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**WAITING FOR DISRUPTION?!
UNDERSEA AUTONOMY AND THE CHALLENGING NATURE OF
NAVAL INNOVATION**

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**S. RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES
SINGAPORE**

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Abstract

This paper looks at the mechanics of military innovation to sound a cautionary note on the current and future use of undersea autonomy. It starts from the premise that undersea autonomy is not yet as inevitable and disruptive as many believe. In particular, this is because of the current threat environment, the limited scope of current missions for unmanned undersea vehicles (UUVs), and the prevailing technology push. For undersea autonomy to lead to disruptive and discontinuous changes in undersea warfare, navies will need to understand how to translate technological advancements into operational advantages. This will require navies, industry and science partners to develop a better understanding of the interplay between operational needs, cultural predispositions, organisational and resource needs, and technological options.

Keywords: autonomous underwater vehicles, concepts of operation, naval innovation, technology

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Daniel Mahon started his carrier as a submarine officer on a German HDW Class 206A submarine. He served for many years on the German HDW Class 212A submarine, ascending to the rank of commanding officer. He attended the German principle warfare officer course and is a graduate of the Federal Armed Forces Command and Staff College. At thyssenkrupp Marine Systems he is working as a captain on newly built HDW class submarines during sea acceptance trials and as a naval analyst focusing on concept studies.

In October 2016, over 40 organisations from 20 different nations gathered on the West Coast of Scotland for the demonstration of Unmanned Warrior. This was the U.K. Navy's first large-scale demonstration that brought together over 50 unmanned systems in the air, land, and sea domains. By performing complex tasks in different mission sets, the Unmanned Warrior gave an overview of the U.K. Navy's state of the art systems and provided a glimpse of tomorrow's battlefield.¹

Unmanned Warrior was testimony of the growing military importance of unmanned systems. Their use is most prevalent in the air domain, as approximately 90 states and non-state actors worldwide use unmanned aerial systems.² The steep increase in demand creates an impression that the use of remotely controlled, automated, and autonomous systems is proliferating across armed forces.³ However, there is need for caution as the developments are evolving at different speeds in the air, land, sea, and undersea domains (see Box 1). It is important to keep these differences in mind when considering the likely strategic effect of these systems on regional stability and the future character of warfare. This prevents hasty conclusions — in particular in on-going policy discussions — that might lead to premature decisions on banning the development, procurement, and use of the respective systems before their full potential is properly understood.⁴

Given the somewhat hyperbolic nature of today's discussion on unmanned systems, this paper looks at the mechanics of military innovation to sound a cautionary note on the current and future use of undersea autonomy. This paper starts from the premise that undersea autonomy is not yet as inevitable and disruptive⁵ as many believe. In particular, this is because of the current threat environment, the limited scope of current missions for unmanned undersea vehicles (UUVs),⁶ and the prevailing technology push. For undersea autonomy to become disruptive, navies will need to understand how to translate technological advancements into operational advantages. This will require navies, industry, and science partners to develop a better understanding of the interplay between operational needs, cultural predispositions, organisational and resource needs, and technological options.

¹ For more on this, see: <http://www.royalnavy.mod.uk/news-and-latest-activity/operations/uk-home-waters/unmanned-warrior> (accessed 12 January 2017).

² Kelley Saylor, *A World of Proliferated Drones: A Technology Primer* (Washington, D.C.: CNAS, 2015), p. 5.

³ This paper defines autonomous systems as systems that can select and execute tasks without prior definition by a human operator; autonomous systems can thus decide themselves how to behave in a given situation. This understanding slightly modifies the definition proposed by: Paul Scharre and Michael C. Horowitz, *An Introduction to Autonomy in Weapon Systems* (Washington, D.C.: CNAS, 2015), p. 16.

⁴ Marcel Dickow, *Robotik: ein Game-Changer für Militär und Sicherheitspolitik* (Berlin: Stiftung Wissenschaft und Politik, 2015), p. 23–24; Scharre and Horowitz, *An Introduction to Autonomy in Weapon Systems*, p. 3.

⁵ Disruptive innovation refers to discontinued conceptual, organizational, and technological change likely to fundamentally alter the nature of undersea warfare. See also: Tai Ming Cheung, Thomas G. Mahnken, and Andre L. Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation", in Tai Ming Cheung (ed.), *Forging China's Military Might. A New Framework for Assessing Innovation* (Baltimore: Johns Hopkins University Press, 2014), p. 37

⁶ We use unmanned underwater vehicles (UUVs) as an umbrella concept that includes autonomous underwater vehicles (AUVs) and remotely operated underwater vehicles (ROV). In addition, navies also use unmanned surface vehicles (USVs).

Three Reasons Why the Undersea Domain is Different

- **Physical Aspects**

Physical characteristics of the undersea domain (such as salinity of water, changing water temperature, water currents, multi-path reflections from the seabed and from the surface) render certain tasks such as navigation and localisation, communications, and data transmission much more difficult than in other domains.

- **Regulatory Aspects**

Undersea traffic differs from air traffic in that there is no undersea traffic management regime, apart from very specific NATO/Partnership for Peace regulations on water space management. Therefore, regime discussion needs to start from scratch and thereby find innovative ways to consider the specifics of traditional and autonomous assets, as well as the contribution of autonomy and automation for water space management. However, this needs to take into account that there is currently no agreed-upon legal status of UUVs.

- **Cultural Aspects**

The command and control (C2) paradigm of the subsea forces is different from that in other domains. Subsea commands are at ease with delegating tasks to assets that need neither constant monitoring nor control, as this might be detrimental to their operational success. Thus, the subsea culture seems more likely to fully embrace the principle of mission command, which could be beneficial to the use of autonomous systems.

Box 1: Three Reasons Why the Undersea Domain is Different

Source: Heiko Borchert, Daniel Mahon, and Tim Kraemer, "Leveraging Undersea Autonomy for NATO: Allies Must Work Together to Avoid Fraction," Cutting the Bow Wave (Norfolk: Combined Joint Operations from the Sea Centre of Excellence, 2016), pp. 50–51.

This article will develop this argument in several steps. It starts by describing current and likely future UUV missions in NATO and non-NATO countries. After a brief discussion of tomorrow's naval conflict picture, which is important to understand why the momentum might turn towards greater reliance on undersea autonomy, this article describes the main motives and drivers of undersea autonomy and paves the way for a look at the literature on the building blocks of naval innovation. This paper concludes by reviewing the main findings and offering specific recommendations to advance undersea autonomy in the future.

Current and Future Autonomous Undersea Missions

NATO and non-NATO navies are currently using UUVs for different but limited tasks. To illustrate current practices, this section will focus on the United States, Russia, China, Singapore, and Norway, as each illustrates a specific set of drivers shaping the use of UUVs. The discussion will show that mine countermeasures (MCM) and intelligence, surveillance, and reconnaissance (ISR) related to MCM are standard practices. Anti-submarine warfare (ASW), anti-surface warfare (ASuW) as well as undersea and offshore protection are emerging as additional missions for UUVs.

United States

The fear of losing technological superiority against future adversaries is the focal point of the military-strategic debate in the United States. This concern results from current geostrategic and

gloeconomic power shifts, the growing risk of global technology proliferation, and the increasing importance of commercial technology for armed forces. Against this background, highly capable peers that are proficient in establishing robust, cross-domain A2/AD challenges are of major concern to U.S. force planners.⁷ These peers limit U.S. freedom of action in areas of strategic interest, increase the vulnerability of U.S. forward deployed bases and assets, increase the cost of military intervention, question the credibility of the U.S. deterrence posture, and thus potentially undermine solidarity with allies, as they call into question the readiness and willingness of the United States to uphold security guarantees.⁸

The U.S. naval strategy for 2015 states that the sea services should provide and guarantee all domain access, assure strategic deterrence, provide sea control by establishing local maritime superiority, support power projection in a broad sense, and contribute towards maritime security.⁹ These strategic goals also shape the tasks of the U.S. subsea fleet, which is of key importance for strategic deterrence. Although the U.S. Navy continues to strive for undersea superiority, planners are mindful of the fact that ambitious regional powers are willing to establish A2/AD barriers in the subsea world, which might deprive U.S. subsea assets of their strategic contributions.¹⁰ In addition, a significant capability gap is opening up, since “the fleet’s undersea strike capacity will plummet by more than 60 per cent relative to today by 2028.”¹¹ The negative consequences of this trend are reinforced by the “domestic ASW gap” resulting from the fact that the U.S. Navy and the U.S. Coast Guard “are not yet ready to respond to unmanned underwater vehicles or unmanned surface vehicles employed by hostile powers, terrorist groups, or criminal organisations” in U.S. waters.¹²

Given the centrality of technology in U.S. strategic thinking, innovation is at the forefront of responses, such as the Third Offset strategy and other concepts, which were developed in response to these trends. U.S. Deputy Secretary of Defence Robert Work has underlined several times that autonomous and unmanned systems take centre stage in this debate.¹³ The key goal is to get technological solutions out to the troops as soon as possible, so that they can use refined technology in their experiments and operations. This has influenced the U.S. approach to undersea autonomy ever since the U.S. Navy published its first UUV Master Plan in 1994, which foresaw the use of autonomous systems for MCM, information collection, and oceanographic tasks. In 2003, Operation Iraqi Freedom saw the first operational deployment of these assets. In 2004, the U.S. Navy published a revised UUV Master Plan, which has had a lasting global impact on naval thinking about undersea autonomy. In particular, the revised document presented several possible missions such as ISR, MCM, ASW, oceanography, communication and navigation network nodes, inspection and identification, payload delivery, information operations, time critical strike, barrier patrol, and sea-base support.¹⁴ However,

⁷ Joint Operational Access Concept (Washington, D.C.: Department of Defense, 2009).

⁸ Richard Martinage, *Toward a New Offset Strategy: Exploiting U.S. Long-Term Advantages to Restore U.S. Global Power Projection Capability* (Washington, D.C.: CSBA, 2014), pp. 33–37.

⁹ *A Cooperative Strategy for 21st Century Seapower* (Washington, D.C.: U.S. Navy, 2015), pp. 19–26.

¹⁰ Bryan Clark, *The Emerging Era In Undersea Warfare* (Washington, D.C.: CSBA, 2014).

¹¹ Martinage, *Toward a New Offset Strategy*, p. 60.

¹² William J. Rogers, “Be Prepared for Maritime Drones,” *Proceedings* 141:10 (October 2015), p. 24.

¹³ Robert O. Work, “Remarks by Defense Deputy Secretary Robert Work at the CNAS Inaugural national Security Forum,” Washington, D.C., 14 December 2015, www.cnas.org/transcripts/work-remarks-national-security-forum (accessed 12 January 2017).

¹⁴ *The Navy Unmanned Undersea Vehicle (UUV) Master Plan* (Washington, D.C.: Department of the Navy, 2004), pp. 9-15.

the plan was way ahead of its time and not implemented properly due to a lack of naval leadership, resources, and adequate processes and procedures to advance undersea autonomy.¹⁵ This might have inadvertently created a gap in expectations that remains open up till today.

Since then, however, things have changed dramatically. According to the Unmanned Systems Integrated Roadmap FY2013–2038, the Department of Defence’s financial planning for FY2014–2018 foresees total spending on unmanned maritime systems at US\$1.96bn, with around US\$352m for research and technology, US\$708m for procurement, and around US\$900m for operations and maintenance.¹⁶ In addition to putting substantial amounts of money behind undersea autonomy, the U.S. Navy has also changed structures. In May 2015, Rear Admiral Robert Girrier was appointed the first-ever director of unmanned weapon systems; this was followed by the appointment of Brigadier General (Ret.) as the first Deputy Assistant Secretary of the Navy for Unmanned Systems in October 2015.¹⁷

Despite its generally broad approach to undersea autonomy, the U.S. Navy has narrowed the mission spectrum from the 2004 Master Plan to MCM as the current focus. For this purpose, several national systems have been developed, such as the Battlespace Preparation Autonomous Undersea Vehicle, different MCM modules for the littoral combat ship (LCS), and the surface mine countermeasure autonomous undersea vehicle (AUV). ISR is the second AUV mission for which several dedicated platforms have been developed as well, with Boeing’s Echo Ranger as the most prominent solution. In addition to these specifically developed systems, the U.S. Navy also uses off-the-shelf solutions, such as the REMUS systems manufactured by Hydroid/Kongsberg mainly for ISR, and SeaFox, the MCM system produced by Atlas Elektronik in Germany. ASW with autonomous systems is a third, slowly emerging mission. For this mission, the U.S. Navy is considering the use of large autonomous undersea systems, such as the Echo Ranger and unmanned surface vehicles (USVs).

Overall, the U.S. Department of Defence has invested ‘aggressively’ in developing unmanned systems. On this basis, the U.S. Navy adopts a holistic view of the undersea world. In addition to investing in autonomous platforms and their payloads, the U.S. Navy also funds technologies that make the undersea battlespace more amenable to autonomous systems. For example, it has established undersea networks for navigation, positioning and communications, forward-deployed undersea energy management, and sub-sea based stationing of payloads for cross-domain operations.¹⁸ In addition, the U.S. Navy is steadily embracing a family of systems approach that helps to develop the size and payload of different types of UUVs commensurate with different mission

¹⁵ Interview by the authors, Washington, D.C., 28 April 2015.

¹⁶ Unmanned Systems Integrated Roadmap FY2013–2038 (Washington, D.C.: Department of Defense, 2013), p. 3.

¹⁷ Megan Eckstein and Sam LaGrone, “Retired Brig. Gen Frank Keley Named First-Ever Deputy Assistant Secretary of the Navy for Unmanned Systems,” USNI News, 27 October 2015, <https://news.usni.org/2015/10/27/retired-brig-gen-frank-keley-named-first-ever-deputy-assistant-secretary-of-the-navy-for-unmanned-systems> (accessed 12 January 2017).

¹⁸ For more on this, see in particular the DARPA website for special projects, such as Tactical Undersea Network Architectures (TUNA), Positioning System for Deep Ocean Navigation (POSYDON), Forward Deployed Energy and Communications Outpost (FDECO), and Upward Falling Payloads (UFP), www.darpa.mil/ (accessed 12 January 2017).

requirements.¹⁹ While UUV launch tests from surface and subsea platforms are already underway,²⁰ other options such as air-launches from fighter jets are under consideration as well.²¹ Different launch options matter as the U.S. Navy is not only interested in the use of single UUVs, but also in deploying collective groups of UUVs as swarms across different domains.

Existing concepts on submarines strongly influence the United States' conceptual approach to undersea autonomy. In this regard, UUVs are mainly seen as detached, multi-mission capability and risk carriers that broaden the mission spectrum of submarines and surface vessels. Current U.S. thinking about the Large Displacement Unmanned Underwater Vehicle (LDUUV) best epitomises this way of reasoning, as the LDUUV could deploy additional, likely smaller UUVs in addition to accomplishing its own mission. Since the U.S. Navy strives for multi-mission capability, its focus is shifting steadily from autonomous platforms to the payloads that it can carry. These payloads are expected to be compact and flexible enough to meet the requirements of different missions such as intelligence collection, mine countermeasures, or anti-submarine warfare at the same time. Consequently, the U.S. Navy also puts a premium on integrating UUVs into the deployment platforms, as underlined by current trials with LCSs and Virginia-class submarines.

Russia

Russia is currently undertaking a fundamental reshaping of its foreign and security policy. Its new national security strategy and military doctrine portray the West as Russia's key strategic challengers, whereas countries in Central and East Asia are mainly seen as partners and allies. The new naval doctrine adopted in July 2015 follows this reasoning and breaks away from the careful regional balance that has been maintained so far. In the future, this is likely to imply more Russian assertiveness in the Atlantic and in the High North.²²

This guidance also affects the strategic thrust of the Russian Navy. The Russian Navy is the country's key instrument for strategic deterrence, but it was largely neglected throughout the 1990s. The 2014 naval modernisation program was therefore instrumental in gradually halting the steady decline of the Russian Navy.²³ Among other things, the modernisation programme introduces new weapons systems and C2 systems, and emphasises the growing importance of unmanned systems. The programme also puts a premium on modernising the subsea fleet, which was in dire need of more

¹⁹ Bryan Clark, "Game Changers: Undersea Warfare," Statement before the House Armed Services Seapower and Projection Forces Subcommittee, Washington, D.C., 27 October 2015, <http://csbaonline.org/publications/2015/10/undersea-warfare-game-changers/> (accessed 12 January 2017).

²⁰ Kris Osborn, "Navy to deploy first underwater drones from submarines," Military.com, 13 April 2015, <http://www.military.com/daily-news/2015/04/13/navy-to-deploy-first-underwater-drones-from-submarines.html> (accessed 12 January 2017).

²¹ The United States is exploring air deployment of UUV. See John Keller, "Raytheon and DARPA Consider Deploying Unmanned Air and Marine Vehicles from Fighter Aircraft," Military & Aerospace, 23 April 2014, www.militaryaerospace.com/articles/2014/04/f18-uav-uuv.html (accessed 12 January 2017).

²² "Russian Federation Marine Doctrine," Press Release, Office of the President of the Russian Federation, 26 July 2015, <http://en.special.kremlin.ru/events/president/news/50060>; Russian National Security Strategy, Russian Federation Presidential Edict 683, 21 December 2015, www.ieee.es/Galerias/fichero/OtrasPublicaciones/Internacional/2016/Russian-National-Security-Strategy-31Dec2015.pdf (accessed 12 January 2017).

²³ Matthew Bodner, "New Russian Naval Doctrine Enshrines Confrontation with NATO," The Moscow Times, 27 July 2015, www.themoscowtimes.com/business/article/new-russian-naval-doctrine-enshrines-confrontation-with-nato/526277.html (accessed 12 January 2017).

attention. This is because around two-thirds of Russia's nuclear-powered submarines are unavailable due to on-going maintenance and modernisation work.²⁴

Russia's armed forces have gotten a glimpse of the operational advantages offered by the adversarial use of unmanned systems in recent conflicts, such as the one in Georgia during 2008. Since then, Russia has ramped up its efforts to develop and introduce these systems in all domains, as they help to avoid Russian casualties, while illustrating the armed forces' technological proficiency. Against this background, UUVs²⁵ are part of the government's procurement programme as well as the Russian Navy's modernisation and research and technology programme. In addition, the armed forces have recently adopted a joint plan to develop robotic and unmanned systems by 2025.²⁶

Russia is one of the few countries emphasising protection as a key driver for UUVs. In particular, the Russian Navy is using autonomous systems for SAR missions for endangered submarine crews and to also advance harbour protection. MCM and the deployment of decoys for ASW are additional UUV missions. In the future, the Russian Navy wants to broaden the existing mission spectrum, among other things, by using UUV for reconnaissance of ASWs, harbours and beachheads. New missions are under consideration as well, particularly with regards to using UUVs for ASuW, to counter adversarial UUVs, for offensive mine warfare, to launch UUV swarms against adversarial high value targets, and to localise, protect, and disrupt offshore infrastructure such as power and communication cables. Like the U.S. Navy, the Russian Navy also considers integrating UUVs into the fifth generation of conventional and nuclear submarines a priority.²⁷

Current assessments of Russia's interest in undersea autonomy tend to forget that the country looks back on almost five decades of tradition and experience in developing the respective technologies. This has provided the former Soviet Union with options to export scientific UUVs to China and the United States. Throughout the 1990s, domestic turbulences almost led to the breakdown of this technological area. However, Russian developers survived thanks to export projects. At the beginning of the 2000s, the Russian Navy needed to reach out to foreign suppliers to acquire new UUVs. Consequently, Saab, Teledyne Gavia, and ECA made inroads into Russia. Today, however, the country is eager to replace these foreign-built systems with locally reengineered or locally built models, such as the harbour protection system Obzor-600 developed by Tetis Pro or a national MCM solution developed by GNNP Region. In addition, Russia has established several research projects focusing, among other things, on undersea communications and undersea localisation of surface platforms.

Overall, Russia's UUV expertise rests with the academic institutes under the umbrella of the Russian Academy of Sciences, whereas the industry is only playing a subsidiary role for the time being. Currently, Russia is working on making its technologies available to export markets again. For this

²⁴ Dmitry Boltanov, "Russian Nuclear Submarine Fleet," Moscow Defense Brief, 6/2014, pp. 18–22.

²⁵ The Russian Navy does not yet make a clear distinction between AUV and ROV.

²⁶ Interview by Heiko Borchert, Moscow, 26 August 2015; Nikolai Novichkov, "Russian Naval Doctrine Looks to the Future," Jane's Defence Weekly, 19 August 2015, p. 24–25.

²⁷ Interview by Heiko Borchert, Moscow, 26 August 2015; "Robots, Drones to Boost Russian 5th Gen Nuclear Subs' Arsenal", RT, 15 December 2014, www.rt.com/news/214563-robot-drone-russia-submarine/ (accessed 12 January 2017).

purpose, the Russian government launched a technology initiative for ocean engineering in 2011 that brought together all relevant centres on undersea autonomy. Local observers also speculate that future exports of the Aleksandr Obukhov MCM vessel might be supplied with the GNNP Region's autonomous underwater system.²⁸

China

The way that China handles its gradual integration into the international system is not only relevant for the country's domestic stability and prosperity, but will also affect neighbouring countries' responses to Beijing's growing influence. Although China might concede that Washington still is the world's key player, it is obvious that Beijing is increasingly willing to offer itself as an alternative to the United States.²⁹ Chinese President Xi Jinping seems more ready than his predecessors to cope with international friction as a necessary price to be paid for the country's rise.³⁰ This is also reflected in the leadership's growing self-confidence, as China is increasingly capable of backing up a more assertive approach with its respective military and non-military means.³¹

The People's Liberation Army (PLA) is central to the country's understanding of the constitutive elements of a powerful nation.³² National defence tasks and the eventual battle over Taiwan still play a powerful role in the PLA's force planning, but China's increasing dependence on land and sea-based supply lines constitutes an additional driving factor for the country's future force posture. This goes hand in hand with China's readiness to project power in areas of strategic interest to Beijing, and the targeting of its investments to bolster the PLA's A2/AD capabilities to protect said areas of interest.³³

The PLA Navy (PLAN) clearly reflects this paradigm shift. Traditionally organised to defend China's coastline and protect national territorial waters, the PLAN is about to broaden its footprint in international waters by conducting increasingly demanding naval operations.³⁴ These two

²⁸ The final two paragraphs build on: Interview by Heiko Borchert, Moscow, 26 August 2015; Dave Majumdar, "Russia vs. America: The Race for Underwater Spy Drones," *The National Interest*, 21 January 2016, <http://nationalinterest.org/blog/the-buzz/america-vs-russia-the-race-underwater-spy-drones-14981> (accessed 12 January 2017).

²⁹ "Diplomat says China would assume world leadership if needed," Reuters, 23 January 2017, <http://www.reuters.com/article/us-china-usa-politics-idUSKBN1570ZZ?il=0> (accessed 24 January 2017).

³⁰ In this regard, the catch of a U.S. Navy Ocean Glider in the international waters near Subic Bay port on the Philippines on 15 December 2016 could be a harbinger of things to come. For more on this incident, see: Julian Borger, "Chinese warship seizes US underwater drone in international waters," *The Guardian*, 16 December 2016, <https://www.theguardian.com/world/2016/dec/16/china-seizes-us-underwater-drone-south-china-sea>; Heiko Borchert, "Catch of the day: Reflections on the Chinese seizure of a U.S. Ocean Glider", CIMSEC, 17 December 2016, <http://cimsec.org/catch-day-reflections-chinese-seizure-u-s-ocean-glider/30153>, Victoria Wei and Shi Jiangtao, "Beijing says it will return seized drone in 'appropriate manner', while US president-elect Donald Trump accuses China of theft", *South China Morning Post*, 17 December 2016, <http://www.scmp.com/news/china/diplomacy-defence/article/2055434/drone-snatch-heralds-new-era-south-china-sea-say> (accessed 12 January 2017).

³¹ Ely Ratner et. al., *More Willing and Able: Charting China's International Security Activism* (Washington, D.C.: CNAS, 2015).

³² In this regard, the 2015 Chinese military strategy leaves no doubt and stipulates: "Without a strong military, a country can be neither safe nor strong." See: China's Military Strategy (Beijing: State Council Information Office of the People's Republic of China, 2015), www.chinadaily.com.cn/china/2015-05/26/content_20820628.htm (accessed 12 January 2017).

³³ Interview by the authors, Washington, D.C., 28 April 2015.

³⁴ Among other things, China's 2015 Military Strategy states: "The traditional mentality that land outweighs sea must be abandoned, and great importance has to be attached to managing the seas and oceans and protecting maritime rights and interests. It is necessary for China to develop a modern maritime military force structure commensurate with its national security and development interests, safeguard its national sovereignty and maritime rights and interests, protect the security of strategic SLOCs and overseas interests, and participate in international maritime cooperation as to provide support for building itself into a maritime power." See: China's Military Strategy, op. cit.

development vectors are closely linked, as a more international role of the PLAN is contingent upon the protection of national sovereignty in territorial waters. This requires close cooperation between the PLAN and the Chinese Coast Guard.³⁵ This growing international ambition also highlights the role of the PLAN subsea fleet, whose nuclear-powered, ballistic missile-carrying submarines (SSBN) are key to China's nuclear deterrence shield. China is investing significantly in bolstering its sub-fleet, and has renewed cooperation with Russia to this end. Despite progress, the subsea domain also shows China's strategic vulnerability, particularly with regard to ASW. This also explains new initiatives such as China's "underwater great wall," which is reminiscent of the former Allied Sound Surveillance System in the Atlantic Ocean.³⁶

Against this background, China understands the strategic relevance of unmanned systems in all domains. As Chase et al. (2015) made clear, Chinese thinking on unmanned systems not only follows but also essentially emulates U.S. thinking.³⁷ From a Chinese perspective, unmanned systems augment existing capabilities, as operations unsuitable to manned platforms have become more manageable.³⁸ In addition, casualty avoidance also gains importance due to the interplay between the long-held one-child policy, the potential loss of these children in combat, and the consequences that this might have for domestic stability. Specific regional features like the lack of undersea capabilities of China's southern neighbours could prompt Beijing to become more daring by testing innovative concepts for the use of unmanned systems in the undersea domain.³⁹

China's use of UUVs is transitioning into a deliberate grey zone between commercial, scientific, and naval operations. Three broad mission areas are emerging: (i) protection of the country's coastal zone and its military infrastructure, in particular, the submarine bases, and the sea-lanes of communication; (ii) mine warfare and MCM with autonomous assets; and (iii) offshore resource exploration. Chinese experts are also discussing additional missions, such as ASW with UUVs, the use of UUVs against military and commercial undersea infrastructure, hydrography, SAR missions, and the protection of artificial islands. Occasionally, Chinese experts also consider the weaponisation of UUVs as an option.⁴⁰

China's military-industrial complex is opaque, but it seems that around 15 teams of designers and researchers are working on UUVs. Importantly, all major institutes are part of the key shipbuilding conglomerates – China State Shipbuilding Corporation and China Shipbuilding Industry Corporation. It is assumed that the PLAN is the key sponsor of most projects, but it is also possible that China's

³⁵ Ratner, *More Willing and Able*; Yves-Heng Lim *China's Naval Power. An Offensive Realist Approach* (Surrey: Ashgate, 2014), p. 165; Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities – Background and Issues for Congress* (Washington, D.C.: CRS, 2016).

³⁶ The PLA Navy: *New Capabilities and Missions for the 21st Century* (Washington, D.C.: Office of Naval Intelligence, 2015); Lyle J. Goldstein, "China's 'Undersea Great Wall,'" *The National Interest*, 9 June 2016, <http://nationalinterest.org/feature/chinas-undersea-great-wall-16222> (accessed 12 January 2017).

³⁷ Michael S. Chase, Kristen Gunness, Lyle J. Morris, Samuel K. Berkowitz, and Benjamin Purser, *Emerging Trends in China's Development of Unmanned Systems* (Santa Monica: RAND, 2015).

³⁸ This view was expressed by General (Ret.) Xu Guangyu, former Deputy Director, PLA General Staff Department, in an interview with CCTV-4, 14 March 2013. Interview by the authors, Washington, D.C., 28 April 2015.

³⁹ Interview by the authors, Washington, D.C., 28 April 2015, 16 July 2015.

⁴⁰ Chase, *Emerging Trends in China's Development of Unmanned Systems*, pp. 2–3; Interview by the authors, Washington, D.C., 16 July 2015; Jeffrey Lin and P.W. Singer, "The Great Underwater Wall of Robots: Chinese Exhibit Shows Off Sea Drones," *Eastern Arsenal*, 22 June 2016, www.popsci.com/great-underwater-wall-robots-chinese-exhibit-shows-off-sea-drones (accessed 12 January 2017).

energy companies, which have significant offshore interests, are supportive as well. The PLAN is using Zhsihui-3, a locally developed UUV, for MCM and SAR missions. In addition, different systems were imported from abroad or co-developed with partners. UUV-related cooperation with Russia has focused on scientific research projects, but it can also be assumed that these projects have been beneficial for naval development projects as well.⁴¹

Singapore

Without significant depth and reach, Singapore's geostrategic position is fragile. Consequently, the city-state is combining deterrence and active diplomacy with maintaining balanced relationships with the United States and China. Singapore's global economic integration and regional prosperity are two key strategic drivers influencing the nation's security and defence posture. The Republic of Singapore Navy (RSN) is the key instrument, which provides for the security and stability of the sea-lanes of communication. In this context, the undersea domain is of particular relevance. Singapore is investing in its submarine fleet, but it is also concerned that the growing number of submarines active in the region could endanger regional shipping and offshore infrastructure operations. Therefore, the Singaporean Chief of Navy has recently launched an initiative to set up a framework to advance submarine safety by exchanging information related to submarine operations.⁴²

Singapore is a high-tech nation, and technology excellence is part of the DNA of its armed forces. As the city-state's staffing level is very thin, autonomous systems augment and multiply existing capabilities of the armed forces, while offering opportunities for local businesses to support the armed forces. Technological innovation that serves Singapore's forces is broadly accepted. However, the city-state's culture of geostrategic restraint limits the technological appetite of the armed forces, which therefore backs away from systems that could endanger the regional power balance. Using (armed) autonomous systems for offensive action is thus currently not on the table.⁴³

Technological maturity and operational benefits are the two key parameters used by Singapore's armed forces to assess whether new technologies are ready to use. Consequently, the RSN's use of UUVs is currently focusing on MCM, which is also likely to remain the primary focus for the future. Singapore is considering additional missions, such as ASW, hydrography, and the protection of offshore infrastructure. Using UUVs for ISR falls into a grey area, as it could intimidate neighbouring countries. For this reason, the RSN might only consider it for defensive purposes.⁴⁴

⁴¹ Interview by the authors, Washington, D.C., 16 July 2015; interview by Heiko Borchert, Moscow, 26 August 2015; Chase, *Emerging Trends in China's Development of Unmanned Systems; China's Industrial and Military Robotics Development* (Washington, D.C.: U.S.-China Economic and Security Review Commission, 2016), pp. 116-117; Jeffrey Lin and P.W. Singer, "Not a Shark, But a Robot: Chinese University Tests Long-Range Unmanned Mini Sub," *Eastern Arsenal*, 4 June 2014, <http://www.popsoci.com/blog-network/eastern-arsenal/not-shark-robot-chinese-university-tests-long-range-unmanned-mini-sub> (accessed 12 January 2017).

⁴² Interview by Heiko Borchert, Singapore, 20 May 2015; Swee Lean Collin Koh, "Best Little Navy in Southeast Asia: The Case of the Republic of Singapore Navy," in *Small Navies. Strategy and Policy for Small Navies in War and Peace*, ed. Michael Mulqueen, Deborah Sanders, and Ian Speller (Surrey: Ashgate, 2014), pp. 117-132; "Singapore Proposes Framework for Submarine Operations Safety," *Channel NewsAsia*, 21 May 2015, www.channelnewsasia.com/news/singapore/singapore-proposes/1861632.html (accessed 12 January 2017).

⁴³ Interviews by Heiko Borchert, Singapore, 20 May 2015.

⁴⁴ *Ibid.*

Singapore's defence ecosystem consists of highly capable government-owned institutes, the local defence industry that has emerged around ST Electronics as the major player, and research institutes at local universities. DSO National Laboratories has developed the Meredith AUV; while ST Electronics has developed the AUV-3. ST Electronics has also cooperated with the National University of Singapore to develop the STARFISH system, a technological demonstration of undersea swarms of autonomous systems. For reasons not publicly known, the RSN has not procured these nationally developed systems.⁴⁵ In contrast, the RSN has equipped its MCM vessels with foreign systems such as REMUS by Hydroid/Kongsberg and K-STER I and K-STER C by French company ECA.⁴⁶

Norway

Norway's foreign and security policy has been based on a security culture of peaceful conflict resolution and emphasises the strategic role of the United States as Oslo's indispensable partner.⁴⁷ The country's geostrategic environment, its dependence on the maritime economy, and its common border with Russia influence Norway's defence posture. This puts a premium on national and collective defence. Although most recent developments in Europe further reinforce this strategic thrust, the Norwegian armed forces are not yet up to the new demands in terms of readiness. This has prompted the Norwegian Chief of Defence to request for far-reaching structural changes that culminate in a significant shift of personnel, to advance the troops' readiness for deployment and a substantial increase in the defence budget, as foreseen by the long-term defence plan adopted in July 2016.⁴⁸

Against this background, coastal defence and blue water operations have been the two key parameters shaping the Royal Norwegian Navy's (RNoN) development. Today, the RNoN is as blue water-ready as before, but the current focus on national and collective defence sets somewhat different priorities. This also affects the navy's future size, which will be significantly smaller than today, with, among other things, five frigates, three logistics and support vessels, and four submarines. In this context, the submarine's main task is to provide deterrence in Norway's waters. On 3 February 2017, Norway selected Germany as strategic partner for new submarines with the goal to sign a common contract for new submarines in 2019. This would then enable Norway to replace six Ula-class submarines with four new U212NG built by thyssenkrupp Marine Systems.⁴⁹

⁴⁵ Given Singapore's overall emphasis on technological maturity it is feasible to assume that its authorities would want to monitor closely what more experienced UUV-developing countries such as the U.S. do, before making bold moves on undersea swarms. We thank the reviewer for underlining this aspect.

⁴⁶ Jermyn Chow, "Unmanned Systems Make a Splash at Maritime Show," *The Straits Times*, 19 May 2011, p. 4; Ridzwan Rahmat, "Singapore Unleashes Its Autonomous Underwater Platform for MCM Operations," *Jane's International Defence Review* (June 2014), pp. 34–35; Yong Han Goh and Su Ying Audrey Lam, "Delivering New Mine Countermeasure Capabilities to the RSN," *DSTA Horizons* (Singapore: DSTA, 2015), pp. 30–35.

⁴⁷ Stale Ulriksen, *Balancing Act: Norwegian Security Policy, Strategy and Military Posture* (Stockholm: Stockholm Free World Forum, 2013).

⁴⁸ Interview by Heiko Borchert, Oslo, 27 October 2015; *Norwegian Armed Forces in Transition* (Oslo: Norwegian Armed Forces, 2015), p. 19; *Capable and Sustainable: Long Term Defence Plan* (Oslo: Norwegian Ministry of Defence, 2016), p. 12.

⁴⁹ Interview by Heiko Borchert, Oslo, 27 October 2015; "Germany chosen as strategic partner for new submarines to Norway", Ministry of Defence Press Release No. 8/2017, 3 February 2017, <https://www.regjeringen.no/en/aktuelt/germany-chosen-as-strategic-partner-for-new-submarines-to-norway/id2537621/> (accessed 6 February 2017).

In the current transition process, the focus of the military leadership is on introducing new large weapon systems and maintaining the internal balance of the Norwegian armed forces. In this regard, autonomous systems are relevant to the extent that they support the need of the armed forces to reduce costs and support risk mitigation. So far, however, the Norwegian armed forces lack a joint approach that addresses the impact of autonomous systems on the services concepts, tactics, and procedures. Amongst all of the Norwegian services, the RNoN is the most advanced user of autonomous systems, acting in tandem with the local industry and the ministry's defence research institute FFI, which builds the core of Norway's naval undersea autonomy ecosystem. Major technologies are developed by FFI and will then be commercialised by Kongsberg. In addition, Norway's oil and gas industry is pushing for more advanced autonomous undersea applications and providing funds to develop the respective technologies.⁵⁰

So far, MCM is the primary mission for undersea autonomy with the RNoN. The navy's mine warfare service is fully convinced of the operational value of autonomous undersea systems such as REMUS built by Hydroid/Kongsberg and HUGIN developed by FFI. The submariners, in contrast, are said to be more reluctant about AUVs. Based on current experience, FFI is considering the use of AUVs for additional future missions, in particular for intelligence collection, ASW, and undersea camouflage and concealment. By 2025, the RNoN's mine warfare service will gradually phase out dedicated surface ships and replace them with mobile teams consisting of modular AUV units ready to be deployed from different platforms. The extent to which Norway's future submarines should have organic AUV modules is under discussion.⁵¹

The Future Maritime Conflict Picture

In the shadow of a remaking of the international political order, competition is heating up over the ideas guiding access to and freedom of navigation in the world's strategic domains. Countries like Russia, China, and Iran are responding to the up-to-now almost unrestricted ability of the United States to project power around the globe by beefing up their A2/AD capabilities and spinning alternative narratives that portray the legitimacy of their action. Consequently, the nature of the maritime domain is changing as systemic risks grow – diverging ideas on the key rules, norms, and principles further the 'balkanisation' of the maritime domain, as different zones of maritime influence emerge at the expense of the domain's global nature. This is relevant, as the maritime domain is the global economy's lifeline, not only facilitating exchanges across regions but also accelerating disruption through maritime interconnections. In parallel, the strategic significance of coastal zones is being reinforced by key trends such as changing demographics and increasing urbanisation that coincide with the need for global connectivity in these vital but fragile regions. Consequently, a new maritime conflict picture is emerging.⁵²

⁵⁰ Interviews by Heiko Borchert, Oslo, 26–27 October 2015.

⁵¹ Interviews by Heiko Borchert, Oslo, 26–27 October 2015 and 31 May 2016.

⁵² The 5C classification builds on: Future Character of Conflict (Shrivenham: UK Ministry of Defence, 2010).

- The maritime domain is becoming increasingly congested as coastal urbanisation grows, and an increasing number of state and non-state actors use the sea for different activities. Greater congestion in maritime areas means that armed forces will have a hard time evading unwanted enemy contact in operations, particularly when adversaries extend their buffer zones via A2/AD. Thus, operations are inevitably becoming riskier. This increases the need for new assets, such as unmanned systems that can be used to take on these risks and avoid enemy contact by moving into other domains.⁵³
- A congested maritime environment also tends to become more cluttered, which benefits those that want to hide. This in turn increases the need to establish a clearer differentiation between cooperative and non-cooperative targets. Consequently, the demand for both joint and interagency situational awareness and understanding is rising. This will need to be established in a cross-regional and cross-domain framework in order to outmatch hybrid adversarial action.
- Digital connectivity reinforces the consequences of a congested and cluttered maritime environment. Connectivity is the key currency for networked sea and sub-sea forces, as the value of every sensor and effector is determined by the degree of its integration in the overall command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) value chain. However, this is also the Achilles heel of networked forces, as a lack of connectivity can significantly lower operational tempo or lead to its breakdown. This is increasingly important, because non-state actors have recently shown significant proficiency in using low-cost technology and improvised concepts to advance their own connectivity.⁵⁴
- All of this implies that the future maritime domain will be much more contested. As Krepinevich has argued, a tit-for-tat race in fielding ever more powerful sensors and effectors could lead to a maritime “no man’s land,” where “only the long-range maritime scouting and strike force capabilities of both competitors overlap.”⁵⁵ Initial evidence suggests that this process is already in the making, as advanced A2/AD systems connect subsea-based sensors, submerged platforms, and surface assets with air systems and space-based assets as well as cyber operations. This could raise the bar for intervening forces as it increases the risk of losing conventional platforms. However, it could also trigger a more frequent use of unmanned assets to overwhelm the adversarial defence posture.
- Finally, naval forces of NATO and European Union member states will need to operate under rules of engagement that are subject to close political scrutiny. Proportionality of the means in use and the need to publicly justify every action might create more constraints for these naval forces than for actors operating on different normative assumptions. In an increasingly cluttered and congested maritime environment, normative guidelines might prompt new needs for graded effects to avoid collateral damage at sea and in the undersea domain. In addition, there might

⁵³ Operational Impact of Unmanned Systems Employed in a Megacity Environment (Arlington: Potomac Institute for Policy Studies, 2015).

⁵⁴ David Kilcullen, *Out of the Mountains: The Coming Age of Urban Guerilla* (London: Hurst & Company, 2013).

⁵⁵ Andrew Krepinevich, *Maritime Warfare in a Mature Precision-Strike Regime* (Washington, D.C.: CSBA, 2015), p. 97.

be requirements for human control of unmanned and autonomous systems and human influence on machine-machine interaction.

All of these trends will change future requirements for naval systems. Due to the future of sensor ubiquity in the maritime domain, stealth, cyber-security, camouflage, concealment, and deception will gain in importance. An increasing number of free-floating smart sensors and autonomous platforms will need to be integrated into the overall naval C4ISR architecture, which in turn needs to be seamlessly connected with similar systems in other domains. Unless protected in novel ways, A2/AD in the future maritime domain will heighten the risk for today's high value assets, which is likely to drive the need for distributed capabilities. This could also reduce today's focus on multi-mission platforms to the benefit of single-mission platforms operating in smart swarms. Consequently, all elements of future networked naval surface and subsea forces will need to be more agile, easy to integrate, and ready to connect across domains.

For autonomous systems, this development serves as the ultimate litmus test – either tomorrow's maritime domain will prove to be too challenging, particularly if adversaries are chasing after connectivity as the digital Achilles heel; or it will become the ultimate driver for autonomy. In any case, it seems that autonomous systems operating in tomorrow's maritime domain will need to become much more agile, respond more quickly and also without prior guidance to unforeseen events, possess improved self-defence capabilities, and be capable of countering adversarial unmanned systems. All of this significantly raises demands for future autonomy that must be more powerful.

Undersea Autonomy: Motives, Drivers, and Added Value

The future of maritime conflict, which was pictured and discussed above, is likely to reinforce the cross-domain character of the subsea domain that is already considered a three-dimensional battle space. Currently, the subsea domain is well saturated in terms of assets in use. Therefore, UUVs introduced into this complex environment need to provide added value beyond already available assets in order to create operational advantages that convince navies and sub-sea forces of their benefits. This defines the primary operational and strategic motives shaping the use of undersea autonomy (Table 1):

- Operational motives

The most important operational motive is to close existing capability gaps with unmanned assets, as discussed above in the case of the U.S. Navy. Secondly, operational motives also derive from the principles of war epitomising a navy's key warfighting paradigms. Making sure that the use of UUVs fits with key principles such as economy of forces, flexibility, or surprise would multiply naval capabilities.⁵⁶ As the next section on military innovation will discuss, it will also require navies to rethink the way that they prepare for and conduct missions with autonomous capabilities, thus closing a substantial conceptual gap that is prevalent today. The

⁵⁶ See, for example: UK Defence Doctrine. Joint Doctrine Publication 0-01 (Shrivenham: Ministry of Defence Development, Concepts, and Doctrine Centre, 2014), pp. 50–51.

third group of motives results from the specifics of undersea operations. As initial concept ideas by the U.S. Navy make clear, UUV-based sensors that are detached from submarines can significantly augment existing capabilities, as it might be possible to keep track of developments in an undersea area of interest without requiring the submarine to be present. In addition, detached UUV-based sensors and effectors can get much closer to potential objects of interest without endangering the respective mother platform. In a future A2/AD subsea world, proximity and reach should be seen as major mission requirements that can be fulfilled with undersea autonomy.

Country	Primary Motives				Secondary Motives
	Close capability gap	Augment capacities	Minimise Risks	Reduce Costs	
United States	■	■	■		<ul style="list-style-type: none"> ▪ Fear of losing technological superiority ▪ Power projection vs. A2/AD
Russia			■		<ul style="list-style-type: none"> ▪ Search and Rescue ▪ Autonomous systems illustrate the technological proficiency of the armed forces
China		■			<ul style="list-style-type: none"> ▪ Keeping pace with the United States ▪ Defending sovereignty at sea
Norway			■	■	<ul style="list-style-type: none"> ▪ Maintaining the national offshore industry
Singapore		■			<ul style="list-style-type: none"> ▪ Societal expectations

Table 1: Primary and Secondary Motives for Undersea Autonomy in Different Countries

- Strategic motives

First of all, a navy's conception of risk is key. In this regard, autonomy cuts both ways, as UUVs can be used to avoid and take risks. It remains to be seen whether and to what extent state and non-state actors are going to interpret the use of autonomous assets as an escalatory means that might worsen geostrategic stability. Second, given the limited financial resources of most Western navies, cost savings is another strategic motive. However, this is a dual-edged sword. For example, China has a different take on costs; low costs are seen as a competitive advantage vis-à-vis different players, also in view of supplying export markets.⁵⁷ Third, force augmentation is a major strategic driver for actors operating on a thin staffing level. Fourth, armed forces believe in the value of benchmarking and thus want to follow 'best in class' examples. But, as will be argued below, this can also be detrimental to a navy's strategic

⁵⁷ Interview by the authors, Washington, D.C., 28 April 2015.

leeway. Fifth, the flip side of benchmarking is a general concern about falling behind others by losing technological advancements. This can also trigger navies to look into the benefits of undersea autonomy. Finally, ambitious emerging powers are showing a growing appetite for setting up robust national defence industries and entering international defence markets.⁵⁸ In this regard, autonomous assets operating in all domains are highly attractive, because the barriers to entry of this segment tend to be lower than in other, more complicated platform segments.

In practice, answers to all of these motives are strongly intertwined with two key questions, “What do navies want to do with UUVs?” and “How do they intend to accomplish the respective missions?” In view of the potentially disruptive nature of undersea autonomy, the second question is more important than the first, as this is where navies need to come up with novel conceptual ideas. Today, most Western navies and armed forces in general focus on the use of autonomous systems on “dirty, dull, and/or dangerous” missions (3D missions). Although this is legitimate in terms of risk mitigation, this approach deprives autonomy of its full potential, since existing concepts and tactics remain largely unquestioned. To push the envelope for undersea autonomy, different ways of using autonomous systems are needed:⁵⁹

- Autonomous systems that can be deployed 24/7 to patrol wide areas increases naval endurance. The same applies to forward deployed assets that would be activated upon request in the future, such as the Defence Advanced Research Projects Agency’s (DARPA’s) Upward Falling Payload program.⁶⁰ If autonomous systems could help to deploy such assets behind the adversary’s undersea A2/AD wall, they might enable allied forces to exploit surprise effects and thus neutralise adversarial defence.
- Future maritime peers can be expected to match allied forces in terms of long-range sensors and effectors. Therefore, it will become more important to take risks. Unmanned systems could help allied navies take more risks by foiling, disturbing, and destroying adversarial sensors and effectors, while increasing allied reach and agility.
- If navies are willing to risk more, they will most likely not want to risk their most expensive assets. Navies need assets that they are willing to lose. Cheap, single-mission, autonomous assets that can be used in swarms are thus likely to lead to a re-emergence of mass as an important feature of future naval forces.⁶¹ This could lead to operational ideas like creating a wide-area surface and subsea sensor curtain that could keep adversarial submarines out of strategic zones by establishing noise barriers, improving undersea detection, and providing localisation data for ASW effectors stationed in other domains.

⁵⁸ Heiko Borchert, “Rising Challengers: Ambitious New Defence Exporters Are Reshaping International Defence Trade,” *European Security & Defence* (February 2015), pp. 61–64.

⁵⁹ Interview by the authors, Washington, D.C., 28 April 2015; Paul Scharre, *Robotics on the Battlefield. Part I. Range, Persistence and Daring* (Washington, D.C.: CNAS, 2014); Paul Scharre, *Robotics on the Battlefield. Part II: The Coming Swarm* (Washington, D.C.: CNAS, 2014).

⁶⁰ <http://www.darpa.mil/program/upward-falling-payloads> (accessed 12 January 2017).

⁶¹ Shawn Brimley, Ben Fitzgerald and Kelley Saylor, *Game Changers. Disruptive Technology and U.S. Defense Strategy* (Washington, D.C.: CNAS, 2013), p. 19.

- Swarms could also lead to new divisions of labour. Distributing capabilities in a swarm could mean that some elements are in charge of observation, while others provide defence and another group focuses on accomplishing the swarm's primary mission. With this, navies would depart from the traditional multi-mission platform approach that is becoming increasingly risky given tomorrow's A2/AD threat.

Military Innovation: What the Literature Says

If and to what extent the use of unmanned and autonomous undersea vehicles changes tomorrow's undersea warfare is of great importance for the future picture of maritime conflict. The simple fact that these vehicles are available does not yet constitute a military innovation.⁶² Military innovation results from the complex interplay between operational needs and conceptual, cultural and organisational, and technological changes. This interplay constitutes the concept of Revolution in Military Affairs (RMA), which describes different innovations such as land warfare during the French and the Industrial Revolutions (e.g., telegraph-assisted communications, railway transport, and artillery weapons), combined-arms tactics and operations in World War I or the *Blitzkrieg* in World War II.⁶³ Digitisation and connectivity brought about by the advent of information and communications technology formed the basis of network-centric warfare that in turn paved the way for today's discussion about the seamless integration of different military services across all relevant domains.⁶⁴

⁶² Following Andrew Ross we define military innovation as "change in how militaries prepare for, fight, and win wars." See Andrew L. Ross, *On Military Innovation: Toward an Analytical Framework*. CITC Policy Brief No. 1 (San Diego: California Institute on Conflict and Cooperation, 2010), p. 1, <http://escholarship.org/uc/item/3d0795p8> (accessed 12 January 2017).

⁶³ Williamson Murray and MacGregor Knox, "Thinking about Revolutions in Warfare," in *The Dynamics of Military Revolution 1300-2000*, ed. Macgregor Knox and Williamson Murray (Cambridge: Cambridge University Press, 2001), p. 13; Tai Ming Cheung, Thomas G. Mahnken, and Andrew L. Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," in *Forging China's Military Might. A New Framework for Assessing Innovation*, ed. Tai Ming Cheung (Baltimore: Johns Hopkins University Press, 2014), pp. 15–46; Michael Raska, *Military Innovation in Small States: Creating a Reverse Asymmetry* (Abingdon: Routledge, 2016).

⁶⁴ David S. Alberts, John J. Garstka, and Frederick P. Stein, *Network Centric Warfare: Developing and Leveraging Information Superiority* (Washington, D.C.: CCRP, 2002); Theo Farrell and Terry Terriff, "Military Transformation in NATO: A Framework for Analysis," in *A Transformation Gap? American Innovations and European Military Change*, ed. Terry Terriff, Frans Osinga, and Theo Farrell (Stanford: Stanford University Press, 2010), pp. 1–13; Raska, *Military Innovation in Small States*, pp. 28–58.

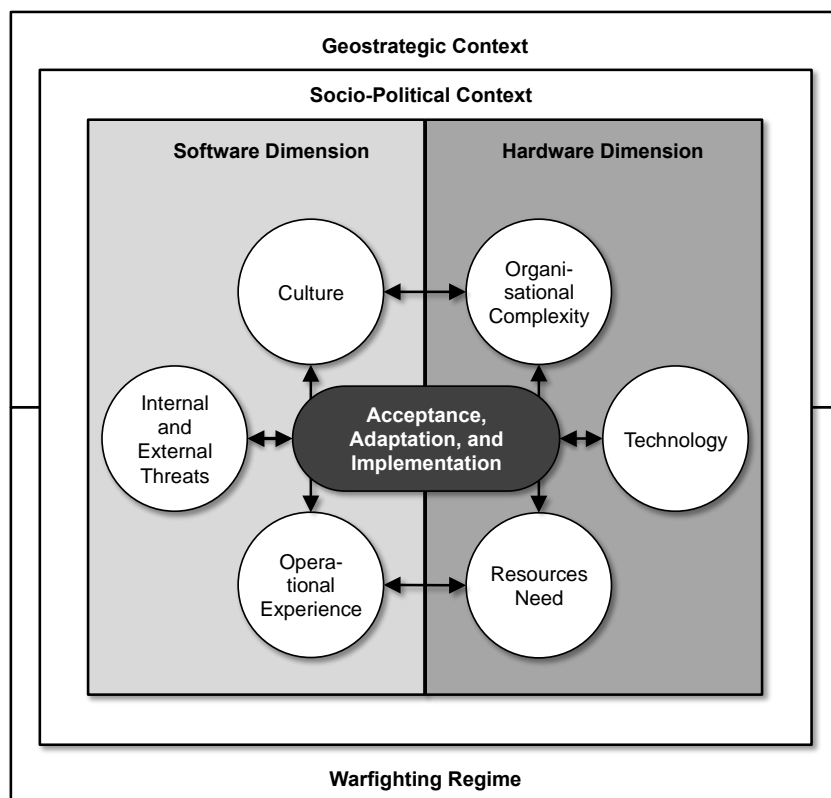


Figure 1: Elements of Military Innovation

Against this background, Figure 1 summarises the key factors discussed in the literature for understanding military innovation within the context of undersea autonomy – the interplay between threats, security culture, and operational experience describes the ‘software’ aspects of military innovation, whereas interactions between technology, organisational complexity, and resources need constitutes the ‘hardware’ dimension. True military innovation requires both dimensions, as conceptual, cultural, organisational, and technological progress do not evolve at the same pace.⁶⁵

Software-based innovation

According to Adamsky, the “relationship between technology and military innovation is ... socially constructed,” which means that the “kind of weaponry that is developed and the kind of military that it foresees are cultural products in the deepest sense.”⁶⁶ The U.S. idea of an LDUUV that mimics the roles and functions of an aircraft carrier perfectly illustrates Adamsky’s point. In addition, societal values are important determinants of the types of wars that a nation fights and the concepts and technology that it uses to do so.⁶⁷ Together, these elements constitute military culture which is defined as “identities, norms, and values that have been internalised by a military organisation and frame the way the organisation views the world, and its role and function in it.”⁶⁸ Military organisational culture

⁶⁵ Ross, *On Military Innovation*, p. 4.

⁶⁶ Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US and Israel* (Stanford: Stanford University Press, 2010), p. 10.

⁶⁷ Interview by the authors, Washington, D.C., 15 July 2015; Brimley, FitzGerald and Sayler, *Game Changers*, p. 12; Scharre, *Robotics on the Battlefield. Part I*, pp. 35–37.

⁶⁸ Theo Farrell’s definition, quoted by Raska, *Military Innovation in Small States*, p. 4.

formed during peacetime, as Murray argues, “will determine how effectively [armed forces] will adapt to the actual conditions they will face in war.”⁶⁹ In this regard, military organisations tend to be conservative in nature, defending the status quo against changes in how they are shaped, how tasks are assigned and executed, and how money is allocated and distributed.⁷⁰ All of these aspects might be needed in order to fully-exploit the benefits of unmanned systems.

Reflections upon the role of culture also need to take into account threat perceptions and operational experience, but the impact of these two additional aspects on innovation is ambivalent. In general, the degree of change armed forces might need to undergo depends on: (i) the scope of changes in their relevant environment; (ii) the impact of these changes on military tasks and capabilities; and (iii) the readiness of the armed forces to deal with these changes and the resulting redefinition of tasks and capabilities. Geostrategic changes can drive military innovation, as they might prompt nations to modify their values if the stakes are high enough.⁷¹ However, the readiness to change is influenced by additional aspects such as organisational age, which is a critical factor as older organisations tend to resist change.⁷² In addition, operational experience can reinforce cultural resistance, as armed forces are “more committed to the ethos of the past than to preparing to meet the future.”⁷³ This explains why armed forces tend to use unmanned systems like the manned platforms that they already have in service, because they have developed tactics, techniques, and procedures (TTP) to deploy them.

This leaves one question to be answered: Can state (or non-state) actors accrue operational advantages from using unmanned and autonomous systems that are of strategic relevance? Once again, the literature suggests that conservative forces are prevailing. First, early movers might enjoy advantages vis-à-vis their peers, but according to Horowitz, relative gains are “inversely proportional to the diffusion rate of the innovation.”⁷⁴ This also suggests that waiting could benefit late movers, as the availability of more information reveals if the risk entailed with military innovation is worth it. As a result, strategic competition tends to create lookalikes, as competitors reflect on their peers’ choices and adopt similar weapon systems.⁷⁵ This suggests, firstly, that “dominant actors derive less value in relative terms from new technologies given their dominance,”⁷⁶ which in turn might affect their readiness to adopt new technologies. Second, emerging powers are also risk averse. When it comes to adopting new, operationally unproven technology, they are likely to imitate their peers if “pursuing their own innovation proves costly relative to imitation, little information exists about the effectiveness of alternative innovations, and the perceived risks of failing to imitate another state outweigh the perceived benefits of pursuing a novel but risky new technology.”⁷⁷

⁶⁹ Williamson Murray, *Military Adaptation in War: With Fear of Change* (Cambridge: Cambridge University Press, 2011), p. 309.

⁷⁰ Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Stanford: Stanford University Press, 2010), p. 38.

⁷¹ Interview by the authors, Washington, D.C., 15 July 2015; Raska, *Military Innovation in Small States*, pp. 197–200; Jeffrey A. Isaacson, Christopher Layne, and John Arquilla, *Predicting Military Innovation* (Santa Monica: RAND, 2007), pp. 4, 12–13.

⁷² Horowitz, *The Diffusion of Military Power*, p. 38.

⁷³ Murray, *Military Adaptation in War*, p. 3.

⁷⁴ Horowitz, *The Diffusion of Military Power*, p. 50.

⁷⁵ *Ibid.* pp. 20–21.

⁷⁶ Brimley, FitzGerald, and Saylor, *Game Changers*, p. 11.

⁷⁷ Yu-Ming Liou, Paul Musgrave, and J. Furman Daniel, “The Imitation Game: Why Don’t Rising Powers Innovate Their Militaries More?,” *The Washington Quarterly*, 38:3 (Fall 2015), p. 159.

Hardware-based innovation

Technology is an important driver for military organisations. Today's main challenge stems from the fact that key technologies no longer originate in the traditional military-industrial complex, but instead in commercial ecosystems. This puts a premium on integrating commercially developed technology into the military domain. In this regard, military innovation depends on three different aspects: (i) organisations, (ii) resources, and (iii) concepts. Organisations and resources are directly linked. Building on Horowitz's insights, military innovations spread less quickly if they require intense organisational change and consume large resources.⁷⁸ This has at least two consequences for the use of unmanned and autonomous systems:

- First, bringing unmanned and autonomous systems close to manned systems already in use, for example by using similar concepts of operations, will lower barriers to acceptance. However, this might be detrimental to innovation, as armed forces will continue to do the same, only with other means.
- Second, unmanned and autonomous systems that break up the status quo are more likely to lead to changes in warfighting. This might translate into operational advantages but also runs the risk of failing to meet armed forces' acceptance.⁷⁹

If and to what extent would military organisations buy into innovations depends on the way that they think about them. Their way of thinking, in turn, depends on several factors – such as the respective actors' access to the sources of power within the political and military establishment, the way that these actors use their institutional weight to advance their own ideas on innovation, and the degree of cooperation or competition between different military services.⁸⁰ In addition, promotional aspects are important. Effective military organisations promote people based on individual proficiency and merit. Thus, it matters to what extent a soldier's abilities in handling unmanned and autonomous systems are seen as a special skill that needs to be rewarded, since this sends positive signals to the troops.⁸¹

Finally, all of this suggests that for technology to have a lasting impact on military and naval innovation, it must be properly integrated into military concepts of operations as well as processes and procedures. It is relatively easy to acquire technology, but it is much more challenging to adapt processes accordingly.⁸² This is underlined by the fact that in all of the aforementioned case studies, technological push is much stronger than concept pull. In balancing these two very different requirements, military planners also need to take into account timing as a crucial factor, since urgent operational requirements can serve as strong levers for change, and thus for the introduction of new

⁷⁸ Horowitz, *The Diffusion of Military Power*, pp. 8–12.

⁷⁹ Interview by the authors, Washington, D.C., 16 July 2015; Horowitz, *The Diffusion of Military Power*, pp. 14–15.

⁸⁰ Raska, *Military Innovation in Small States*; Adamsky, *The Culture of Military Innovation*; Thomas Jäger and Kai Opermann, "Bürokratie- und organisationstheoretische Analysen der Sicherheitspolitik: Vom 11. September zum Irakkrieg," in *Methoden der sicherheitspolitischen Analyse*, ed. Alexander Siedschlag (Wiesbaden: VS Verlag für Sozialwissenschaften, 2006), pp. 105–134.

⁸¹ Caitlin Talmadge, *The Dictator's Army. Battlefield Effectiveness in Authoritarian Regimes* (Ithaca/London: Cornell University Press, 2015), p. 13–15; P.W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: The Penguin Press, 2009), p. 253.

⁸² Adamsky, *The Culture of Military Innovation*, p. 21; Horowitz, *The Diffusion of Military Power*, p. 34.

concepts and technologies.⁸³ However, in doing so, force planners once again need to act cautiously to balance urgent operational requirements with long-term force requirements to make sure that armed forces develop a balanced capability portfolio augmented by the benefits of autonomous and unmanned systems.

Conclusion

Military innovation resulting from the interplay between operational needs, concepts, the cultural-institutional framework, and technological progress is very demanding. Autonomous systems have the potential to promote innovation in undersea warfare, as they enable navies to close capability gaps, broaden the mission spectrum, and operate more daringly. The extent to which UUVs will change the tempo and dynamic of undersea warfare and thus affect regional stability depends on the concepts that navies use to operate UUVs. For the time being, disruption is not in the cards, since conservative forces prevail.

None of the countries analysed in this article has managed to synchronise innovation along the three vectors of conceptual, cultural, and organisational change. Consequently, first-degree innovation that has been achieved so far with undersea autonomy closely mirrors existing concepts and current platforms. Thus, UUVs have initially replaced manned platforms, but traditional tactics, techniques, and procedures remain largely unchallenged. Second-degree innovation would mean that navies would start using UUVs in a way that deviates from the current use of undersea platforms or that UUVs would be tasked to accomplish missions not currently assigned to manned platforms. This could lead to disruptive innovation that would replace existing tasks or current procedures, platforms, or technologies. However, that would require navies to launch sweeping conceptual and organisational changes, which currently do not exist. Instead, current UUV missions are evolving in line with the literature on military innovation. MCM has emerged as the key mission, as operational needs (e.g., threats by sea mines), navies' striving for risk reduction (e.g., self-protection of mine divers and surface platforms), and operational value-adds (e.g., increased efficiency in searching sea minefields) have all come together. As a result, dedicated Concepts of Operations (CONOPS) have emerged, which in turn has prompted suppliers to develop tailored technologies.

If navies want to push innovation in undersea warfare with the help of autonomous systems, more needs to be done. Three aspects are of particular importance:

- First, if navies want to broaden the UUV spectrum, they will need to develop different, task-oriented missions serving as role models. This requires them to replace today's technological push with a much stronger focus on concepts that exemplify how to accrue operational advantages by advancing undersea autonomy. This will require navies, industry, and scientific partners to develop a more modular maturity level approach. This approach would define different modules ready to use for specific missions. The maturity level approach would also

⁸³ Brimley, FitzGerald, and Saylor, *Game Changers*, p. 13.

illustrate the kind of conceptual, cultural, organisational, and technological changes that are needed to accomplish the respective missions. An iterative approach of that kind could help overcome hurdles to acceptance of UUVs, as it would support naval risk mitigation.

Three geostrategic key actors, namely the United States, Russia, and China, are about to develop and deploy UUVs. This suggests that different role models could emerge, with each nation trying to back up its ideas with concepts, training support, interoperability requirements, and UUV exports. In the long-run, this could lead to a breakup of the current, primarily U.S.-dominated undersea warfighting regime, if Russia and China were to develop UUVs that fit their specific undersea warfighting concepts.

- Second, a more comprehensive view is needed because undersea autonomy is not just the use of an autonomously operating platform. Rather, it reinforces the need for networked approaches integrating all platforms, sensors, and effectors operating in the undersea domain and for combining them with assets operating in other domains. Cross-domain autonomy as one of the key ideas for future warfighting will reinforce the need for modular and scalable approaches based upon open architecture and open standards rather than proprietary solutions. To this purpose, navies and their sister services should set up cross-service and cross-domain expert groups that jointly address the implications of the use of autonomous systems on key issues like concept development, research and development, procurement, and operational deployment.
- Finally, unlike autonomous aerial systems, UUVs need to be carried into areas of operations. As long as UUVs depend on submarines or surface platforms for deployment, platform-centric thinking is likely to dominate operational concepts for the use of UUVs. This raises a key question: Are UUVs adapting to submarines and surface platforms, or are these platforms adapting to deploy UUVs?⁸⁴ Navies and industries will need to team up to address this question, since tomorrow's platforms will have to offer many more options to deploy different kinds of payloads. This, in turn, will shape the design of deployment platforms beyond existing disposal platforms such as torpedo tubes or payload modules for submarines.

⁸⁴ See also: Megan Eckstein, "Navy seeking unmanned underwater advances to field today, to inform next generation sub design in 2020s", USNI News, 31 October 2016, <https://news.usni.org/2016/10/31/navy-seeking-uuv-advances-to-field-today-to-inform-ssnx-design-in-2020s> (accessed 12 January 2017).

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