THE MK 41 VERTICAL LAUNCH SYSTEM

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About Citadel Analytics (UK) Ltd.
At the Intersection of Missile Defense and Advanced Innovation

Citadel is a think tank co-founded by Dr. James Bosbotinis and Harris S. Fried, Esq. Colonel David Shank (US Army (ret.)) and an expert in Air and Missile Defense joined the board in 2021 as a key advisor. Citadel's mission is to engage with government, military, and industry to create the best solutions to the increasingly vital job of improving our defensive capabilities. We seek to utilize our defensive capabilities and any appropriate advance in technology to maintain and/or achieve superiority across all domains, providing the equipment that the warfighter needs in the most expedient and cost-effective manner possible. Citadel through its network of affiliates also serves as a consultant, advisor, and partner to industry in its quest for supply chain solutions.

Our Vision

In 2016, Citadel Analytics (UK) Ltd. ("Citadel") first published its vision for the future of the Missile Defence industry, believing that key geopolitical, military, and industrial trends pointed to a near-term future where missile defense was paramount in the face of increasing threats, while new technologies would greatly enhance defensive efforts. Throughout the integrated air and missile defense (IAMD) industry supply chain, especially via the introduction of cutting-edge technologies, such additive manufacturing, industry should have as a top priority the delivery of a qualitatively superior product to the warfighter in an expedited mode. This entails a new look at supply chains and how the advent of advanced innovation can be and is being utilized to make sure that the US and its allies do not yield superiority to our adversaries across any weapons system and any domain.

Introduction

This paper provides a case study of the Mk 41 vertical launch system (VLS) and the opportunities investment in its supply chain presents. The Mk 41 is a critical enabling system for the US and allied navies and as will be discussed below, new variants are being developed for land-based applications, providing additional growth potential. The Mk 41 has been in production since the 1980s and will remain in production for the foreseeable future, thus ensuring a long-term requirement for maintenance and support. The paper will first provide a brief overview of the evolving strategic environment, in order to establish the context for why systems such as the Mk 41 are important and constitute potential investment opportunities. Proceeding from this, the paper provides an overview of the Mk 41 itself, its variants, and prospects. This is followed by a discussion of the Mk 41 supply chain, including its prime contractors, key locations, and sub-contractors.

The analysis in this paper is founded on a multidisciplinary methodology, drawing on the author's extensive background and experience in academia and in the provision of bespoke analysis encompassing geopolitical, strategic, and related subjects. Drawing exclusively on open sources, the below case study into the Mk 41 highlights the range and depth of expertise Citadel Analytics (UK) can deploy via its own team and network.

The Strategic Environment

The global strategic environment is in a period of distinct flux, highlighted by the growth of Chinese power and Sino-US rivalry, the regional challenges posed by Iran and North Korea, and most dramatically, Russia's invasion of Ukraine. Driven by neo-imperial ambition and the desire to redefine the post-Cold War balance of power, Moscow's war against Ukraine constitutes the gravest threat to international security in decades, and dramatically highlights the need for investment in robust armed forces that can deter and when necessary, respond to threats. Russia's large-scale employment of ballistic and cruise missiles, including the combat debut of the hypersonic Kinzhal, and heavy caliber artillery rockets, in particular in indiscriminate attacks against civilian areas, also provides a vivid demonstration of the critical importance of integrated air and missile defense (IAMD). Ukraine continues to receive critical Western military aid, including advanced air defense systems such as the Kongsberg/Raytheon National Advanced Surface-to-Air Missile System (NASAMS), the Diehl Defence IRIS-T, and the US MIM-104 Patriot, which are providing it with an enhanced ability to defend against Russian air and missile attacks.

The war in Ukraine also dramatically highlights the spectrum of air and missile threats that need defending against (and conversely, point to the opportunities for offensive operations). In this regard, the war in Ukraine has seen the use of small unmanned air systems (UAS) on the battlefield (for example, the US-supplied Switchblade); heavy caliber artillery rockets such as the US-made M-30 Guided Multiple Launch Rocket or the Russian Smerch; the SS-21 and SS-26 short-range ballistic missiles; long-range cruise missiles, including the low-observable AS-23A (Kh-101), and ex-Soviet unmanned aircraft operating as improvised missiles (Ukrainian Tupolev Tu-141);[1] supersonic anti-ship cruise missiles with a secondary land-attack capability; and the Kinzhal air-launched ballistic missile. Depending on the course of the war, the possibility that Russia employs, albeit on a very limited basis, additional hypersonic weapons such as the ground-launched version of the Tsirkon or the developmental air-launched Kh-95, cannot be dismissed. Likewise, the possibility of the transfer of Iranian ballistic missiles to Russia exists.[2] Iran has already provided Russia with the Shahed-136 UAV, which as Thomas Newdick explains, "fly low and relatively slow and have small radar and infrared signatures making them a challenge for even advanced air defense systems".[3]

The use of air and missile systems in Ukraine reflects wider trends in the developing threat environment. Iran has used ballistic missiles to prosecute strikes against targets in Iraq, including against US forces at Al Asad airbase following the assassination of General Qasem Soleimani, while its Houthi proxies in Yemen have also conducted ballistic missile strikes against Saudi Arabia and the United Arab Emirates (UAE): in a January 2022 attack launched by the Houthis against the UAE, involving medium-range ballistic missiles (MRBMs), cruise missiles and drones, the UAE successfully intercepted an incoming MRBM with the THAAD

[1] Piotr Butowski, "How A Soviet-Era Reconnaissance UAS Became a Cruise Missile", *Aviation Week*, 15 December 2022, https://aviationweek.com/defense-space/missile-defense-weapons/how-soviet-era-reconnaissance-uas-became-cruise-missile.
[2] Tyler Rogoway, "An Iranian Ballistic Missile Storm is on Ukraine's Horizon", *The War Zone*, 7 November 2022, https://www.thedrive.com/the-war-zone/an-iranian-ballistic-missile-storm-is-on-ukraines-horizon; and Sine Ozkarasahin, "Iranian Ballistic Missiles Threaten to Change Battlefield Dynamic in Ukraine", *Eurasia Daily Monitor*, Vol. 20, Issue 13, 23 January 2023, https://jamestown.org/program/iranian-ballistic-missiles-threaten-to-change-battlefield-dynamic-in-ukraine/.
[3] Thomas Newdick, "Russia Bombards Ukraine with Iranian 'Kamikaze Drones'", *The War Zone*, 17 October 2022, https://www.thedrive.com/the-war-zone/russia-bombards-ukraine-with-iranian-kamikaze-drones.

missile defense system.[4] Iran has also prosecuted complex attacks with cruise missiles and UAVs against oil infrastructure targets in Saudi Arabia, namely in September 2019. Coordinated, complex, multi-directional attacks involving the use of ballistic and cruise missiles with UAVs pose significant defensive challenges, which will be exacerbated by the use of low-observable cruise missiles and UAVs, and ballistic missiles equipped with maneuvering re-entry vehicles. Moreover, the development and deployment of hypersonic weapons will provide their operators with a significantly enhanced strike capability and pose a major defensive challenge. The combination of speed, endoatmospheric maneuverability, flight altitude and the unpredictable trajectory provide major challenges to the detection, tracking and interception of hypersonic weapons, by compressing the timelines for detecting an incoming threat, the engagement window and time available to attempt additional interceptions. The integration of artificial intelligence into missile and unmanned air systems, for example, to provide the latter with swarming capabilities, will also complicate defensive efforts.

The increasingly complex and diverse air and missile threat spectrum emphasizes the requirement for versatile, flexible, and robust IAMD capabilities that can effectively counter such threats. It warrants highlighting that effective air and missile defense is a combination of both defense and offense: targeting an adversary's air and missile systems left-of-launch, in counterforce operations, is critical. In this context, the development of multi-mission launch systems that can be armed with a variety of missiles, offering a mix of capabilities, whether defensive, offensive or a mix thereof, offers advantages in terms of flexibility and providing choice at the tactical, operational and strategic levels. Such systems are already in use in the naval domain, with perhaps the leading example being the Lockheed Martin Mk 41 VLS. A number of other VLS are in service or development, including the Russian UKSK/UKSK-M; China's HT-1E intended for export (likely derived from the domestic VLS used on the Type 052D and Type 055 destroyers); the French DCNS' Sylver; South Korea's Agency for Defense Development/Hanwha Defense Korean Vertical Launch System; with Turkey also developing an indigenous VLS – MIDLAS, deriving from the Turkish for National Vertical Launch System.[5] The US also operates a second type of VLS, the Mk 57, which equips the three-strong *Zumwalt*-class of destroyer.[6] The Mk 57 is a peripheral VLS, in contrast to the centrally-placed Mk 41.[7]

The Mk 41

Originally developed in the 1970s and introduced into service from 1986 onboard the *Ticonderoga*-class cruiser, USS *Bunker Hill*, the Mk 41 represents the leading and most successful example of a naval vertical launch system. The Mk 41 equips the US Navy's *Ticonderoga*-class cruisers, *Arleigh Burke*-class destroyers, will equip the forthcoming *Constellation*-class frigate and will also initially equip the next-generation DDG(X) destroyer,

[4] Jen Judson and Joe Gould, "THAAD, in First Operational Use, Destroys Midrange Ballistic Missile in Houthi Attack", *Defense News*, 21 January 2022, https://www.defensenews.com/land/2022/01/21/thaad-in-first-operational-use-destroys-midrange-ballistic-missile-in-houthi-attack/.
[5] Tayfun Ozberk, "Turkish Indigenous VLS 'MIDLAS' Performs First Ever Launch", *Naval News*, 4 December 2022, https://www.navalnews.com/naval-news/2022/12/turkiyes-midlas-debuts-with-hisar-surface-to-air-missile/.
[6] Raytheon Missiles and Defense, "Zumwalt-Class Destroyer", https://www.raytheonmissilesanddefense.com/what-we-do/naval-warfare/command-and-control/zumwalt-class-destroyer.
[7] BAE Systems, "Mk 57 VLS", https://www.baesystems.com/en-media/uploadFile/20210610163542/1434666505665.pdf.

which is intended to replace the *Ticonderoga*-class, supplement the *Arleigh Burke*, and provide the core of the US Navy's surface combatant force into the long-term.[8] It may also equip unmanned surface vessels. The Mk 41 is also in service with multiple allied navies, including those of Japan (the second-largest user after the US, with 30 ships fitted with the Mk 41), Australia, Denmark, Germany, the Netherlands, New Zealand, Norway, South Korea, Spain, Thailand and Turkey.[9]

Moreover, additional navies, including those of Canada, Finland, Saudi Arabia, and the UK will equip surface combatants currently under construction with the Mk 41; Japan also intends to build two large ballistic missile defense (BMD) destroyers, known as the Aegis System-Equipped Vessel, which will be equipped with a large, as yet undetermined number of VLS cells, most likely the Mk 41.[10] The ASEVs will replace a previously planned acquisition of the Aegis Ashore BMD system. It is likely that further customers for the Mk 41 will emerge, given the utility of the system. The Mk 41 will thus remain in production through the 2020s and into the 2030s, and potentially beyond. Further, given the typical 30-40-year service life of a warship, vessels being commissioned this decade or in the 2030s, will remain in service into the 2060s and 2070s; the requirement for logistic, maintenance and sustainment of deployed Mk 41 VLS will be required for the long-term.

The success of the Mk 41 is driven by its modularity and flexibility. Hein van Ameijden, Managing Director at Damen Naval, describes the Mk 41 in the following terms:

> It's "Any Weapon/Any Cell" design allows a MK41 cell to fire any integrated missile providing maximum flexibility. With over 14,000 deployed VLS cells across more than 150 vessels, 4,500 operational and test firings and an operational availability of greater than 99 percent, MK 41 VLS stands as a remarkable testament of the ingenuity.[11]

The Mk 41 employs a modular, cell-based configuration, that is inherently scalable and intended to support multiple missile types, as explained by Lockheed Martin:

> The basic building block of the system is an eight-cell MK 41 VLS module that can be assembled in desired numbers to meet specific mission and hull requirements. MK 41 VLS is currently deployed in 13 configurations, ranging from a single module with eight cells to 16 modules with 122 cells.[12]

The modules are of two lengths: the tactical module, which is 6.7 meters long, and the strike module, which is 7.6 meters long.[13] The strike module can hold larger missiles, such as the

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[8] Sam LaGrone, "Navy Unveils Next-Generation DDG(X) Warship Concept with Hypersonic Missiles, Lasers", *USNI News*, 12 January 2022, https://news.usni.org/2022/01/12/navy-unveils-next-generation-ddgx-warship-concept-with-hypersonic-missiles-lasers.

[9] Based on data in the IISS, *Military Balance 2022*, (London: Routledge for the International Institute for Strategic Studies, 2022).

[10] Naval News Staff, "Japanese MoD Releases Further Details About Its Future BMD Destroyers", *Naval News*, 25 December 2022, https://www.navalnews.com/naval-news/2022/12/japanese-mod-releases-further-details-of-asev-bmd-destroyers/.

[11] Rick Van De Weg, "Another Milestone for the F126 project: MK 41 Vertical Launching System Under Contract", Damen, 16 February 2022, https://www.damen.com/insights-center/news/another-milestone-for-the-f126-project.

[12] Lockheed Martin, "Mk 41 Vertical Launching System", 2019, https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/naval-launchers-and-munitions/MK41_VLS_Vertical_Launching_System_Product_Card.pdf.

[13] Ibid.

Tomahawk cruise missile, the SM-3 interceptor, and the SM-6 multi-role missile. While a cell typically holds one missile, the RIM-162 Evolved Sea Sparrow (ESSM) and MBDA Sea Ceptor/Common Anti-air Modular Missile can be quad-packed, that is, four missiles to a cell.[14]

This enables a ship to be armed with multiple missile types encompassing the full spectrum of operational roles, that is, air defense, BMD, land attack, anti-surface warfare, and anti-submarine warfare. Further, the system is designed with an open architecture to facilitate the integration of new technologies and missiles:

> The launch control system features an open, distributed architecture that allows for easy integration of future technologies. Open architecture both in the weapon control interface and the missile mechanical and electrical interface allows the system to support any missile in any cell… Since the mid-1980's, MK 41 VLS has maintained a common mechanical structure, and the system electronics have been continuously upgraded. The upgrades incorporate new missile integration capabilities, mitigate obsolescence and leverage the benefits of commercial off the shelf products and open system architecture to provide an affordable product.[15]

The modularity and flexibility of the Mk 41 design is also evident in proposed derivatives, seeking to expand the range of ships capable of being equipped with the system. Lockheed Martin has developed the Single Cell Launcher, which "maximizes commonality through use of the structure, software and electronics associated with the combat proven MK 41",[16] and the Host Extensible Launching System, which provides "a low-cost solution that integrates new missiles and munitions into the MK41 and MK57 Vertical Launching Systems (VLS) variants installed aboard surface combatants".[17] A stand-alone, 3-cell version of the Extensible Launching System has also been developed, which again, reuses Mk 41 VLS components and systems.[18] Similarly, BAE Systems has developed the Adaptable Deck launcher (ADL), which provides "a fixed angle, low elevation, deck-mounted ship defense launching system (SDLS) for near-term application onboard U.S. Navy and allied ships", and utilizes the cells, canisters, and launch systems developed for the Mk 41.[19] The Single Cell Launcher, Extensible Launch System and Adaptable Deck Launcher are intended to enable a more diverse deployment of advanced missile capabilities, including onto smaller warships and vessels other than surface combatants, such as amphibious warfare vessels.

The open architecture of the Mk 41 is intended to facilitate the integration of new missiles with it, enabling the deployment of new and or expanded capabilities without having to develop a new launcher and all that would entail in terms of systems integration. In this regard, Lockheed Martin displayed at the Surface Navy Association 2023 symposium, held in January 2023, the integration of the Patriot Advanced Capability (PAC)-3 Missile Segment Enhancement (MSE)

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[14] Raytheon Missiles & Defense, "ESSM Missile", https://www.raytheonmissilesanddefense.com/what-we-do/naval-warfare/ship-self-defense-weapons/essm-missile; and MBDA, "Sea Ceptor", https://www.mbda-systems.com/product/sea-ceptor/.
[15] Ibid.
[16] Lockheed Martin, "Single Cell Launcher", 2019, https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/naval-launchers-and-munitions/VLS_SCL_Single_Cell_Launcher_Product_Card_8.5x11_042419.pdf.
[17] Lockheed Martin, "Host Extensible Launching System", 2019
[18] Lockheed Martin, "3-Cell Extensible Launching System", 2019, https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/naval-launchers-and-munitions/VLS_3_Cell_ExLS_Launcher_Product_Card_8.5x11_042419.pdf.
[19] See BAE Systems, "Adaptable Deck Launcher", https://www.baesystems.com/en-media/uploadFile/20210813155115/1434614211149.pdf.

with the Mk 41.[20] The integration of the Patriot missile with the Mk 41 raises the potential for deploying it onboard the Mk 41-equipped ships of the US and allied navies, and with it, contributing to a significant enhancement in naval air and missile defense capability. The PAC-3 is a hit-to-kill interceptor that can defend against multiple air and missile threats, "including tactical ballistic missiles, cruise missiles and aircraft - using direct body-to-body contact that delivers exponentially more kinetic energy on the target than can be achieved with blast-fragmentation kill mechanisms".[21] This is contrast to, for example, the SM-6 interceptor which employs a blast fragmentation warhead. The Patriot is currently a land-based system, a core component of the US Army's IAMD capability, and widely deployed internationally. While its integration with the Mk 41 would enable the missile to be deployed at sea, it also points to an emerging new role for the Mk 41 itself, that is, as a land-based missile launcher.

Although the Mk 41 forms part of the Aegis Ashore ballistic missile defense system already operational in Romania and under construction in Poland,[22] the development of new mobile ground-based missile launchers for the US Army and Navy respectively offers significant military utility. The developmental Army Strategic Mid-Range Fires (SMRF) system, and Navy Mk 70 Mod 1 Expeditionary Launcher both utilize the Mk 41 VLS as the launch component; the US Marine Corps has also expressed interest in deploying a land-based maritime strike variant of the Tomahawk cruise missile, which would likely again utilize the Mk 41.[23] The Mk 70 Mod 1 Expeditionary Launcher, demonstrated in September 2022 in Europe, is a road-mobile, SM-6-armed system, although further information on the Mk 70, including what its intended operational role is, remains undisclosed.[24]

In contrast, the Army's SMRF, formerly known as the Mid-Range Capabilities (MRC) system,[25] also known as the Typhon, is intended to provide a mobile ground-based weapon system, armed initially with the SM-6 and Tomahawk, capable of prosecuting long-range precision strikes in support of multi-domain operations.[26] At the core of the Typhon weapon system is the Mk 41: a four-cell launcher is installed on an M983A4 Heavy Expanded Mobility Tactical Truck, manufactured by Oshkosh, and used by the US Army for a variety of roles.[27] Developed under the auspices of the US Army's Rapid Capabilities and Critical Technology Office (RCCTO), Lockheed Martin was awarded the contract in November 2020 to develop and deliver a prototype system in three years, with the prototype delivered in December 2022;

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[20] Aaron-Matthew Lariosa, "Lockheed Martin Showcases Patriot Integration With Mk 41 VLS", *Naval News*, 11 January 2023, https://www.navalnews.com/event-news/sna-2023/2023/01/lockheed-martin-showcases-patriot-integration-with-mk-41-vls/.

[21] Lockheed Martin, "PAC-3® MSE", 2023, https://www.lockheedmartin.com/content/dam/lockheed-martin/mfc/pc/pac3-mse/22-15541-iamd-pac-3-mse-pc-r1.pdf.

[22] Missile Defense Agency, "Aegis Ashore", *Fact Sheet*, 23 August 2022, https://www.mda.mil/global/documents/pdf/aegis_ashore.pdf.

[23] Peter Ong, "U.S. Marines Experimenting With Tomahawk For Land-Attack And Anti-Ship Missions", *Naval News*, 17 June 2021, https://www.navalnews.com/naval-news/2021/06/u-s-marines-experimenting-with-tomahawk-for-land-attack-and-anti-ship-missions/#prettyPhoto.

[24] Joseph Trevithick, "Navy Unveils Truck-Mounted SM-6 Missile Launcher In European Test (Updated)", *The War Zone*,

[25] Andrew Feickert, "The U.S. Army's Strategic Mid-Range Fires (SMRF) System (Formerly Mid-Range Capabilities [MRC] System)", Congressional Research Service, IF12135, Updated 27 December 2022, https://crsreports.congress.gov/product/pdf/IF/IF12135.

[26] Ibid; and Lockheed Martin, "Keeping the U.S. Army Ahead of Ready With Next Generation Launch Systems", 2023, https://www.lockheedmartin.com/en-us/news/features/2023/keeping-the-us-army-ahead-of-ready-with-next-generation-launch-systems.html.

[27] United States Army Acquisition Support Center, "Heavy Expanded Mobility Tactical Truck (HEMTT)/HEMTT Extended Service Program (ESP)", https://asc.army.mil/web/portfolio-item/cs-css-heavy-expanded-mobility-tactical-truck-hemtthemtt-extended-service-program-esp/.

the system comprises four launchers, a battery operations center, reload trailer and support vehicles.[28]

Although the Typhon is initially intended to be armed with the SM-6 and Tomahawk, and provide an offensive capability, the inherent versatility of the Mk 41 will also enable the system to undertake other roles, including air and missile defense. The SM-6 has a nascent counter-hypersonic capability,[29] while the aforementioned integration of the Patriot with the Mk 41 would raise the possibility of equipping the Typhon with the Patriot, supplementing or replacing the Army's current Patriot launchers.[30] Due to the versatility of the Mk 41, in principle, a single Typhon launcher could carry multiple missile types, for example, to provide a mix of offensive and defensive options. Current plans call for the deployment of one Typhon battery with each of the Army's Multi-domain Task Forces, with the Army requesting $404 million its Fiscal Year 2023 Budget for research and development for the system.[31] However, it is likely that additional systems will be procured. Given its interest in developing land-based missile systems, the acquisition of the Typhon by the US Marine Corps is possible; allied interest may also be forthcoming.

The Mk 41 Supply Chain and Prospects

The Mk 41 has and continues to be a highly successful product: according to Lockheed Martin, more than 1,700 VLS have been produced since 1984, and deployed by 13 navies on nearly 180 ships.[32] The prospects for the Mk 41 in the mid-to-long term are also positive. Under the President's Budget 2023 for the Future Years Defense Program encompassing fiscal years (FY) 2023-2027, the US Navy seeks to acquire 10 (two per year) *Arleigh Burke*-class destroyers and seven *Constellation*-class frigates, all of which will be equipped with the Mk 41.[33] Long term planning assumptions, that is, covering the 2030s and 2040s, calls for the acquisition of typically four surface combatants (a mix of large and small) per year.[34] In this context, a "large surface combatant" would be a destroyer such as an *Arleigh Burke*-class or the developmental DDG(X), while "small surface combatant" would be a frigate. In terms of VLS capacity, an *Arleigh Burke*-class is equipped with 96 cells, whereas the *Constellation*-class will be equipped with 32 cells. Current plans call for the construction of 20 *Constellation*-class frigates but given wider force structure considerations and the evolving strategic environment, additional ships

[28] Lockheed Martin, "Keeping the U.S. Army Ahead of Ready With Next Generation Launch Systems"; and Emma Helfrich, "First Land-Based Tomahawk And SM-6 Launcher Delivered To Army", *The War Zone*, 6 December 2022, https://www.thedrive.com/the-war-zone/first-land-based-tomahawk-and-sm-6-launcher-delivered-to-army.

[29] Joseph Trevithick, "SM-6 Missiles Are America's Only Defense Against Hypersonic Weapons Missile Defense Chief Says", *The War Zone*, https://www.thedrive.com/the-war-zone/44142/sm-6-missiles-are-americas-only-defense-against-hypersonic-weapons-missile-defense-chief-says.

[30] Joseph Trevithick, "Patriot Missiles Paired With Naval Vertical Launchers Pitched By Lockheed", *The War Zone*, 10 January 2023, https://www.thedrive.com/the-war-zone/patriot-missiles-paired-with-naval-vertical-launchers-pitched-by-lockheed.

[31] Justin Katz, "Lockheed Delivers First Typhon Missile Launcher Prototype to Army", *Breaking Defense*, 5 December 2022, https://breakingdefense.com/2022/12/lockheed-delivers-first-typhoon-missile-launcher-prototype-to-army/.

[32] Lockheed Martin, "Mk 41 Vertical Launching System", https://lockheedmartin.com/content/dam/lockheed-martin/rms/documents/naval-launchers-and-munitions/mk41-infographic.pdf.

[33] Office of the Chief of Naval Operations, Deputy Chief of Naval Operations for Warfighting Requirements and Capabilities - OPNAV N9, "Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2023", April 2022, https://s3.documentcloud.org/documents/21660365/fy2023-pb23-shipbuilding-plan-18-apr-2022-final.pdf, p. 13.

[34] Ibid., p15.

may be required. Moreover, the US Navy is looking to significantly enhance its surface VLS capacity over the long-term.[35]

International demand for the Mk 41 is also likely to remain strong, in particular as the deteriorating strategic environment, highlighted by Russia's invasion of Ukraine, stimulates increased defense investment. The US Defense Security Cooperation Agency (DSCA) reports a near 50 percent increase in sales in FY 2022 compared to FY 2021, driven by geopolitical developments in Asia and the War in Ukraine.[36] For example, in its latest Defense Buildup Program released in December 2022 alongside an updated National Security Strategy and National Defense Strategy, Japan announced it will expand its Aegis destroyer fleet from eight to 10, and build two (noted above) BMD-focused ASEVs, all of which will be equipped with the Mk 41. While the UK is also examining options for deploying the Mk 41 on a wider range of vessels than solely the planned Type 26 *City*-class, including potentially the Type 31 frigate and refitting the Type 45 *Daring*-class.[37] As discussed above, the development of land-based missile systems utilizing the Mk 41 VLS also opens additional market opportunities, primarily in the US, but allied interest cannot dismissed.

As the war in Ukraine demonstrates, air and missile defense is a critical capability; the Biden Administration's FY 23 Budget Request includes "$24.7 billion for a category it calls "missile defeat and defense," an increase from the $21.9 billion enacted in 2022".[38] The cost of the Mk 41 varies significantly, given the range of options for configuration, that is, number of cells, whether the cells are of tactical or strike length, etc. However, the 2018 DSCA notification regarding the potential sale to Finland of four strike-length Mk 41s to equip the four *Pohjanmaa*-class corvettes to be built, provides valuable cost data. The notification states that the four Mk 41 systems, plus the provision of "spares, handling equipment, test equipment, operator manuals and technical documentation, U.S. Government and contractor engineering, training, technical, and logistical support services, and other related elements of logistical support", would cost a total of $70 million.[39] Based on the confirmed orders for US and allied warships, projected demand, and the introduction of ground-based missile systems such as Typhon, Mk 41-related contracts are likely to be worth in the hundreds of millions of dollars through the 2020s and into the 2030s, with long-term maintenance and sustainment work extending into the 2040s and 2050s.

The supply chain, and support infrastructure for the Mk 41 is centered on the US, with a significant degree of international participation, both in manufacturing and support, given the international user base.

Indicative Supply Chain Map

- Lockheed Martin: prime contractor.

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[35] Ibid., p. 9.
[36] C. Todd Lopez, "Ukraine, Asia Drove 50% Increase in FY22 Arms Sales", *DoD News*, 25 January 2023, https://www.defense.gov/News/News-Stories/Article/Article/3277733/ukraine-asia-drove-50-increase-in-fy22-arms-sales/.
[37] George Allison, "Type 45 Destroyers may be fitted with Mk41 VLS", *UK Defence Journal*, 25 February 2022, https://ukdefencejournal.org.uk/type-45-destroyers-may-be-fitted-with-mk4-vls/.
[38] Wes Rumbaugh, "FY 2023 Missile Defense and Defeat Budget Tracker," Missile Threat, Center for Strategic and International Studies, June 17, 2022, last modified June 17, 2022, https://missilethreat.csis.org/fy-2023-missile-defense-and-defeat-budget-tracker/.
[39] Defense Security Cooperation Agency, "Finland – MK 41 Vertical Launching Systems", No. 17-75, 20 February 2018, https://www.dsca.mil/press-media/major-arms-sales/finland-mk-41-vertical-launching-systems.

- BAE Systems: lead sub-contractor, and design agent of the mechanical portion of the system (awarded $164 million contract in 2021).[40] In 2020, BAE Systems was awarded a five-year contract potentially worth up to $955 million for Mk 41 canisters (in which the relevant missile is stowed within the cell).[41] Canister production is undertaken at Aberdeen, South Dakota, and Minneapolis, Minnesota.[42]
- Raytheon
- Mitsubishi Heavy Industries

Small Businesses

- Superior Motion Control
- Pacific Engineering Inc.
- Wolverine Solutions
- Data Con
- Enable Tech MFG
- Renmark Pacific
- Trimble Sustainment Engineering
- In Depth Engineering

The above is a snapshot of those companies involved in producing the Mk 41. The Mk 41 is a complex system comprising hundreds of parts and components, including mechanical, electromechanical and electronic systems. To put this into perspective, Lockheed Martin has a global network of 13,700 suppliers, the majority of which are in the US.[43]

[40] BAE Systems, "BAE Systems wins $164 Million U.S. Navy design contract for Vertical Launch System", 18 May 2021, https://www.baesystems.com/en/article/bae-systems-wins-164-million-us-navy-design-contract-for-vertical-launch-system.
[41] BAE Systems, "BAE Systems to produce more Vertical Launching System Canisters for U.S. Navy", 11 June 2020, https://www.baesystems.com/en/article/bae-systems-to-produce-more-vertical-launching-system-canisters-for-u-s--navy.
[42] BAE Systems, "MK 41 Missile Canisters", 2021, available via https://www.baesystems.com/en/multimedia/vls-mk-41-missile-canisters: and 'Minneapolis Fact Sheet", https://www.baesystems.com/en-media/uploadFile/20210610163555/1434666507197.pdf.
[43] Lockheed Martin, "Your Mission is Ours", https://www.lockheedmartin.com/content/dam/lockheed-martin/eo/documents/lockheed-martin-fact-sheet.pdf.