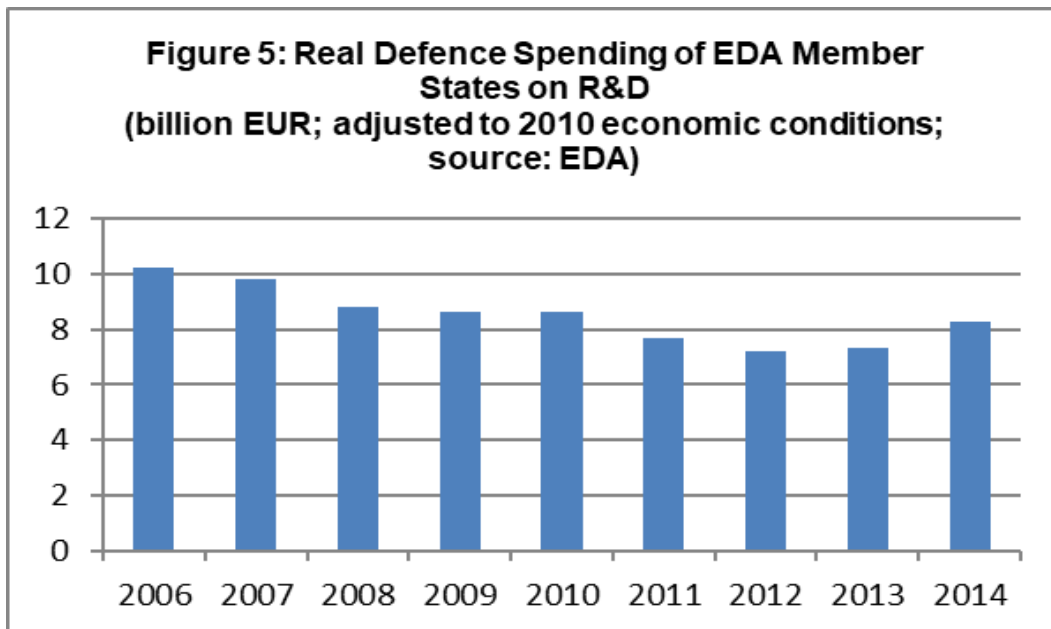
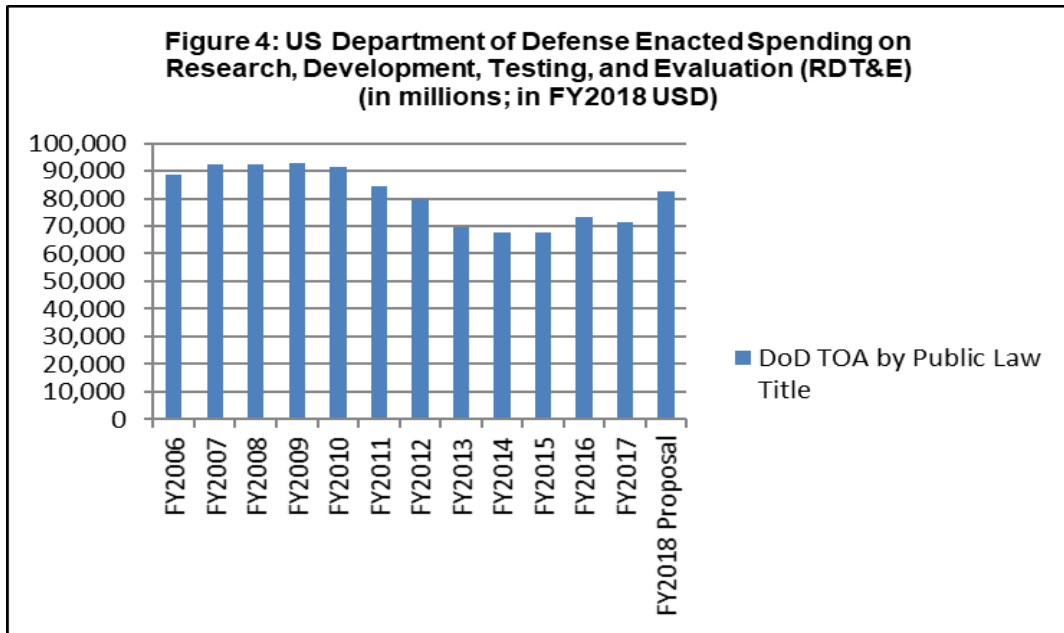
	2010	2011	2012	2013	2014	2015	2016	2017e
Albania	15.69	13.36	14.44	16.29	16.65	8.92	8.01	17.33
Belgium	6.79	6.27	3.57	2.84	3.52	3.44	4.66	5.30
Bulgaria *	15.41	6.33	3.68	4.52	1.03	3.47	9.15	29.54
Canada	13.81	9.67	8.31	11.16	13.03	10.46	10.84	19.42
Croatia	8.12	15.79	14.72	10.72	7.35	10.58	10.09	9.07
Czech Republic	12.42	13.30	14.78	9.49	6.53	11.76	6.70	12.90
Denmark	14.10	9.68	9.03	11.26	10.99	11.50	13.68	19.25
Estonia	11.88	10.11	13.69	14.48	22.15	12.82	17.86	19.27
France	30.20	28.17	30.58	24.53	24.64	25.04	24.44	24.17
Germany	17.59	16.41	16.45	12.74	12.94	11.93	12.21	14.08
Greece	17.98	5.86	7.47	12.06	8.17	10.26	13.43	15.44
Hungary	12.10	12.29	5.84	11.08	7.76	9.75	13.37	13.29
Italy	10.92	11.74	8.87	12.51	10.92	9.72	19.09	20.94
Latvia	15.62	10.78	10.45	12.09	7.55	13.60	19.28	20.29
Lithuania	10.00	9.38	11.20	9.23	14.06	21.55	30.06	31.09
Luxembourg	34.45	21.86	17.11	14.57	22.61	33.33	30.07	32.99
Montenegro	3.66	1.73	4.44	1.32	7.46	5.43	4.46	8.20
Netherlands	15.70	14.43	13.41	12.57	10.68	11.16	14.14	16.80
Norway	18.13	17.04	17.76	18.89	21.17	22.49	24.05	25.65
Poland	18.13	16.13	15.16	13.90	18.84	33.20	21.70	22.50
Portugal	13.20	12.07	9.34	8.65	8.43	8.70	9.95	10.31
Romania	8.80	7.57	4.14	10.71	15.77	19.65	20.43	46.49
Slovak Republic	9.81	7.15	9.56	7.39	11.12	18.28	15.31	20.16
Slovenia	18.00	5.70	1.20	1.27	0.66	1.85	1.02	6.09
Spain	12.10	6.74	22.86	12.37	13.49	14.82	6.65	19.31
Turkey	27.98	24.57	21.21	26.89	25.08	25.13	25.59	30.40
United Kingdom	24.47	22.01	19.54	21.89	22.82	21.75	21.56	22.03
United States	24.02	26.99	26.97	25.83	25.97	25.41	25.03	28.55

* Defence expenditure does not include pensions.

13. In the United States, the Department of Defense (DoD) budget for Research, Development, Test, and Evaluation (RDT&E) reached a high point in Fiscal Year (FY) 2009 with USD 92.6 billion (in 2018 USD). However, the funds appropriated for RDT&E experienced a sharp decline in the following years (see figure 4) and reached a low point in FY2015. At this point, RDT&E amounted to only USD 67.6 billion (in 2018 USD), i.e. a fall of 27% in real terms, as compared to FY2009. In FY2016, the budget rose by 8.6% to USD 73.4 billion (in 2018 USD). This demonstrates the United States takes the challenge in defence R&D seriously. President Donald Trump and the US Congress plan to substantially increase defence spending. Indeed, the President's 2018 budget called for a 16% rise in the RDT&E budget in real terms.

14. Expenditures for defence research in EU member states have likewise suffered enormously in recent years (see figure 5). (It should be noted that the data in this paragraph cannot be used to directly compare US and European R&D spending, as the data is not compatible.) The budgets allocated to defence R&D in the EU member states participating in the European Defence Agency (EDA) (i.e. all except Denmark) saw a steep decline from 2006 to 2012. In 2006, EDA member states spent EUR 9.8 billion on defence R&D (in current EUR). In 2012, they only spent EUR 7.5 billion (in current EUR), amounting to a fall of 23.5% in absolute terms. Expenditures for defence

Research and Technology (R&T) – a subset of R&D² – fell even more dramatically: by 27% between 2006 and 2013 (European Commission, 2016). National decreases varied widely, in the 2006-2013 timeframe: for example, France -13%; Germany -7%; Italy -41%; Spain -55%; Sweden -3%; and the UK -30% (European Defence Agency, 2016). In 2007, EDA member states agreed on a target of spending 2% of the total defence expenditures on defence R&T, but since then, defence R&T spending has barely been over 1% (Mauro & Thoma, 2016). These negative trends have finally been reversed: the years 2013 and 2014 (the last year with complete EDA data) saw year-on-year growths in defence R&D spending of 0.8% and 14.1% respectively (in real terms). In short, EU member states are beginning to take defence (and R&D) seriously again.



² The EDA defines defence R&D and R&T as follows (EDA, 2016):
 - “Defence Research and Development (R&D) expenditure: any R&D programs up to the point where expenditure for production of equipment starts to be incurred. R&D includes R&T.”
 - “Defence Research and Technology (R&T) expenditure: expenditure for basic research, applied research and technology demonstration for defence purposes. It is a subset of R&D expenditure.”

B. DEFENCE R&D TRENDS IN CHINA

15. For China, accurate defence spending data are notoriously difficult to obtain, if not impossible. However, it is safe to assume that China's defence R&D budget has been growing significantly, in line with the massive growth in its defence budget. Over the last ten years, the defence budget has grown by 150% (European Commission, 2016). The US DoD expects China's defence budget to increase by an annual average of 7%, growing to USD 260 billion by 2020 (Office of the Secretary of Defense, 2016). Indeed, in terms of its defence R&D budget, one team of experts argues that, in 2014 and based on conservative assumptions, it "amounted to almost EUR 20 billion" (Mauro and Thoma, 2016). Some defence analysts think that China's defence R&D budget could overtake the DoD's by 2022.

16. As a consequence, it comes as no surprise that the 2017 International Institute for Strategic Studies (IISS) Military Balance argued that "in some capability areas, particularly in the air domain, China appears to be reaching near-parity with the West" (IISS, 2017). Indeed, the IISS underlines that "China's progress in research and development, and its improved military capabilities, mean that it is now the single most important driver for US defence developments."

17. The DoD reports that "Over the past decade, China has made dramatic improvements in all defence industrial production sectors" (Office of the Secretary of Defense, 2016). The People's Liberation Army (PLA) continues to decrease its reliance on foreign weapons acquisitions, but remains dependent on foreign assistance to fill critical, near-term capability gaps. In the long term, China aims to establish a comprehensive indigenous defence industrial and technological base with strong commercial underpinnings in order to meet the needs of PLA modernization and to compete globally.

18. To develop China's defence-industrial and technological base, it relies on foreign investments; commercial joint ventures; academic exchanges; the experience of Chinese students and researchers; and state-sponsored industrial and technical espionage. According to news reports, the US DoD is also reviewing China's investment in emerging technologies in US technology start-ups (Mozur and Perlez, 2017). Between 2010 and 2016, Chinese citizens and companies invested roughly USD 30 billion into emerging technologies in the United States. The worry is that, through such investments, China is gaining access to important dual-use technologies, for example artificial intelligence, augmented reality, robotics and self-driving technologies.

C. DEFENCE R&D TRENDS IN RUSSIA

19. Globally, Russia is ranked number eight globally for government R&D spending (Industrial Research Institute, 2016). Indeed, the country has strong infrastructure and scientific leadership in many industries, including aerospace, military/defence, manufacturing/production and materials/resources. Russia's political infrastructure and aspirations have, however, limited its R&D capabilities since the collapse of the Soviet Union. A troubled economy, low oil prices and Western sanctions as well as a high level of corruption diminish its overall abilities to increase its technological capabilities in the long term. For a long time, R&D has suffered from restricted budgets, recruiting limitations, falling morale and a failing infrastructure.

20. Russia's economic troubles have also had a negative effect on its USD 720 billion military modernization effort, a ten-year program launched in 2010.³ Its main aim is to go from 10% of equipment classed as "modern" to 70% by 2020 (The Economist, 2014). Moscow's success in these efforts has been mixed: while exact numbers are hard to find, it seems clear that the share of modern equipment in service has been increasing (Mugg, 2017). However, experts believe that

³ See the 2015 STC General Report [176 STC 15 E rev.1 fin] on [Russian Military Modernisation](#).

Russia’s “armed forces also retain significant strength in traditional competencies like armoured and electronic warfare and in capabilities like rocket artillery” and that “Russian equipment outranges the missile and rocket artillery systems of NATO’s most capable power, the US” (IISS, 2017).

21. From 2012 to 2015, Russia’s defence R&D doubled (Mauro and Thoma, 2016). In 2015, the budget item on “applied scientific research in the area of defence” was valued at RUB 286 billion (c. EUR 4.1 billion at 2015 exchange rates), and in 2016, it amounted to RUB 311 billion (c. EUR 3.5 billion in 2016 exchange rates). The Russian Ministry of Defence controls 47 science institutions, and it has initiated further development of defence R&D institutions. A key effort is the Advanced Research Fund, established in 2015 and with a budget of c. EUR 200 million (Mauro and Thoma, 2016). Part of these plans is the establishment of five research institutions, to be overseen by First Deputy Minister of Defence Valery Gerasimov. Each of the institutions will specialize in a particular research area, such as aviation, biotechnology, laser technology and surveying as well as navigation software. The recently established Military Scientific Committee of the Armed Forces will have control of all research (Gerden, 2015).

III. US DEFENSE INNOVATION INITIATIVE/THIRD OFFSET STRATEGY

22. In November 2014, then-Secretary of Defense Chuck Hagel announced the Defense Innovation Initiative under then-Deputy Secretary of Defense Robert Work. He hoped the Initiative would become the foundation of a Third Offset Strategy (for its Cold War-era predecessors, see figure 6). In a time where “American dominance in key warfighting domains is eroding, Secretary Hagel argued that “we must find new and creative ways to sustain, and in some areas expand, our advantages even as we deal with more limited resources” (Hagel, 2014). The Defense Innovation Initiative/Third Offset Strategy approaches defence technology innovation in three ways: defence R&D within the DoD, importing/integrating R&D from the non-defence private sector and repurposing existing DoD technologies (in the form of the Strategic Capabilities Office) (Carter, 2016).

Figure 6: Previous US Offset Strategies	
First Offset Strategy (1950s): New Look	Development of tactical nuclear weapons to offset conventional superiority of the Soviet Union.
Second Offset Strategy (1970s/1980s): Offset Strategy	Military superiority through innovation, including through stealth aircraft, precision-guided munitions as well as new intelligence, surveillance and reconnaissance platforms

23. Secretary Hagel’s successor Secretary Ashton Carter vigorously supported and built upon the Defense Innovation Initiative. The Initiative is currently under review in the DoD. However, new Secretary of Defense James Mattis told Senators during his confirmation hearing that “In general, those areas identified in the development of the Third Offset Strategy are worthy of investment,” adding that he “will review the current portfolio of technologies under development and ensure that those provide the nation with long-term technological superiority” (Mattis, 2017). He added that the United States “should be tolerant of risk in order to foster innovation and encourage technological leaps”. The fact that Deputy Secretary Work was kept on until July 2017 has been seen as a positive sign as well.

24. Crucially, the Defense Innovation Initiative/Third Offset Strategy is, to a large degree, not only about defence R&D spending. The DoD realizes that adaption to the new technological landscape, including related disruptive technologies, is also about industrial readiness, systems integration, cultural receptivity and organisational capacity (Hasik and Callan, 2014). In fact, a Long-Range Research and Development Planning Program was only one of five work strands when the Defense Innovation Initiative/Third Offset Strategy was announced (see figure 7). According to Deputy Secretary Work, “This is not about a revolution in military affairs. There’s always going to be a strong technological component, but it is strategy-based, technologically oriented, and you want operational and organizational constructs that give you an advantage and an offset against your adversaries who might outnumber you” (Work, 2015a).

Figure 7: Areas of the US Defence Innovation Initiative
Leadership development reform
New long-range R&D planning programme
Reinvigorated wargaming effort
New operational concepts
Business practice reform

25. In terms of defence technology, the Defense Innovation Initiative/Third Offset Strategy has three components or stages (Work, 2015b). In the near term, the recently created Strategic Capabilities Office (SCO) is responsible for repurposing technologies and capabilities already in the DoD’s inventory. The SCO identifies, analyzes and introduces disruptive applications and new and unconventional uses of existing systems and near-term technologies. An early success story was the repurposing of SM-6 Standard Missiles – defensive ship missiles designed to shoot down aircraft and cruise missiles – into an offensive anti-ship missile. Other projects include an “arsenal plane”, which will be a plane loaded with different payloads to make it extremely flexible, and adapting ground-to-ground howitzers into anti-ship missiles. In the medium-term, the DoD will conduct strategic portfolio reviews of technologies that could feed into the Third Offset Strategy. Over the long term, the DoD will identify, develop and field in game-changing technologies and systems. The Long-Range Research and Development Planning Program under the Defense Innovation Initiative is a crucial input into this effort and helped the DoD improve their understanding and prioritization of new or unconventional applications of technology.

26. In 2015, Work listed the following areas as central for the Third Offset Strategy: autonomous “deep learning” machines and systems, human-machine collaboration, assisted-human operations, advanced human-machine teaming, and semi-autonomous weapons for an electronic warfare environment (Work, December 2015a). Another particular focus of developing Third Offset technologies is overcoming China’s anti-access/area-denial capabilities and addressing its growing maritime warfare capabilities (Quencez, 2016). However, the Defense Innovation Initiative/Third Offset Strategy is ultimately concerned with the preservation and expansion of technological supremacy.

27. The most novel part of the Defence Innovation Initiative/Third Offset Strategy is the increased outreach to the non-defence private sector. A new Defense Innovation Board has joined the ranks of advisory boards to the Secretary of Defense, in order to rapidly bring in innovative ideas from this sector. The members of the Defense Innovation Board all have careers within innovation outside the DoD. The Board is chaired by Google Alphabet’s Eric Schmidt, and members of the Board include Amazon’s Jeff Bezos, LinkedIn’s Reid Hoffman, United Technologies’ Mike McQuade, and Admiral William McRaven (retired US Navy). Secretary Carter has already acted upon three initial recommendations: improved recruitment of computer scientists and software engineers; challenges and prize competitions on machine learning; and the creation of a Chief Innovation Officer.

28. A novelty is also the creation of the Defense Innovation Unit Experimental (DIUx), aimed to improve relations and exchanges with and access to the commercial technology community. The first DIUx was established in 2015 in Silicon Valley in order to connect startups and technology companies with DoD challenges. In 2016, the institutional setup was reformed (in its DIUx 2.0 form, it now provides nationwide access for the private sector); a second DIUx opened in Boston; and an outpost was established in Austin. The DIUx focuses on engagement with the private sector, maturing and adapting technologies for the DoD as well as a venture mechanism to bring in commercial technologies into the DoD. The DoD has also made it easier for personnel as well as private sector employees to come in and out of the department (so-called on- and off-ramps).

29. In conclusion, the United States has embarked upon an important change in direction in terms of the way it conducts defence innovation. However, it remains to be seen what the outcome of the review of the Innovation Initiative/Third Offset Strategy will yield.

IV. NOVEL NATIONAL DEFENCE R&D EFFORTS

30. Next to the US Defense Innovation Initiative/Third Offset Strategy, a number of other Allies are engaged in a re-examination of their approaches to defence R&D. It goes beyond the scope of this report to take into consideration all recent initiatives. Indeed, NATO itself does not have a clear picture at this time (see Section VI). Still, this section briefly presents some recent efforts to showcase that the field of defence R&D is shifting in Allied countries.

31. **Canada** released a new long-term defence strategy in June 2017, with a notable focus on innovation and future preparedness. One instrument to enhance the defence sector's innovation system will be the Innovation for Defence Excellence and Security (IDEaS) program, which will invest CAD 1.6 billion over the next 20 years. The program stipulates the following:

- creating clusters of defence innovators, bringing together academia, industry and others, to conduct leading-edge R&D;
- holding competitions open to innovators on specific defence and security challenges;
- implementing flexible new procurement mechanisms to develop and test ideas and to be able to follow through on the most promising ideas

32. Moreover, in 2017, Canada has consolidated strategic innovation funding in several fields, including in the aerospace and defence sector, into a simplified Strategic Innovation Fund, with a budget of CAD 1.26 billion over five years. The Fund aims to encourage R&D; facilitate the growth of firms; attract and retain large scale investment; and advance industrial research, development, and technology.

33. In **France**, the Ministry of Defence is increasingly relying on partnerships with the private sector and civilian research organizations, especially with regard to dual technologies. For this, the Directorate General of Weapons Procurement (*Direction Générale de l'Armement* (DGA)) has set up several support programs open to civilian researchers. Since 2009, the RAPID program has targeted SMEs involved in industrial research with potential military applications and has a budget of EUR 50 million (in 2016). Since 2011, the ASTRID program has focused on fundamental and industrial long-term research. It is open to civilian research laboratories and provides with maximum grants of EUR 300,000. In the separate EUR 12 million ASTRID Maturation program, promising projects can be awarded with additional grants of up to EUR 500,000.

34. Moreover, the DGA in partnership with two private defence consultancies has established the DGA Lab in June 2016. It works as a contact point between DGA and civilian start-ups to spur defence innovations. Along the same line, the French Air Force established a partnership with several innovative start-ups under the "Smart Base" initiative, which pairs military engineers and

private entrepreneurs. Every year since 2012, DGA also organizes an “Innovation Forum” to showcase around 100 innovative projects financed through DGA various support programs. Finally, in May 2017, DGA and BPI France (the French Public Investment Bank) signed a joint agreement establishing a defence investment vehicle with an initial endowment of EUR 50 million to complement existing support programs. This new investment fund will primarily support SMEs and start-ups with know-how of strategic importance for French defence industries.

35. In **Germany**, innovation approaches are being implemented in the cyber defence sector, in line with an effort to bolster defence against cyber-attacks and hackers. A new Cyber and Information Space Command became operational in April 2017 as the sixth branch of the Germany military. The German armed forces now must attract additional cyber and IT professionals and knowledge to build the Command. To meet the demand, the armed forces started a pilot project called Cyber Innovation Hub. The hub aims to be the interface between start-ups scene, R&D and science communities, industry and the armed forces. It is supposed to take the roles of innovation, procurement and recruitment agencies, focused on cyber. Its three-year budget amounts to EUR 27.6 million.

36. The **United Kingdom** has embarked on a fundamental overhaul of its defence innovation efforts. Officially launched on 12 August 2016, the Defence Innovation Initiative (DII) aims to boost research capabilities and adapt to new threats. Inspired by the US Defense Innovation Initiative, the UK DII aims to foster a culture of systematic innovation, which is “innovative by instinct”. The UK has thus several new tools:

- a £800 million fund (over 10 years) to back promising research projects from inside and outside the Ministry of Defence, through an open competitive process with regular calls for projects;
- a Defence and Security Accelerator to help selected project grow faster, bringing together partner research institutions, academia and SMEs
- an Innovation Research Insights (IRIS) unit to identify and anticipate future challenges and make recommendations on defence investment priorities.

37. In addition, in the context of the broader Defense Growth Partnership, the UK government established a Defense Solutions Centre in 2015 to foster innovation and increase the global competitiveness of British defense industries. The Centre works as a coordination and planning body for the whole industry, with a view to boost the export potential of British defense products. The Defense Solutions Centre has so far launched two major, innovation-related initiatives: the Innovation Challenge, a competition to create new technologies to solve current defense challenges; and the Innovation and Collaborative Engagement Lab, a small space where different actors of the defence industry (i.e., SMEs, international clients, researchers) can meet, exchange and test ideas and concepts.

38. The big defence R&D spenders are not the only ones rethinking the way they innovate. The Netherlands are in the process of setting up the Innovation Centre FRONT, with direct access to the Dutch Chief of Defence Staff. The Spanish Ministry of Defence published a new Defence Technology and Innovation Strategy in 2015, seeking to improve interactions between the armed forces and technology providers involved in military R&D, including universities and private businesses. And as Poland and Turkey are increasing their defence sector ambitions and budgets, including on R&D, they are also developing their approaches to innovation.

39. In conclusion, national-level defence R&D landscapes are shifting in many Allied countries, as many armed forces are thinking through and adapting to increasingly demanding S&T environment.

V. EUROPEAN UNION DEFENCE R&D

40. When it comes to defence, the history of European institutions is a long, complicated and, at times, controversial one. However, over the last few years, the EU and its member states have increasingly stated the need for a stronger Europe. The EU is thus working on a range of defence and security policy initiatives to, ultimately, achieve strategic autonomy.⁴ It must be noted, however, that the EU stresses that contribution to and cooperation with NATO remain vital. Indeed, the EU argues that “A more credible European defence is essential also for the sake of a healthy transatlantic partnership with the United States” (European Union, 2016).

41. For decades, European collaborative defence R&D efforts have been modest, despite important formats such as the Independent European Programme Group (from 1976) or the Western European Armaments Group (from 1992). To further improve military- and armaments-focused collaboration, EU member states established the EDA in 2004. Since then, the EDA has supported its member states in over 150 R&T projects through a variety of cooperative instruments, amounting to close to EUR 1 billion funded by member states and industry. The EDA is an intergovernmental coordination agency with a general budget of EUR 31 million in 2017 and governed by a Steering Board consisting of the EDA member states. In terms of cooperative R&T, it has three cooperative instruments at its disposal: small and large projects or programs as well as research and technology studies. Recently, the EDA has also launched a study aimed at understanding what impacts defence innovation.

42. Despite these efforts, today more than 90% of R&T in the EU member states occurs at the national level (European Commission, 2017). For several years, European institutions and certain member states have thus called for new efforts to strengthen EU collaborative defence R&D. Consequently, the European Parliament initiated a landmark for EU defence in late 2014. Its call for a Pilot Project on EU defence research was included in the 2015 EU budget. While the Pilot Project amounts to only a very modest EUR 1.4 million, it marks the first time that EU-level funds have been allocated to defence research (EU research funding can already be obtained for certain dual-use security research). The Pilot Project resulted in three grants signed in October 2016 (see figure 8), which will be managed by the EDA as the implementing body.

Figure 8: EU Pilot Projects on Defence Research
Inside Building Awareness and Navigation for Urban Warfare
Standardisation of Remotely Piloted Aircraft System Detect and Avoid
Unmanned Heterogeneous Swarm of Sensor Platforms

43. In 2016, the EU set out its shared interests and principles with regard to foreign and security policy – for the first time since 2008. The EU Global Strategy stressed that the EU must strengthen its credibility in the world. To this end, the Global Strategy makes clear that “investment in security and defence is a matter of urgency. Full spectrum defence capabilities are necessary to respond to external crises, build our partners’ capacities, and to guarantee Europe’s safety” (European Union, 2016). To live up to the new level of ambition, the Global Strategy stresses that dedicated EU funding is an essential prerequisite.

44. In November 2016, the European Commission followed up with proposal for next steps, releasing European Defence Action Plan (European Commission, 2016). The EU member states have welcomed the Action Plan and called for all relevant actors to take the work forward. The European Defence Action Plan focuses heavily on defence technologies and products to address

⁴ A discussion of all initiatives goes beyond the scope of this report, but 2017 reports in the Defence and Security Committee and the Economics and Security Committee complement this report, discussing *NATO-EU Cooperation after Warsaw* and *The State of Europe’s Defence Industrial Base*.

Europe's defence and security needs and rests on three pillars: a European Defence Fund; investments in defence supply chains; and the single market for defence.

45. In terms of defence R&D, the European Defence Fund could become a key element in strengthening European defence R&D. In June 2016, EU member states welcomed the European Commission's proposal on the European Defence Fund, looking forward to its swift operationalisation. When he spoke to the Committee during its meeting at the Spring Session in May 2017, Dick Zandee, Senior Research Fellow at the Netherlands Institute of International Relations 'Clingendael' even argued that it could become a "game-changer". The European Commission's aim is to create two defence R&D pillars under the Fund: a research window and a capability window. Together, they are supposed to provide incentives, along with the full defence industrial cycle, to increase collaborative and cooperative defence projects. In terms of overall governance, the Commission proposes that both windows be overseen by a Coordination Board, consisting of representatives from the European Commission, the High Representative for Foreign Affairs and Security Policy, the EDA, member states and, if appropriate, defence industry.

46. With regard to the research window, the European Commission aims to move towards an ambitious European Defence Fund in the next EU multiannual financial framework (2021-2027). To lay the groundwork, the previously mentioned Pilot Project and a Preparatory Action on Defence Research are already being implemented. Both are important tests to demonstrate the added-value of EU-funded research in defence. The Preparatory Action is a follow-on from the Pilot Project. It launched in 2017 and will run until 2019 at a total expected budget of EUR 90 million, spent mainly in the form of grants. In terms of governance, the EU member states give an opinion on its work program, with the EDA as an observer. The European Commission then decides on the work program, assisted by a group of member state experts as well as an advisory expert group drawn from industry, R&T organizations, academia, EDA and the European External Action Service. The work program in turn is managed by the EDA on the Commission's behalf.

47. For the period 2021-2027, the European Commission proposes that the research window become a substantial defence research program. To make a substantial difference on defence R&D within the EU, it proposes that the annual budget should amount to EUR 500 million. If implemented, the EU would be among the top four investors in defence research in Europe. It is envisaged that projects and programs would be financed by grants and possibly pre-commercial procurements, i.e. the procurement of R&D of new innovative solutions before they are commercially available. The European Commission argues that only a limited number of programs should be pursued, and those selected should focus on key research projects agreed upon by member states. The European Commission is keenly aware that the final governance model must reflect the specificities of the defence sector as well as the experiences from the Pilot Project and the Preparatory Action. The European Commission has called for adoption of a final proposal in 2018.

48. In contrast, the capability window would support the joint development of defence capabilities in the proposal by the European Commission. For the years 2021 to 2027, the European Commission is working towards a capability window to bridge the gap between research and development – also known as the "valley of death". It suggests a reference amount of EUR 5 billion per year, which would amount "to 2.5% of total national spending on defence within the EU and 14% of national spending on defence capabilities" (European Commission, 2016). Under the capability window, member states could come together and pool national contributions in order to develop defence capabilities in the late R&D phase. Member state contributions could be treated as "one-offs" under the EU Stability and Growth Pact, to incentivise members to invest in the capability window. Moreover, the European Commission proposes that the EU could encourage such cooperation through EU financing and incentives, thus reducing risks in the early stages of development.

49. To prepare for such an ambitious capability window in the next multiannual financial framework, the European Commission proposed a European Defence Industrial Programme in June 2017. A total budget of EUR 500 million for 2019 and 2020 would support the European defence industry in the development phase of collective high-end investments. This potential EU investment could lead to a EUR 2.5 billion total investment through co-financing, the European Commission argues. In terms of initial governance, the European Commission proposes that it would be responsible for overall execution of the program, assisted by a program committee of member state experts as well as an advisory expert group drawn from industry and other experts, EDA and the European External Action Service. The European Commission would have the possibility to delegate certain tasks to an implementing body. In parallel to the European Defence Industrial Programme, the European Commission is also working with stakeholders towards the development of a financial toolbox; an internal task force to provide support on collaborative procurement projects; and a permanent financial structure beyond the context of projects.

50. In conclusion, the EU initiatives could indeed become a crucial factor in correcting the transatlantic imbalance in defence, including R&D. However, many important decisions lie ahead for the EU and its member states over the next few years before the eventual effects of its new emphasis on defence can be judged.

VI. SCIENTIFIC AND TECHNOLOGICAL COLLABORATION WITHIN NATO

51. Scientific and technological collaboration within NATO has a history of more than six decades. It started with the Advisory Group on Aerospace Research and Development (AGARD) in 1952. In 1957, the predecessor of the NATO PA – the Conference of NATO Parliamentarians – was instrumental in the creation of a NATO Science Committee. A report by the late US Senator Henry M. Jackson was particularly influential in creating the NATO Science Committee. Senator Jackson forcefully argued that the world was entering a time of scientific and technological revolution at a time when NATO was confronted with a genuine crisis in S&T. The Senator would continue to push for more NATO S&T as chair of the Scientific and Technical Committee – the predecessor of the STC.

52. NATO S&T efforts focus mainly on basic and applied research essential to the Allies, NATO and partner states. Those efforts help supporting capability development, fostering consultation and partnerships, and delivering evidence-based advice (NATO, 2013).

53. With NATO's agencies and command structure reform of 2011, the Alliance also adapted and reformed its approach to S&T. This led to establishing the NATO Science and Technology Organization (STO) in 2012. The most fundamental changes in the approach to S&T within NATO were the re-introduction of the position of the NATO Chief Scientist and the introduction of the NATO Science and Technology Board (STB). As mandated by the North Atlantic Council, the STB is responsible for NATO S&T unified governance as well as STO governance. In the STB, all NATO S&T stakeholders are represented. The NATO Chief Scientist chairs the Board.

54. In addition to the STB, the STO comprises seven Scientific and Technical Committees (see figure 9) and three executive bodies, namely:

- the Office of the Chief Scientist at NATO headquarters, which supports the STB and the Chief Scientist;
- the Collaboration Support Office in Neuilly-sur-Seine, France, which provides a collaborative environment and support to the S&T activities carried out through the Scientific and Technical Committees; and

- the Centre for Maritime Research and Experimentation in La Spezia, Italy, which organizes and carries out projects and experiments in the maritime domain, in particular in the undersea environment.

Figure 9: NATO Scientific and Technical Committees
Applied Vehicle Technology
Human Factors and Medicine
Information Systems Technology
NATO Modelling and Simulation Group
Systems Analysis and Studies
Systems Concepts and Integration
Sensors and Electronics Technology

55. NATO S&T activities cover a broad range – from information exchanges to joint projects and program, including cooperative demonstrations of technologies, lecture series and technical courses. Allies and Partners, if allowed, can participate on a voluntary basis in collaborative NATO S&T efforts, according to their capabilities, interests and needs. Funding predominantly comes from the states participating in such efforts, but NATO funds can contribute when efforts support overarching Alliance objectives. Overall, the STO brings together a network of around 5,000 active defence and security scientists and engineers and carries out over 250 activities every year.

56. NATO's Allied Command Transformation (ACT) promotes and leads efforts to transform NATO's military structure, its armed forces, capabilities and doctrines. ACT is thus one of the key stakeholders in the STO, in particular through its Directorate on Capability Development with its particular focus on S&T. The STO and ACT have signed a structured partnership. ACT is the largest customer for the Centre for Maritime Research and Experimentation. Moreover, ACT sponsors research activities undertaken by the STO. S&T is also a key aspect of ACT's Strategic Foresight Analyses (see the Annex). Other stakeholders include the Defence Investment Division and the Emerging Security Challenges Division at NATO headquarters, the NATO Communications and Information Agency, the Science for Peace and Security programme, and the NATO Industrial Advisory Group.

57. In February 2015, the NATO PA's Secretary General and the NATO Chief Scientist signed a letter of intent to develop a more structured partnership with the Assembly. Indeed, staff-to-staff contacts have led to concrete collaboration on a number of matters, including on topics such as intelligence, surveillance, and reconnaissance as well as emerging and disruptive technologies. The Chief Scientist also regularly briefs the STC. In 2016, the STC visited NATO's Centre for Maritime Research and Experimentation on its [visit to Italy](#).

58. In line with an Allied goal to develop a strategic relationship with the EU, the STB has established a working group to further improve the staff-to-staff collaboration between the STO and the EU. It has also progressed through staff engagement with the EDA.

59. In the run-up to NATO's 2016 Warsaw Summit, there was interest in establishing a framework for innovation within the Alliance. This framework would have connected, synchronised and capitalised on new national defence innovation efforts and proposed EU defence research. However, the defence innovation framework did not come to fruition in 2016. At the Warsaw Summit, the Alliance nevertheless noted that "For the Alliance to keep its technological edge, it is of particular importance to support innovation with the aim to identify advanced and emerging technologies, evaluate their applicability in the military domain, and implement them through innovative solutions. In this regard, NATO welcomes initiatives from both sides of the Atlantic to maintain and advance the military and technological advantage of Allied capabilities through

innovation and encourages nations to ensure such initiatives will lead to increased cooperation within the Alliance and among Allies”.

60. Building on the Warsaw Communiqué, the Conference of National Armaments Directors (CNAD) approved a framework for CNAD Efforts to Facilitate Innovation in its May 2017 plenary meeting. This framework and the related CNAD Work Programme to Facilitate Innovation has been composed from contributions across the Alliance, including ACT and the STO. It identifies those measures that the CNAD community can take, in coordination with relevant NATO stakeholders, to maintain NATO’s military advantage, including the technological edge. The accompanying CNAD work program calls for a compilation of information on existing NATO tools and initiatives that support innovation, this will provide the basis for further CNAD work to promote and facilitate innovation within the Alliance and among Allies.

61. Furthermore, during their June 2017 meeting, Defence Ministers endorsed the annual report on Institutional Adaptation. This report emphasizes the importance of innovation and calls for the promotion of innovative ways of working within NATO and the sharing of information among Allies. Allies should share promising innovation opportunities, best practices, lessons identified and areas where innovation has made a difference or where emerging technologies and innovative efforts are being considered for integration in national capability programmes.

VII. CONCLUSION

62. For the 29 Allies, NATO remains the bedrock of their defence and security policies. NATO is the most successful political-military alliance in history, and its success is rooted in its credibility, shared democratic values and strength. Article 5 rests on the promise that, if an armed attack takes place against any Ally, it is an attack against all. If any potential adversary believes that there might be a chance that some Allies will not honor this commitment, the Alliance will crumble. But credibility is also rooted in Allies living up to the other commitment they made to each other under Article 3: “to maintain and develop their individual and collective capacity to resist armed attack”.

63. For a long time, the Allies have had a goal of spending 2% of their Gross Domestic Product (GDP) on defence. Today, however, the United States continues to carry a disproportionate burden: 67.3% of total NATO defence spending is US defence spending (2017 estimate; NATO, 2017). To remedy this situation, Allies made a series of solemn pledges at the 2014 Wales Summit. Most importantly, they vowed to move, within a decade, towards spending 2% of their GDP on defence and 20% of their annual defence spending on major new equipment, including related R&D.

64. As US Secretary of Defense Mattis recently underlined, “it is a fair demand that all [...] carry their proportionate share of the necessary costs to defend our freedoms” (Guttermann, 2017). NATO Secretary General Jens Stoltenberg rightly argued that “This is not the U.S. telling Europe to increase defense spending. [...] this is about implementing something, which 28 heads of state and government have agreed that we will do together” (Herszenhorn, 2017). European Allies must do more on defence spending, including defence R&D. If all Allies fulfilled the Wales Defence Investment Pledge, the Alliance would have over USD 100 billion more at its disposal for defence spending every year and, thus, over USD 20 billion for major new equipment, including related R&D. Under these circumstances, your Rapporteur has no doubt that the Alliance will keep its technological edge. However, if Allies do not live up to the pledge in a timely manner, the Alliance will lose its technological edge and might even fall behind.

65. To maintain the technological edge, increasing defence R&D spending is essential. Beyond budgets, however, this report shows that adaptation to the new S&T landscape is equally essential.

Business as usual in defence R&D is no longer viable. Allies are starting to realize this and are adapting through various efforts at the national, bilateral, multilateral, EU, and NATO level.

66. This report showcases some important examples that illustrate potential approaches. However, there is no single blueprint to adapt defence R&D. Some approaches will work and others will not. It is important, however, that Allies deepen their information sharing on their experiences, best practices and lessons learned. In this respect, the Committee very much welcomes the NATO efforts underway in the CNAD and between Defence Ministers and looks forward to learning more about NATO proposals to promote and facilitate innovation within the Alliance. For its part, the Committee will further explore novel or little-used approaches to defence innovation. There are a multitude of associated questions: Could the use of open systems with defined interface standards lead to the rapid adoption of new capabilities? Could enhanced (rapid) prototyping lead to rapid innovation? Could early testing of incomplete systems with operators lead to faster adaptation? And could 'scouts' roam the technology world to discover new technologies earlier?

67. While Allies should share more information to reap the benefits of learning from each other, improved coordination of defence R&D initiatives between Allies must also occur – despite the well-known challenges. Crucially, pursuing individual defence initiatives, while not taking into account NATO requirements, could lead to inefficiencies and innovation at odds with itself as well as to additional technological gaps within the Alliance. This could ultimately affect interoperability – a crucial component of an effective Alliance. General Denis Mercier, NATO's Supreme Allied Commander Transformation, called for a "new momentum" in this respect. He argued that "if we want to remain 'One NATO', connections must be established with those Nations that have already triggered their own Defence Innovation Initiative, such as the United States. NATO should also be connected with its Partners and especially the European Union" (Mercier, 2016). Your Rapporteur wholeheartedly agrees. Allies must innovate with the same end goal in mind: to make the Alliance stronger. NATO must remain the forum where such coordination and knowledge exchange happens- -connecting the scientists and engineers across the Alliance. Indeed, Allies should harness the transatlantic S&T community's strengths and bolster NATO collaboration. To maintain NATO's technological edge, a transatlantic fingerprint on S&T adaptation, innovation and modernisation is needed. There is no doubt that the Alliance needs to do more.

68. As for the United States, your Rapporteur can assure members of the Committee that the US Congress will work with the new US administration to continue to increase investment in defence R&D. Some Allies fear that the Defense Innovation Initiative/Third Offset Strategy puts too much emphasis on high-end technology solutions for specific operational environments, for example in the Pacific Region, that European Allies currently would not be able or willing to engage in (Fiott, 2016). However, the US effort is about the full spectrum of capabilities (Work, 2015b). Thus, many opportunities exist for Allies to connect, especially for those who are currently adopting their own innovation strategies. Indeed, the US DoD is already reaching out to its allies and partners.

69. In Europe, the EU still needs to decide on the exact modalities of the European Defence Fund. However, it could become a crucial part in rebuilding the European pillar of NATO, contributing to one of the goals in the Joint Declaration signed in Warsaw, i.e. to "Facilitate a stronger defence industry and greater defence research and industrial cooperation within Europe and across the Atlantic" (Tusk, Juncker & Stoltenberg, 2016). Common funding of EU-wide defence R&D and facilitating joint projects and programs could help immensely in spurring defence R&D capabilities and restore the health of the European defence and technological industrial base. However, EU member states must ensure that the new European defence initiatives lead to actions in a timely manner. Moreover, your Rapporteur strongly believes that European efforts must not compete with or duplicate NATO efforts. The EU must ensure that this will not be the case and demonstrate this to the Alliance.

70. In recent years, the STC has worked to re-examine the global S&T landscape. At the NATO PA 2016 Spring Session, then-Chairman of the STCTTS, Jan Arild Ellingsen (Norway), delivered remarks on this topic. He outlined his concerns about the fundamental changes underway in global S&T as well as the opportunities for the STC to once again take up a leadership role on NATO S&T. He argued that, “as parliamentarians of the Alliance, we must make sure that our defence and security capabilities correspond with the need to ensure our common defence and security and the well-being of our citizens and societies. To do so, the Science and Technology Committee must play an important role in safeguarding our science and technology capacities.” The world is fraught with risks and threats. The Alliance must be ready for them. Defence and security S&T is vital in this endeavour because today’s defence R&D lies at the heart of preserving tomorrow’s credibility and freedom of action.

ANNEX

NATO
(NATO, 2015; NATO, 2016a)
Strategic Foresight Analysis: S&T Theme
Technology accelerates change
Increased access to technology
Centrality of networks
<i>Emerging trends</i>
Proliferation of autonomous weapons systems enabled by Artificial Intelligence
Breakthrough in energy technologies
<i>Further analysis needed</i>
Loss of state/government monopolies over advanced technologies
S&T Priority Areas
Precision Engagement
Communications & Networks
Advanced Human Performance & Health
Autonomy
Cultural, Social & Organisational Behaviours
Power & Energy
Information Analysis & Decision Support
Platforms & Materials
Data Collection & Processing
Advanced Systems Concepts

EU
(European Defence Agency, 2014)

EDA Capability Development Plan: Priorities (2014)

<div style="background-color: #0070C0; color: white; padding: 5px; text-align: center;"> Gaining information superiority </div> <div style="background-color: #D9E1F2; padding: 5px;"> <ul style="list-style-type: none"> Counter Cyber Threats (Cyber Defence) Provide SATC OM Capabilities Enhance Battlespace Information and Communication Services Remotely Piloted Aircraft providing Surveillance (RPAS) </div>	<div style="background-color: #00A68A; color: white; padding: 5px; text-align: center;"> Enabling Expeditionary Operations </div> <div style="background-color: #D9E1F2; padding: 5px;"> <ul style="list-style-type: none"> Inter-Theatre Air Capabilities Intra-Theatre Combat Capabilities Enhance Logistic Support for Deployed Forces Provide Medical Support to Operations </div>
<div style="background-color: #0070C0; color: white; padding: 5px; text-align: center;"> Protection of Forces in Theatre </div> <div style="background-color: #D9E1F2; padding: 5px;"> <ul style="list-style-type: none"> Enhance C- IED and CBRNe Capabilities in Operations Provide Air and Missile Defence for deployable forces </div>	<div style="background-color: #70AD47; color: white; padding: 5px; text-align: center;"> Securing Sea lines of Communication </div> <div style="background-color: #D9E1F2; padding: 5px;"> <ul style="list-style-type: none"> Maritime Patrolling and Escorting Naval Surveillance systems </div>
<div style="background-color: #0070C0; color: white; padding: 10px; text-align: center; font-weight: bold;"> Crosscutting Drives </div> <div style="background-color: #D9E1F2; padding: 10px; display: flex; justify-content: space-between;"> <div style="width: 45%;"> <ul style="list-style-type: none"> Energy and Environmental Protection SESAR </div> <div style="width: 45%;"> <ul style="list-style-type: none"> Modeling, Simulation and Experimentation Space based information service </div> </div>	

United States
(Work, 2016)
Areas of Focus for Third Offset Strategy
Autonomous “deep learning” machines and systems
Human-machine collaboration
Assisted-human operations
Advanced human-machine teaming
Semi-autonomous weapons for an electronic warfare environment
CHINA
(Office of the Secretary of Defense, 2016)
S&T Strategic Areas with Military Implications
Material design and preparation
Manufacturing in extreme environmental conditions
Aeronautic and astronautic mechanics
Information technology development
Nanotechnology research
Technology Areas for Rapid Development
Information technology
New materials
Advanced manufacturing
Advanced energy technologies
Marine technologies
Laser and aerospace technologies
Priority Subjects for the Defence Industries
Advanced manufacturing
Information technology
Defence technologies, including:
<ul style="list-style-type: none"> • Counterspace capabilities • Secure Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) • Smart materials • Low-observable technologies
Select areas with potentially disruptive S&T developments
(result from expert survey conducted by the STC in 2016)
Additive manufacturing
Alternative sources of energy
Artificial intelligence
Big Data
Biotechnologies
Climate engineering
Counter-space technologies
Chemical weapons
Crypto-currencies
Cyber technologies
Deep machine learning
Directed energy weapons
Earth observation analytics
Internet of Things
Missile defence
Nanotechnology
Missile and torpedo technologies
Nuclear weapons
Quantum computing and cryptology
Social media technologies
Surveillance technologies
Synthetic biology
Unmanned vehicle technology and robotics
Virtual reality

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