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Industry Study

Final Report

Missile Defense

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MISSILE DEFENSE 2020

ABSTRACT:

Homeland and regional missile defense are clear strategic imperatives in foundational national security directives to protect Americans and their way of life. An uncertain economy and possible reductions to the defense budget, however, necessitate an examination into a more affordable ballistic missile defense architecture. This paper applies a thorough analysis of the current missile defense industrial base, research into the roles of government in diplomacy and international collaboration, and a study of supplemental capabilities and technologies. Our team proposes an interoperable, multilayered missile defense architecture utilizing domestic and foreign systems, resulting from collaborative processes across an international industrial base and persistent diplomatic engagements with allies and great power competitors. These findings imply a needed shift in the current missile defense strategy and reassertion of U.S. global leadership and diplomacy.

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- Joint Functional Component Command for Integrated Missile Defense (JFCC IMD) Briefing

Virtual Presenters:

- Lockheed Martin (Huntsville) Panel Discussion
- Mr. Wes Rumbaugh, Center for Strategic International Studies, Missile Defense budget exercise
- Dr. Kenneth Sullivan, Micro Craft Inc.
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- Raytheon Corporation, Andover, MA
- Lincoln Labs, Boston, MA
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Introduction

During an impassioned address to Congress in 1958, then Senator John F. Kennedy warned the United States of an impending "missile gap" with the Soviet Union: "I realize that it is hard for us to accept the reality of our danger…I realize that we are reluctant to reexamine policies arduously reached, or to believe that these problems cannot be postponed. But it is precisely this substitution of our preferences for our responsibilities that has led us to the brink of the gap."[1] The United States and its allies stand at a similar precipice in 2020, albeit with multiple enemies that threaten the safety of its citizens. As a response to the shifting international environment, the 2017 National Security Strategy (NSS) outlines U.S. security interests during a time of great power competition, amidst concerns over rogue states and violent terrorists.[2] U.S. threats are expanding, as its adversaries invest in military modernization, develop new nuclear systems, and increase aggressive behavior towards the U.S. and its allies. These threats drive the need to modernize and innovate corresponding defenses to protect the U.S. homeland, regionally deployed forces, and its allies. The integrated, multilayered ballistic missile defense architecture built for this express purpose is an "essential component" of U.S. strategy according to the 2019 Missile Defense Review (MDR).[3] Enhancing missile defense is also listed as a priority action under the first pillar of the NSS: to protect the American people, the homeland, and the American way of life.[4]

Department of Defense (DoD) is requesting $20.3 billion for missile defense in its fiscal year (FY) 2021 budget proposal (inclusive of all DoD agencies and services), down 5.6% from funds appropriated in 2020.[5] In addition to a decrease in funding, the 2021 budget proposal indicates changes to missile defense capabilities, with program cancellations, delays, and shifts in funding away from innovative projects such as hypersonic defense and directed energy. Researchers in the Missile Defense Project at the Center for Strategic and International Studies

believe "[these] changes represent an inflection point for the missile defense enterprise, one characterized by as much uncertainty about policy, posture, programs, and institutions as any time in the last decade."[6] The significance of missile defense in foundational national security directives juxtaposed against exorbitant costs of a technologically relevant architecture in an uncertain economy presents incredible challenges for the U.S. government and missile defense industrial base.

The Executive Summary of this paper will discuss the U.S. missile defense industry, to include its current condition, challenges, and future outlook, the role of government in diplomacy and innovative missile defense technologies. The Essays section then provides research into affordable solutions that address emerging threats from regional and homeland missile defense perspectives, foreign procurement opportunities, and engagement with allies.

EXECUTIVE SUMMARY

Industry Defined: Porter's Five Forces

Rivalry Among Competitors

The diversity of segments within the missile defense industry (radar, sensors, command and control, propulsion) presents a challenge to clearly defining this defense market sector. However, analyzing the missile defense industry using Michael Porter's Five Forces (Rivalry Among Competitors, Bargaining Power of Suppliers, Threat of Substitutes, Bargaining Power of Buyers, and Threat of New Entrants) provides an effective framework to scope the industry. The concentrated network of major firms providing missile defense systems and capabilities include Boeing, Lockheed Martin, and Raytheon, as well as smaller corporations such as Aerojet Rocketdyne, all employing a form of product differentiation.[7] The Department of Defense (DoD) subsequently selected specific missile defense technologies over the last several decades to perform its mission requirements, including Patriot, Terminal High Altitude Area Defense

(THAAD), AEGIS, and ground based mid-course defense (GMD) interceptors. The supply and support of these differentiated legacy systems are important sources of revenue for the small group of competitors within the missile defense industry.[8]

Bargaining Power of Suppliers

Within the small network of missile defense suppliers, the bargaining power is medium to high. Most of these firms are subcontracted on major programs, requiring the capability to scale for primes while meeting unique classification, information security and quality assurance requirements. The resultant environment limits most suppliers to larger corporations, such as IBM, Microsoft, Honeywell and Cisco, as well as international (Taiwan Semiconductor), and smaller domestic corporations with niche market supplies.[9] Suppliers can effectively compete directly with larger missile defense firms or may be vertically integrated into prime contractor teams.[10] Regardless of the approach, the high standard placed concomitant to the minimum number of firms supplying services and components drives dependence on primes, increasing their bargaining power.

Threat of Substitutes

The threat of substitutes to current missile defense contractors is considered medium. Use of legacy systems by the services precludes wholesale adoption of new systems without significant changes to training, procedures, and interoperability. In the missile defense industry, customers tend to pursue incremental upgrades or modular additions to existing legacy missile defense systems, rather than moving to an entirely new architecture (as recently evidenced on the Next Generation Interceptor (NGI)).[11] Examples of systematic capability improvements include the progression of AEGIS radar and software baselines,[12] modification to existing interceptor capabilities of Patriot[13], and incorporation of Israel's Iron Dome[14] into existing point defense systems. The observed historical trend does not preclude significant future research and

development (R&D) efforts (both by industry or federal research laboratories) to create Directed Energy (DE),[15] Electronic Attack (EA),[16] space, or cyber capabilities that could invert the current cost curve of destroying lower cost missiles with higher cost interceptors.[17]

Bargaining Power of Buyers

The bargaining power of the primary missile defense system buyers, U.S. and allied governments, is considered medium to high, characterizing the industry as a monopsony on the market structure spectrum.[18] There is a limited set of government purchasers for missile defense systems and the U.S. government restricts the sale of defense capabilities through policy and law.[19] With few producers to choose from when part of an alliance, significant requirements mandate the need for integration with current systems.[20] Impediments to changing systems for governments, referred to as "switching costs," also exist and include maintaining interoperability with alliance partners and costs associated with introduction of new systems requiring re-training and new supply chains.

Threat of New Entrants

The ownership of intellectual property (IP) rights by competitive firms prevent adoption or modification of legacy systems by new competitors, thereby keeping the threat of new entrants low.[21] Other high barriers to entry include classification requirements and economies of scale required by DoD. These obstacles limit the pool of new entrants to companies with large amounts of capital that are capable of sustaining long-term R&D efforts until contracts are awarded from the DoD.

Current Condition: The Strategic Game Board

Where to compete

Similar to employing Porter's Five Forces when defining the missile defense industry, McKinsey and Company's Strategic Game Board can be applied to analyze where, how, and

when firms can compete in the market.[22] Within the missile defense industry, major firms typically rely on sales to the U.S. government and foreign military sales (FMS). Sales to the DoD tend to be cyclical and defense firms routinely rely on FMS or Direct Commercial Sales (DCS) to keep production lines active. FMS and DCS benefit the U.S. missile defense industry, as well as international customers, by strengthening relations, enhancing interoperability among strategic partners, and lowering missile defense costs.

How to Compete

Many missile defense companies concentrate their core product development on characteristics that enhance differentiation within the industry. By emphasizing differentiation, defense contractors deliver shareholder value through leading-edge products that meet specific customer requirements for high, middle, and lower-tier missile defense needs. As an example, Lockheed Martin's (LMT) expertise in radar allows the firm to effectively employ product differentiation with production of Long-Range Discrimination RADAR, Aegis Combat Systems, the Space Fence, and Aegis Ashore.[23] Similarly, Raytheon, a global leader in the provision of advanced radar systems maintains a large market share of differentiated systems designed to track missiles, including monitoring the range, angle, and velocity of projectiles.

When to Compete

Missile defense firms independently analyze cost and risks to decide which markets are most appealing. Product and technology innovation are integral to the ability of missile defense firms to remain competitive. Innovation allows missile defense firms to improve existing products, production processes, and support services, providing better value to customers. As evidenced by advanced laboratories, employing automated analytical tools and geospatial information systems, such as Raytheon's Failure Analysis and Materials Engineering Lab, is critical to developing cutting-edge missile defense technologies. Additionally, Aerojet Rocketdyne continues to push the

boundaries on propulsion in partnership with Raytheon, recently proving new thruster technologies that improve engagement of "short- and medium-range ballistic missiles in the boost and ascent phase of flight."[24] These types of efforts are indicative of the importance of firms being first to market with innovative and quality products if the corporation wants to develop its reputation as a market leader. When a firm is consistently first to market it can lead the industry in competition and remain a viable contender for future development efforts.

In addition to advancements in innovative products, missile defense firms continually examine opportunities for vertical and horizontal integration to remain competitive. Many firms accomplish this through acquisition of businesses and investments that add value to the portfolio and broaden opportunities for new customers and technologies. In April 2020, Raytheon finalized a merger with the United Technology Corporation, ensuring enhanced horizontal integration by consolidating aerospace functions with missiles and surveillance systems, including propulsion systems and avionics.

Economic Health of Key Firms

The FY2021 defense budget includes $20.3 billion earmarked for "missile defense and defeat" programs allocated in support of government and industry efforts across the missile defense portfolio. DoD directly supports the National Security Strategy (NSS) through the activities outlined in the budget, including "traditional missile defense efforts in the Missile Defense Agency (MDA) and also those in the Space Development Agency (SDA), the Defense Advanced Research Projects Agency (DARPA), and several military services."[25] The budget also includes activities historically associated with strategic warning and programs to defeat missiles before launch, focusing specifically on hypersonic strike.[26] These combined projects represent enduring and future opportunities that impact the financial viability for a cross section of notable missile defense firms—LMT, Raytheon, Boeing, and Aerojet Rocketdyne.

Lockheed Martin

Based on MarketLine data and a review of FMS and U.S. defense contracts, the top five U.S. defense firms account for more than 35% of global sales for weapons systems and related services. As a leading defense contractor, Lockheed's weighted average cost of capital (WACC) is 7.68% while the company's return on invested capital (ROIC) is 49.17%. Lockheed Martin's Missiles and Fire Control Business Unit had over $10 billion in sales, much of which was comprised of sales to the U.S. military and foreign military sales, including THAAD and PAC-3 Missile systems. Similarly, Lockheed's 2019 Annual Report and Securities and Exchange Commission filings indicate that Lockheed's book-to-bill backlog, the company's number of outstanding orders compared with the number of fulfilled orders, is "2.7x for space and nearly 2.0x for missiles," suggesting that revenues and sales for missile defense-related components is strong. A growing emphasis on programs for production and sustainment activities in Qatar, Saudi Arabia, UAE, Japan, the Republic of Korea, Poland and Taiwan, coupled with increased sales of Patriot, THAAD, and Aegis contracts, likely indicates continued future growth for LMT.

Boeing

The Boeing Company derives most of its revenue from the commercial airplanes segment (42% of total Boeing revenue in 2019) with its defense, space, and security segment second in revenue generation (34% in 2019).[27] While Boeing posted a WACC of 7.40% for the end of the F019, the impact of the recent 737 MAX accidents affected Boeing's ability to create value despite higher revenues from their defense, space, and security segment, resulting in a ROIC of -4.22%.[28] Due to the MDA's direction to stop work, Boeing ceased development efforts for the Redesigned Kill Vehicle (RKV) associated with ground-based midcourse defense interceptors.[29] Although this stoppage on the development effort paves the way for the firm to compete on the request for proposal for the next generation interceptor, the technical issues experienced during

RKV development pose significant obstacles for government acceptance of its bid and introduces risk in the sustainability of Boeing's missile defense portfolio.[30] Given financial burdens and interruptions to defense contracting, aerospace, and related industries, FMS will become increasingly important to Boeing should the firm expect to remain a leader in the defense contracting arena. Further, the consideration by the Trump Administration to provide Boeing with significant federal aid illustrates the importance of keeping the U.S. defense industrial base (DIB) secure. Given the large impact that Boeing has on state economies with the employment of over 150,000 people across the U.S., it is imperative that Boeing improves its financial outlook so supply chains, including thousands of small- and mid-sized enterprises (S/MSE) are not compromised.

Raytheon

The Raytheon Company contains a portfolio of systems that span the entire missile defense industry, including "radars, command and control technology, and interceptors," resulting in an influential industry presence.[31] Similar to Lockheed, Raytheon supplements U.S. government sales with FMS to keep its production lines current. As of early 2020, Raytheon's WACC is 7.2% and its ROIC is 27.04%,[32] indicating a profitable position for Raytheon. As stated in the corporate 10-K, "Raytheon Company generates higher returns on investment than it costs the company to raise the capital needed for that investment." [33] Missiles and sea-based weapon systems are critical to Raytheon's financial well-being, solvency, and profitability. Given the passage of defense bills for FY2019 and FY2020 in excess of $750 billion, representing 2% growth from prior years, coupled with geopolitical tensions throughout the Middle East and Asia, Raytheon expects an increase in sales over the coming years, based on SEC filings and the 2020 corporate full-year outlook. Specifically, according to the 2019 year-end financial results, Raytheon recorded bookings in excess of $36 billion and a strong book-to-

bill ratio (future deliverables) of 1.54, which is indicative of continued growth. As full-year net sales rose nearly eight percent to nearly $30 billion, it is possible that Raytheon will place an emphasis on securing new business in an effort to ensure continued growth.

Aerojet Rocketdyne

Aerojet Rocketdyne is a smaller defense contractor in the missile defense industry specializing in propulsion expertise, with $1.9 billion in revenue in 2019. Unlike defense contractors that compliment commercial business by providing government products, the government accounted for 96% of Aerojet Rocketdyne's Net Sales (NASA: 27%, MDA: 23%, USAF: 14%, Army: 19%, and Navy: 6%). Their ability to create value based on firm investment is slightly above average using WACC (6.9%) and ROIC (11.32%) as benchmarks. Aerojet Rocketdyne gains ground on other companies due to their management of risk and inherent expertise in the propulsion domain. The corporation is both liquid and solvent according to current and debt to equity ratios even though they hold some long-term debt. However, the company offsets that debt with a significant amount of backlog, totaling $5.4 billion at the end of 2019; Aerojet Rocketdyne expects to realize $2 billion of that backlog in 2020. These benefits translate to strong performance in the stock market, as the company's stock price was up 42% over a 12-month period at the end of 2019. Additionally, Aerojet Rocketdyne outperformed Standard and Poor's (S&P) 500 from 2016-2019 and the Aerospace and Defense Industry from 2017-2019, all during a significant market increase over that period.

Industry Challenges

Increasing missile defense budgets and accompanying financial performance of the aforementioned firms indicate a positive trend in this market sector, but challenges persist for the government and industry. The prioritization of missile defense in foundational national security directives demonstrates the importance of collaboration between industry and international

partners to counter increasingly sophisticated missile capabilities employed by rogue states, non-state actors, and other adversaries. The maintenance of strategic partnerships within the missile defense industry is integral to the U.S. military's ability to expand battlefield parameters, safely deploy forces, and support allies and partners. Similarly, changing threat landscapes combined with measured increases in the employment of asymmetric tactics used to target U.S. interests validate the need to analyze the full range of missile defense capabilities. Consequently, the ability to augment existing missile defense capabilities to combat increasingly diverse and expansive ranges of missile systems requires the missile defense industry to refine existing technologies, ensure supply chains are secure and redundant, and prioritize research and development that addresses the significant cost of new system development.

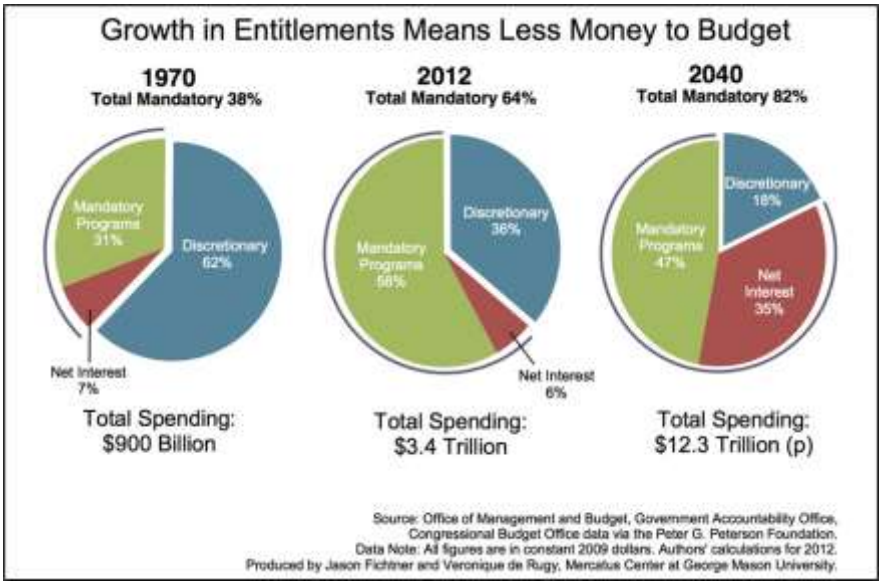
U.S. efforts to provide homeland defense, maintain regional security, and combat the proliferation of advanced missile technologies require a more comprehensive and integrated multi-tier missile defense architecture. Specifically, the maturation and evolution of new technologies, including cruise missiles and hypersonics, require the prioritization of research and development to combat novel offensive capabilities of enemy weapon systems, including rapid advancements in range, destructive power, volume, and speed capabilities. Improvements to enemy command, control, communications, and computer (C4) systems further complicate U.S. ability to maintain an Integrated Air and Missile Defense (IAMD). These complications require partnerships between DoD, key allies, and industry providing missile defense technologies through domestic and FMS. In an effort to mitigate resource scarcity, protect intellectual property, and maintain supply chains, the missile defense industry must consider cooperative efforts that are anchored by an "economy of force approach" to afford greater defense against asymmetric and conventional threats.

Other important challenges for the missile defense industry include identification of

redundant suppliers to secure the supply chain, the ability to rapidly acquire missile components from discriminate sources during increased hostilities, and availability of cost-effective acquisition vehicles that generate innovative defense systems. In order to mitigate the constraints associated with the procurement of strategic materials, maintain the ability to operate within fluid business environments, and map and manage the entirety of the supply, the missile defense industry must advocate for continued strategic alliances that deepen interoperability and advance mutual defense. The exorbitant costs of reliable missile defense systems remain an economic challenge. Notwithstanding tumultuous economic and foreign policy-related hurdles, including costs related to the COVID-19 crisis and recovery, reductions in the Future Years Defense Program (FYDP) necessitate a whole-of-government reprioritization of missile defense programs to ensure the U.S. maintains a resilient and capable missile defense architecture. Due to constrained defense budgets, industry, Congress, and DoD must effectively weigh these tradeoffs to ensure the acceptance of appropriate risk, while concurrently deciding which programs and future technologies to fund without compromising efforts to develop innovative technologies, procure new systems, construct needed facilities, and provide for operations and maintenance into the future.

Industry Outlook

In addition to navigating current challenges, firms must consider how political and economic uncertainties will impact the missile defense industry in the near (FY2025) and long-term (FY2035). Due to uncertainties associated with COVID-19, unsustainable increases in non-discretionary spending, rising debt to GDP ratios, and a Presidential election year, impacts to DoD's budget and the missile defense industry are likely. Prior to Congressional relief packages approved to address the COVID-19 pandemic, non-discretionary spending was rising at an unsustainable rate, threatening to crowd out future defense spending as shown below.[34]



Additional economic challenges, including an increase in closures amongst S/MSE, restrictions in commerce, and supply chain complications, may limit industry's ability to effectively maintain the capability to surge and mobilize.[35] Consequently, contractors must utilize innovative efficiencies, such as artificial intelligence and autonomy, quantum computing, directed energy solutions, and multi-domain operations to maintain the strength and resilience of the missile defense industry.[36]

In the near-term, the missile defense industry appears to be healthy as MDA's budget requests continue to grow (even though the total DoD missile defense budget request declined in FY2021), further strengthening the missile defense ecosystem. Robust R&D expenditures into the RKV, NGI, Aegis, THAAD, and Patriot missile systems have bolstered missile defense and resulted in the provision of adequate funding to meet future resource requirements.[37] Emerging threats require MDA to reallocate priorities to strengthen homeland defense by integrating an underlay system of regional and transregional capabilities, specifically Aegis ballistic missile defense (BMD) (SM-3 IIA) and THAAD.[38] The layered architecture, coupled with the existing GMD system, will serve as a capability gap-fill until NGI is fielded. MDA's FY2021 budget submission includes $39.3 million for Aegis Combat System (ACS) and $273.6 million for

THAAD expanded use and upgrades.[39] MDA expects to test the SM-3 IIA against an ICBM target in 2020 and requested $139 million to commence development and field a new interceptor prototype for THAAD.[40] Additionally, Defense officials note that Aegis Ashore is under consideration for Guam, where one THAAD battery is currently deployed.[41]

Over the long term, MDA's priority will be the new NGI platform and R&D of a more robust space-based sensing architecture. NGI and space sensors are expected to play prominent roles in future defense of the homeland. NGI accounts for the most substantial monetary commitment over the FYDP (FY2021-2025), more than $4.8 billion,[42] while the R&D funding for space sensors remains under review. These upgraded systems will be capable of handling decoys and multiple warheads and possess a resilient battle management network and layered architecture.[43] The missile defense mission will remain a strategic priority and is expected to provide sustainability for the associated DIB.

To maintain a preeminent position in the global marketplace, key firms must undertake technological advancements and innovative solutions to improve GMD network effectiveness and capabilities that counter emerging threats. The missile defense industry needs to develop solutions for countering 21st century threats, including ballistic, conventional, and now hypersonic missiles.[44] Additionally, industry should build an effective network capable of responding to the threat of long-range stealth strike systems, including long-range bombers and submarines.[45] Expanded R&D investments and next generation projects will position the United States as a leader in the "missile defense race" of the information era and will require development and sustainment of systems capable of protecting the homeland from attacks by adversaries.

Government Goals and Role

In order to maintain the missile defense industry, the government must specify capability

development goals within the domain and effectively facilitate multidimensional roles. The 2019 MDR refers to missile defense as an "essential component" of U.S. strategy contributing to deterrence, diplomacy, and defense goals.[46] The government must work with adversaries, allies, partners, industry, and academia to achieve missile defense-related goals in areas of agreements, innovation, efficient acquisition policies and practices, and education. Considering existing anti-trust laws, policies, and requirements that ensure free commerce, the U.S. must consider novel ways to guarantee supply chains remain secure, industry remains willing to invest in industrial research and development (IR&D), and the industrial base is capable of supporting burgeoning requirements associated with varied threats from conventional and non-traditional actors.

Working with adversaries, allies, and partners is a multi-faceted approach. Through engagement with Russia and China, the United States should focus on actions to reduce the spread of technology to rogue states and transnational actors, new confidence building measures, and initiatives to more clearly identify whether missiles have nuclear components. Further, an extension to the New Strategic Arms Reduction Treaty (START) could signal U.S. willingness to pursue future talks encompassing "non-strategic" nuclear weapons (a category not covered by New START), as well as opening future dialogues on strategic nuclear weapons.[47] In addition, the United States needs to increase allied and partner missile defense system support through enhanced interoperability and additional capability. Leveraging the European Deterrence Initiative and pursuing a Phased Integration approach to integrate North Atlantic Treaty Organization (NATO) missile defense systems into a central command and control (C2) hub is a key step. Similarly, DoD leadership should leverage the proposed United States Indo-Pacific Command Deterrence Initiative and explore opportunities with Pacific partners and allies.[48] These actions can strengthen the U.S. role in missile defense diplomacy and build consensus on missile threats among allies and partners.

DoD can leverage these development efforts and encourage innovation through sustained R&D and efficient acquisition policies and practices. Advancements in space-based and unmanned systems with associated facilities, including federally funded labs and test ranges, support continued innovation in missile defense, as demonstrated by Federally Funded Research and Development Centers (FFRDC) such as MIT-Lincoln Laboratory. Similarly, expansion of innovation hubs supports continued use of commercial, dual-use technologies in space and unmanned systems that expand revenue possibilities, further enticing industry participation.

As a complement to innovative developments, DoD continues to review and refine acquisition and associated policies and practices.[49] Based on industry feedback, areas for emphasized efficiency reviews include cyber requirements and approvals, clearance quotas and approvals, International Traffic in Arms Regulations (ITAR), Tri-Service Committee (TSC) policy, and supply chain security. Cyber and clearance requirements continue to grow and, likewise, the approval review levels and timelines increase.[50] DoD needs to review requirements and approval levels for overlap and processing timeline impediments. The continuing changes in ITAR and TSC policy would also benefit from accompanied training for industry and DoD acquisition professionals. Finally, missile defense faces a shrinking set of suppliers, or a single supplier in the case of ammonium perchlorate which is used as an oxidizer in rocket propulsion. As the sole customer, the government must ensure availability of supply. The DoD acquisition community needs to look at the defense acquisition ecosystem to ascertain whether policies, practices, and requirements frameworks have a negative impact on the evolving supply base. Concurrently, contracting officers must review requests for proposals in consideration of potential impacts on suppliers.

By working with academia, the government needs to expand science, technology, engineering, and math (STEM) scholarships and research opportunities. The government should

increase and leverage space grant universities, DoD scholarships and research opportunities, and expand STEM-related opportunities for critical trades.[51] Industry and government may utilize established DoD consortiums as an opportunity to work together on STEM scholarship and research opportunities.

ESSAYS

Homeland Defense

Layered ballistic missile defense of the homeland requires a multifaceted solution set to combat burgeoning and evolving threats. Novel tactics, techniques, and procedures (TTP) employed by rogue states, emerging nations, non-state actors, and traditional actors require an integrated architecture to ensure U.S. missile defense systems are capable of the defense of the homeland and strategic partners. Specifically, integration, on a global and regional spectrum, must include partnerships with allies, systemic improvements to the U.S. industrial base, and a focus on diplomacy to ensure constrained resources provide adequate deterrence. Consequently, while internal forces clearly and directly impact the missile defense industry, external stimuli also must be considered to fully incorporate kinetic and non-kinetic strategies to address global and regional missile defense.

The 2019 MDR states that U.S. missile defense must adopt a "balanced and integrated approach to countering missile threats through a combination of deterrence, active and passive missile defenses, and attack operations."[52] Several factors require DoD to explore creative, affordable options to ensure a more robust global missile defense architecture. First, the threat environment is evolving quickly as the United States and its allies grapple with the return to great power competition and face continued rogue challenges.[53] China and Russia methodically recapitalized military assets and built up forces that now rival that of the United States in several mission areas, including missile capabilities and missile defense.[54] North Korea and Iran

continue to develop their ballistic missile capabilities and reach.

As enemy threats advance and display the ability to reach the United States, the push for more homeland defense assets capable of responding to a direct attack has caused a resource shift from the provision of support to allies to investments in layered missile defense capabilities.[55] Expanding threats from U.S. adversaries, exhibited through their investments into modernization, development of new nuclear systems, and increasingly bold actions towards the United States and its allies, drive the need to develop corresponding defenses to protect the U.S. homeland, its people, and its allies. The MDA Director, Admiral Jon Hill, highlights the need to move missile defense into a multi-domain operations environment and exploit all data inputs to detect, engage, and neutralize threats. Admiral Hill's directive underscores the need for inventive options that will secure the nation's missile defense architecture.[56] Yet competing priorities, technical feasibility, and the geopolitical environment continue to fuel discussion about the affordability of an expensive missile defense capability.[57] In an era of shrinking budgets and great power competition, the United States can deliver robust missile defense capabilities through greater investment in traditional nuclear systems and space-based systems.

Recommendations

To meet the mandates outlined in the 2019 MDR, the U.S. must adapt its strategy through innovation of current and future missile defense systems. As outlined in the Executive Summary, missile defense firms pursue innovative solutions as a strategy to remain competitive in the industry and must continue this corporate strategy in the future, contributing to the potential for finding novel solutions for a space-based sensor layer system. This advanced missile defense system would provide tracking and possibly, a "space enabled intercept" feature, giving the sensor the ability to communicate directly to a future space-based interceptor and eliminate the ground station relay.[58] DoD outlined $108 million for FY2020 for technology and program

development in this area, ensuring capability progression. Innovative systems will require access to live-fire testing capability and the Reagan Test Site provides an unmatched ballistic missile defense research, development, and testing capability in the Republic of the Marshall Islands. As China seeks to make inroads into the Pacific, the United States must continue to ensure it maintains a mutually beneficial strategic partnership with the Republic of the Marshall Islands.

Notwithstanding the need to consider space-based systems, the United States should also pursue accelerated upgrades to current nuclear deterrent capabilities and the promotion of interoperability for active and passive missile defense systems, including testing facilities. Given the escalating costs to ensure missile defense, integration throughout the industrial archetype and diplomacy must complement the existing missile defense architecture to allow for continued investments in modernization of U.S. nuclear capabilities through quicker pursuit of new delivery systems for each leg of the nuclear triad.[59] Funding from the proposed $20.3 billion for research, development, and procurement spending for missile defense and defeat could be reallocated towards nascent technologies in an effort to bolster nuclear deterrence, currently funded at less than $15 billion.[60] Including low-yield nuclear weapons and novel solutions in the U.S. arsenal would deter low-yield attacks and provide the flexibility of response to combat traditional and asymmetric threats. Given that Undersecretary of Defense for Policy, John Rood, states that low-yield capability "demonstrates to potential adversaries that there is no advantage to limited nuclear employment because the United States can credibly and decisively respond to any threat scenario," identification of systems capable of countering multidimensional threats remains critical. [61]

Regional Missile Defense

In addition to protecting the homeland, the United States must enhance regional BMD capabilities and strategies with limited additional investment. The maritime and land domains

provide specific opportunities where DoD can reallocate resources and capitalize on targeted investments and strategies to increase U.S. capabilities. Potential maritime solutions include use of unmanned surface vessels for the Navy and expeditionary missile defense for the Marines. For land-based defense, incorporation of Directed Energy (DE) and Electronic Attack (EA) as part of the Army's missile defense systems are analyzed and discussed with recommendations also given for these innovative capabilities.

Maritime: Unmanned Surface Vessel Contributions to the Missile Defense Archipelago

Increasing demand for BMD capable U.S. Navy (Aegis) ships has, and will continue to, strain the Surface Fleet. In the era of great power competition, DoD must consider cutting edge technology to build robust networks and systems across all warfare domains, to fight in a "Mosaic Warfare" concept.[62] At a procurement cost of $1.9 billion per ship, the Navy can only sustain limited inventories of Aegis Large Surface Combatants (LSC).[63] Constrained inventories limit the ability to provide regional or homeland missile defense. Alternatively, the Navy should look to Unmanned Surface Vessels (USV), with a procurement goal of $200 million per unit, to reduce the demand strain on LSC and make the missile defense archipelago more robust. Assuming the unit cost targets are achieved, these USVs also relieve the already constrained missile defense budget that may decrease in the future, as outlined in the "Industry Outlook" section of the Executive Summary.

Recommendations

The Navy should reduce the size of the projected LSC fleet and invest those savings into research, development, test, and evaluation (RDT&E), procurement, and operation and support (O&S) costs of USVs. To mitigate reductions to the LSC inventory, USV cost savings, expendability, and efficiency in the battlefield may be capitalized. Further, USVs in their BMD role should be capable of performing various subsets of the missile defense kill chain (sensing

and intercepting). Additional funding may develop and expand proof of concepts, C2, operational planning, and training to effectively employ these next generation weapon systems.

Maritime: Marine Corps' 'Objective Force' Medium Range Intercept Capability

The Marine Corps lacks a missile defense capability to ensure force and infrastructure protection as a contributor to the Navy/ Marine Corps team in Expeditionary Advanced Base and Distributed Maritime Operations. Missile defense is an opportunity for Corps and Navy alignment to provide mutual support and needed BMD depth for the U.S. and allied partners. By prioritizing investment in expeditionary, ground-based missile defense system diversification and recapitalizing current force structure, Marine Corps contributions to joint theater resiliency within the terminal defense segment of the layered active missile defense system will be optimized.

Recommendations

In order to rapidly generate a credible and resilient medium-range intercept capability (MRIC), the Marine Corps should reduce the current planned F-35C investment by four aircraft per year over the course of the next four years and a fifth in FY2025, thereby generating approximately $480 million per budget year and approximately $2 billion over the course of the FYDP. That redirected sum will roughly double the currently planned combined investments in Artillery Weapons System (HIMARS & ROGUE), long-range precision fires (LRPF) munitions, Air & Missile Defense (MADIS and MRIC), providing a more predictable industry landscape for firms; this solution addresses the "cyclical" nature of government acquisition described in the "Current Conditions" section above.[64] The reduction of one additional F35 in FY2025 will enable investment of three additional Ground/Air Task-Oriented Radar (G/ATOR) systems and reserve approximately $13.5 million in remaining funds. As the 'Objective Force' MRIC becomes operational, the $13.5 million delta can be invested into C4ISR software compatibility

refinements to smooth the merger into the overarching BMDS ecosystem.

Land: Army's Approach to Building New Systems in support of Regional Missile Defense

The United States continues to make significant progress in the development, deployment, and modernization of regional active missile defense capabilities. Developing scalable, efficient, and compact high energy laser technology holds the potential to provide a future cost-effective capability to destroy boosting missiles in the early part of the trajectory.[65] The Army's contribution to the Directed Energy Weapons (DEW) program is resurging in expectations, but has yet to produce a successful capability. The current plan is for the Army to purchase three 50kw prototypes High Energy Lasers (HEL) in FY2021 as proofs of concept.

Recommendations

According to the analysis from the Army's prototype program for directed energy, the service should develop a legislative change proposal for the FY2022 National Defense Authorization Act (NDAA) that recommends amending FY2018 NDAA section 863-864 focused on DEW. Exercising the "Government's Role" (outlined in the Executive Summary) to specify goals and engage Congress, DoD leadership should prepare a proposal with two specific changes. First, it will require the services to establish and publish their DEW master plans. This requirement will be accompanied by an authorization for the funding to develop the master plan. Second, the proposal will require DoD to establish a Consortium for Directed Energy. The plan combined with the consortium will help the entire DE ecosystem frame the services' problems and understand their direction. The consortia will then provide a centralized structure for coordination to facilitate future advancements. These recommended legislative proposals increase the ability to ensure DoD execution of needed DEW programs.

Land: Utilize Non-Kinetics to Increase Base Defense Effectiveness[66]

Purchasing more interceptors and launchers imposes significant costs to the U.S. before

the adversary has fired a single shot. EA, Electronic Warfare (EW), or DE systems can defeat, destroy, or prevent an adversary missile from hitting its intended target. Pursuing non-kinetic technologies would also contribute to interceptor savings and should be a part of ground-based, layered missile defense to increase effectiveness.

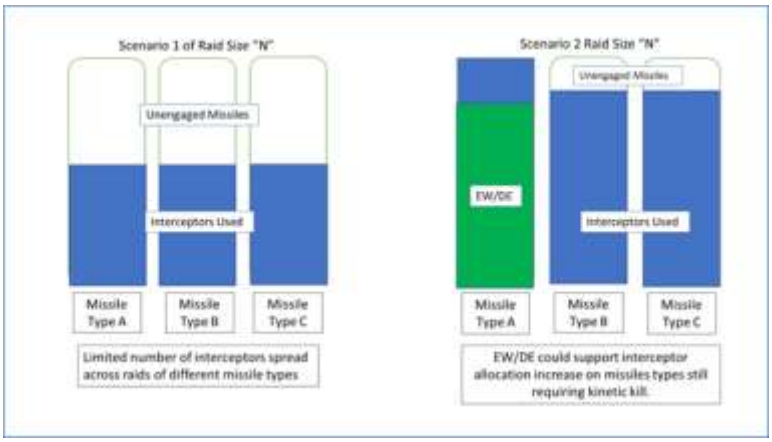


Figure 1: Adding EW/DE to Increase Defense Effectiveness (Source: Author)

Even if EA, EW, DE systems only work against a specific type of missile, training and coordination between system operators may conserve interceptors for other missile variants that are unaffected, thus reducing the overall numbers of unengaged missiles.

Recommendations

The Army has significant efforts in progress for ground-based missile defense and EW. Incorporating EA/DE capabilities as part of a layered approach integrated with already fielded Patriot and Indirect Fire Protection Capability (IFPC) systems increases ground-based interceptor capabilities. The EA/DE system will not be constrained by inventory and will continue to attack even if Patriot or IFPC inventories are depleted. If systems cannot conduct a "hard-kill," additional capabilities should be researched that may cause errors in targeting or flight to prevent missiles from hitting intended targets, thereby improving overall base defense effectiveness.

Foreign Procurement Opportunities

Given the advanced missile systems of great power competitors, the maturation of rogue

states' and non-state actors' missile capabilities, and the pursuit of innovative offensive weapons by all three groups, the U.S. must modernize and develop an integrated, multi-layered missile defense architecture.[67] The burgeoning costs and debatable feasibility associated with modernization at "the speed of relevance," should prompt the U.S. to consider expanding its capabilities through foreign weapon systems procurement.[68] As described in the "Current Condition" section of the Executive Summary, the missile defense industry is already poised to exploit international opportunities as firms pursue FMS and DCS to steady fluctuating DoD demand. The many advantages to incorporating foreign systems into U.S. missile defense include U.S. and foreign industry "teaming arrangements" to form a strong industrial base, shared responsibility of research and development in common interest areas, system interoperability, and overall greater affordability.[69] Potential areas for foreign cooperation include procurement or lease-option contracts of Israeli systems and consideration of novel, innovative technologies. Further, based on foundational national security documents requiring integration to provide for homeland, regional, and global defenses, industry and foreign procurement of missile defense systems provides an opportunity to acquire systems specifically designed to counter threats from traditional adversaries in DoD's "2+3" matrix, including China, Russia, North Korea, Iran, and transnational terrorist groups.

In the regional missile defense realm, Israeli technologies would be an appropriate supplement to the U.S. architecture "to yield a more robust, flexible, and affordable system."[70] Specifically, the Israeli David's Sling Weapon System (DSWS) and Stunner missiles, co-developed with Raytheon, could provide almost equal capability to the U.S. Patriot system at one-third of the price.[71] Raytheon's Program Manager for Skyceptor, a Stunner variant, estimates DSWS and Patriot interoperability efforts and retrofitting to cost approximately $250 million and span only two years.[72] Similarly, Israel's Arrow anti-ballistic missile system is a

cost-effective alternative to the U.S. THAAD system, providing a significantly comparable capability and superior radar capacity.[73] Both of these examples illustrate the advantages previously stated of acquiring foreign systems.

A further consideration of incorporating foreign systems into the missile defense architecture is an equipment lease versus outright purchase of the Israeli DSWS or Arrow systems. Leasing weapons allows a significantly smaller investment as the government only needs to budget for each year's payment versus identifying billions of dollars in program costs.[74] In addition to cost savings, leases foster interoperability, encouraging efficient operations, maintenance, and sustainment contracts for the U.S. while decreasing deployment footprints for system delivery, emplacement, and disposition.[75] Finally, leasing provides a low-risk approach to evaluating the viability of larger international cooperative efforts, which could potentially expand the limited customer base described when analyzing the missile defense industry "Strategic Gameboard." Should these efforts result in an expanded DIB, new suppliers would also address a missile defense industry challenge described above and bolster a fragile segment of the market.

Recommendations

In order to strengthen the feasibility of maintaining pace with asymmetrical and conventional threats, the MDA must invigorate its charge to innovate advanced technologies and defenses, specifically through collaboration with international partners.[76] In a 2019 Atlantic Council study, former deputy undersecretary of defense for industrial policy and federal acquisition Bill Greenwalt advocated for a trade space where trusted partners and allies can share "innovation, technology, and investment" to work together.[77] Modifications to technology transfer laws and policies are required to enable this kind of space, but Greenwalt argues, "a go-it-alone strategy will leave the U.S. to compete on its own...as allies and the commercial

marketplace hold back better technology."[78] An area that could be modified is the National Technology Industrial Base agreement (NTIB), an agreement created after the end of the Cold War to foster cooperation between the United States and Canada.[79] The NTIB was later expanded to include the United Kingdom and Australia; DoD could ratify another increase to include more NATO partners, bolster DIB capability, and address its critical skills shortage.[80] Within the trade space, entities must develop realistic and achievable requirements, focus on reliability throughout system design and development, ensure supplier redundancy, and secure the supply chain so MDA can effectively communicate with Congress, DoD service partners, and the DIB throughout product development to instill confidence and buy-in from all stakeholders.[81] Close collaboration with strategic partners through diplomacy may support DoD effort's to procure new systems, ensure resiliency, safeguard the supply chain for critical components and materials and reduce the costs associated with missile defense.

Diplomacy and Engaging Allies on Missile Defense

Changes to the geopolitical landscape since U.S. withdrawal from the Anti-Ballistic Missile (ABM) treaty in 2002 and possession of ballistic missiles by more than 25 nations necessitates a reexamination of diplomatic efforts and allied engagement regarding global missile defense.[82] Due to shifting threat landscapes associated with the new era of great power competition and ongoing concerns about rogue states and violent terrorists, the United States must strengthen strategic stability and reassert its global leadership. As noted in Government Goals and Roles above, diplomatic engagement is an area where the United States can increase international influence. In a period of limited resources, increasing diplomatic engagement with allies and adversaries through arms control negotiations and information sharing on missile defense is a low-cost approach to improving U.S. leadership. The United States may also benefit from NATO allies in Europe sharing international missile defense obligations, including burden

sharing of expenses associated with missile defense, and acquisition of foreign missile defense systems that may prevent gradual siphoning of funds better suited for system modernization.[83]

Recommendations

The U.S. withdrawal from the Intermediate-Range Nuclear Forces (INF) Treaty and the Joint Comprehensive Plan of Action (JCPOA) and indecision on extending the New Strategic Arms Reduction Treaty (START) could be interpreted as a U.S. retreat from arms control negotiations as a foreign policy tool.[84] Treaties and agreements offer valuable opportunities for cooperation, predictability, and transparency[85] while demonstrating U.S. leadership. One critical advantage of existing treaties, such as the United Nations Treaty on the Non-Proliferation of Nuclear Weapons and New START, is the verification component.[86] Another beneficial element of cooperation is the overall security of excess weapons and materials, shown through the Nunn-Lugar Cooperative Threat Reduction Program.[87] Reassertion of its position as the global leader on arms control issues may allow the United States to take advantage of this key soft power tool and reduce opportunities for malign actors to utilize ballistic or nuclear weapons with existential consequence.[88]

The United States should engage Russia and China on areas of mutual interest, including actions to reduce the spread of missile technology to rogue states, new confidence building measures, and initiatives to more clearly identify whether missiles have nuclear components. The U.S. invitation to Beijing in December 2019 to start a "two-way strategic security dialogue" represents a positive move in the right direction.[89] U.S. commitments to Russia to extend New START while exploring information sharing on missile defense could also provide for diplomatic inroads. If the United States fails to address Chinese and Russian concerns about missile defense, these countries will continue producing the very types of threats the United States has the most difficult time countering, thereby exacerbating missile defense costs and

increasing instability.[90]

Finally, the United States should invest in interoperability and integration with our allies for active and passive missile defense systems. As mentioned in the Government Goals and Roles section of the Executive Summary, the U.S. government should work with allies to outline a long-term strategy and address restrictive policies that may prevent unfettered international system development. DoD should outline and execute a Phased Integration Approach with NATO to require up-front integration of all new BMD developments and a phased transition plan to incorporate current systems from the untapped European BMD supply. The approach will increase NATO BMD capability and provide opportunities to both lessen U.S. resource burdens and enhance the DIB, challenges previously identified for the U.S. missile defense industry both in the near and long term. This strategy also guarantees funding commitment early in the development process and helps avoid integration issues that tend to materialize later in system development and testing.[91] To supplement the required investment, the United States should apportion a segment of the $5 billion requested in FY2021 for the European Deterrence Initiative (EDI), helping DoD to shift future years resources from Aegis-capable ship and Patriot Battery deployments to homeland defense BMD infrastructure improvements. In addition to funding infrastructure improvements, future EDI investments in multinational exercises are vital to ensure effective integration of these various missile defense systems.[92] The collective U.S. investment encourages NATO allies to maintain a broader view of alliance capabilities, helping them envision system developments for common systems in a NATO enterprise approach vice developing standalone assets.

Conclusion

Missile defense solutions are often complex and subsequently expensive, but as adversarial threats to the U.S. homeland, its people, and its allies increase, demand for an

enduring and innovative ballistic missile defense architecture will remain strong. Within that architecture are opportunities to pursue affordable solutions that enhance missile defense capabilities while acknowledging the reality of constrained resources. First, the United States must engage allies and foreign industry to form an interoperable, global architecture that incorporates existing technologies but also shares costs to innovate new systems that counter emerging threats. Second, the United States must consider reallocating portions of expensive, technologically advanced program funds to pursue cost-effective solutions, such as unmanned vessels, directed energy, and accelerated modernization and procurement of nuclear deterrent capabilities. Third, in order to facilitate this cooperation and interoperability, the government must alter laws and policies to foster an open trade space amongst an expanded NTIB and trusted partners. Last, the criticality of diplomatic engagement to spur foreign cooperation in these areas cannot be understated, as well as the need to negotiate with great power competitors Russia and China, including missile defense.

Missile defense remains a strategic priority. Though the country seems to be at an "inflection point" for allocation of the budget in this critical domain, the outlook for the missile defense industrial base seems promising with current initiatives, such as the NGI and a space-based sensing architecture, in addition to budgeted upgrades to existing systems. Competing priorities, technical feasibility, and the geopolitical environment could, however, threaten the future of this expensive missile defense capability. As with DoD, industry should be leaning into foreign partnerships and collaboration to offer affordable solutions and influence lawmakers to smartly adjust government regulations on international commerce and cooperation. The implications of an era of great power competition and competing defense priorities necessitate affordable solutions to complement national capabilities and avoid a modern “missile gap” that Senator Kennedy warned against over sixty years ago.

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Task Oriented Radar (G/ATOR)- The Artillery Weapons System (AWS) consists of the High Mobility Artillery Rocket System (HIMARS), which is the platform for GBLRPF munitions and the Remotely Operated Ground Unit Expeditionary Fires (ROGUE-F). ROGUE-F is the JLTV chassis mounted remotely operated launcher for the ground based anti-ship Naval Strike Missile (NSM). FYDP requests merely $493 million over the next 5 years to build and stand up the AWS capability. GMLRS missiles are allocated $555 million for 3,602 missiles. MADIS and MRIC, counter UAV and Medium Range Intercept Capability startup requests total approximately $1.054 billion. And finally, the AN/TPS 80 G/ATOR radar request is approximately $640 for 16 radars.

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