

# Spring 2022 Industry Study Final Report

## Missile Defense

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The return of great power competition coincides with the emergence of an age of missiles. The United States competes with a rising China and increasingly unstable and provocative Russia to shape security architectures and global norms and practices. In addition to Russia and China, the missile threat emanating from the rogue nations of North Korea and Iran toward the United States and its interests is evolving, and so must the United States' ability to counter these rising threats. The U.S. missile defense enterprise is challenged to effectively counter adversaries' growing offensive capabilities, including cruise missiles and hypersonic glide vehicles (HGV). A weak defense industrial base (DIB), the need to reallocate responsibilities amongst the entities involved with missile defense research, development, procurement, and sustainment, as well as the need to update the U.S. missile defense strategy and increase the speed and effectiveness of research and development hamper the U.S.'s ability to provide adequate missile defense.

The U.S. Missile Defense Agency's mission to "develop and deploy a layered Missile Defense System (MDS) to defend the United States, its deployed forces, allies, and friends from missile attacks in all phases of flight"<sup>1</sup> summarizes the United States' broad objectives for missile defense. Recognizing the need for an integrated and comprehensive approach to missile defense, the Department of Defense (DoD) integrated both the Nuclear Posture Review (NPR) and Missile Defense Review (MDR) into the National Defense Strategy (NDS) for the first time in 2022. The NDS unclassified fact sheet highlights the importance of this alignment with the President's Interim National Security Strategy Guidance (INSS) and recognizes that the DoD's first priority is to defend the homeland while explicitly acknowledging China as the foremost threat to the United States. The NDS's second priority is to deter strategic attacks against the United States and its allies and partners. Finally, its third priority is to deter aggression from

China in the Indo-Pacific, followed by Russia in Europe.<sup>2</sup> A robust missile defense system is integral to addressing *all* of these strategic priorities.

Both China and Russia have made standoff weapons a key element of their respective military doctrines and developed advanced missile technologies explicitly intended for use against the United States. Similarly, the rogue nations of North Korea and Iran are designing increasingly sophisticated missiles directed toward the United States. The U.S. missile defense enterprise struggles to keep pace with these rapid advancements, undermining the United States' ability to counter rogue nations and peer competitors alike. The United States must strengthen its homeland and regional missile defenses. To do so, the United States must reorient its missile defense strategy, reform the missile defense agency, and strengthen the missile defense industrial base.

### **U.S. Strategic Environment and Emerging Threats**

U.S. competitors' and adversaries' advanced missiles pose a growing threat to the U.S. homeland, its deployed forces, and its allies. Intercontinental Ballistic Missiles (ICBMs) have historically represented the most pressing missile threat to the homeland. As missile technology advances, however, the United States is increasingly concerned with the growing threat from nuclear and conventional cruise missiles as well as conventional hypersonic glide vehicles (HGV).<sup>3</sup> The United States currently relies on its nuclear arsenal to deter Russian and Chinese nuclear attacks.<sup>4</sup> However, Russia's recent nuclear threats against NATO Allies suggest the U.S.'s nuclear retaliatory capabilities might no longer be an effective deterrent on its own. Currently, conventional cruise missiles and HGVs are the most likely peer missile threat to the U.S. homeland as opposed to ICBMs.<sup>5</sup> In an armed conflict, a peer adversary would most likely use conventional cruise missiles and HGVs to deny the U.S.'s ability to deploy its military

forces.<sup>6</sup> The United States lacks an appreciable ability to defend itself against such an attack, much less to deter it.<sup>7</sup> Yet, the rogue state nuclear threat that has been the focus of homeland BMD has not gone away and is getting worse. As North Korea and Iran continue to threaten the United States with nuclear weapons, their strategic missile capabilities are also evolving. As they continue to advance, the United States will be hard-pressed to effectively counter emerging threats relying solely on its ability to intercept incoming missiles with Ground-Based Interceptors (GBI).

Russian, Chinese, North Korean, and Iranian regional missile threats are numerous and varied, and each country has missiles that could effectively hold U.S. and allied forces at risk.<sup>8</sup> Although the United States has designed its regional missile defenses to intercept threats from any source, the volume of missiles that any one of these four nations could fire far exceeds the U.S.'s capacity to intercept. For example, the prospect of an overwhelming Chinese medium-range ballistic missile barrage on the U.S. territory of Guam, discussed in detail below, highlights the extent to which regional missile attacks have strategic consequences.

Technological advancements in multiple independently targetable reentry vehicles (MIRV), maneuverable reentry vehicles (MaRV), decoys, and jamming systems challenge the U.S.'s active missile defenses.<sup>9</sup> The adage "shooting a bullet with a bullet" describes a simplified problem. One bullet becomes multiple bullets (or missiles, in this case) in today's security environment, which are considerably more challenging to track and intercept. Similarly, given current hit-to-kill technology and sensors, it is difficult to intercept non-ballistic cruise missiles and HGVs that utilize low flight profiles and high maneuverability.<sup>10</sup>

## **Homeland and Regional Missile Defense**

The line between homeland and regional missile defenses is important but has become increasingly blurred over the years. *Homeland* missile defense, by policy, is designed to intercept rogue nations' ballistic missiles (North Korea/Iran). An essential component of the INSS, homeland missile defense is designed to deter adversary aggression and support U.S. military operations if traditional nuclear deterrence fails. It is designed to protect the American people, leadership, and vital infrastructure against missile attacks, hedge against future uncertainties and risks, and help preserve U.S. freedom of action to meet and defeat adversary aggression.<sup>11</sup>

By policy, the United States will also defend against *regional* missile attacks from any source and is committed to protecting its deployed forces and allies and partners from regional missile threats. As adversaries continue to present a global missile threat by expanding capabilities and capacity, the United States must effectively deter adversaries, reassure allies in Europe, Asia, and the Middle East, and protect and defend U.S. and allied freedom of action.<sup>12</sup>

## **Protecting U.S. Territories - Defense of Guam**

The DoD recently designated the defense of Guam a strategic priority.<sup>13</sup> Critical to the United States' ability to project power in the Indo-Pacific region, Guam is highly vulnerable to attack. The defense of Guam from an adversary missile attack is of strategic consequence and vital to ensuring national security. To counter this threat, MDA requested \$539 million in FY23 to defend Guam from ballistic, cruise, and hypersonic missile attacks.<sup>14</sup> Congress and the DoD are aligned on the importance of defending Guam. In FY22, Congress provided an additional \$80 million above the DoD request to advance the architecture,<sup>15</sup> which the DoD envisions as a distributed system with mobile launchers.<sup>16</sup> The considerable number of adversary missiles that

have the potential to reach Guam further complicates an already complex missile defense problem.

### U.S. Missile Defense System (MDS) Capability

The MDS is an integrated, layered architecture that incorporates land, sea, and space-based defense elements to track, target, and destroy offensive ballistic missiles of different ranges, speeds, and sizes after launch. Elements of the MDS include Ground-Based Midcourse Defense (GMD), Aegis Ballistic Missile Defense (BMD), Terminal High Altitude Area Defense (THAAD), and Patriot Advanced Capability-3 (PAC-3) systems. The Space-Based Infrared System-High (SBIRS-HIGH) and other sensors provide surveillance and early warning of theater and strategic missile launches to complement these systems.



Figure 1: The Missile Defense System



The Hypersonic and Ballistic Tracking Space Sensor (HBTSS) is the successor to the Space Tracking and Surveillance System (STSS).<sup>17</sup> HBTSS will “incorporate signal-to-clutter algorithms that are a pivotal new component designed to distinguish a fast-moving threat from the surface of the Earth.”<sup>18</sup> This medium field-of-view system can provide continuous tracking and custody of HGVs and ballistic missiles during flight and provide fire control solutions to shooters.<sup>19</sup> HBTSS is only one of dozens of new satellites (among an architecture of hundreds in low-Earth orbit) that will make up the Space Development Agency’s Missile Tracking Layer.<sup>20</sup>

One of the goals of this Missile Tracking Layer is to provide eventual global coverage that can “detect HGVs from low-Earth orbit, communicate with each other in space and with ground-based units, demonstrate interoperability and successful data transfer between satellites, and overall good infrastructure and algorithms that enhance the communication’s bandwidth.”<sup>21</sup> Ultimately, this system aims to close detection gaps in the current missile defense infrastructure and assist missile defense batteries in countering advances in hypersonic and ballistic missile threats.<sup>22</sup>

C2BMC (Command and Control, Battle Management, and Communications) is “the force multiplier that globally and regionally networks, integrates, and synchronizes autonomous sensors and weapons systems to optimize performance (of the Ballistic Missile Defense System).”<sup>23</sup> The MDS’s strength is its ability to provide fire control data by integrating an advanced sensor system network with a sophisticated command and control (C2) system to launch interceptor missiles for layered defense.

While the GMD system protects the homeland with 44 interceptors (40 at Fort Greely, Alaska, and four at Vandenberg Air Force Base, California), THAAD, PAC-3, and Aegis BMD support regional missile defense on land and sea across the globe. The DoD continues to invest

in modernizing and expanding its capabilities to counter the rapid advances in offensive missile threats effectively. In FY22, the DoD allocated \$20.4 billion for missile defense and defeat programs, including strike programs and other items that can play a role in “missile defeat.”<sup>24</sup>. Despite the tremendous resources allocated to the MDS, the United States requires additional solutions to address the remaining significant homeland and regional missile defense challenges. Ensuring a robust and nimble defense industrial base, coupled with a strategic realignment and government reform, is paramount to advancing U.S. capabilities to counter current and emerging threats. The industry faces challenges ranging from lack of competition to difficulties attracting the necessary workforce to keep up with the innovation needed to meet the U.S.’s growing missile defense requirements.

### **Defense Industrial Base (DIB) Structure-Conduct-Performance Analysis**

The Structure-Conduct-Performance model best captures the overall missile defense industry’s condition, sufficiency, and potential to meet domestic and allied missile defense needs.<sup>25</sup> The industry’s supply and demand participants demonstrate a balancing act between oligopoly and monopsony forces in the missile defense markets. The field of competitive producers is minimal and essentially limited to the industry’s “Big-5.”<sup>26</sup> Despite lacking a dominant leader in the industry, the limited number of suppliers threatens reduced overall competition. Countering the oligopolistic industry position is the U.S. government’s monopsony power. Although there are some commercial applications for rocket boosters, space and terrestrial sensors, and command and control systems, most missile defense components serve only the military and government. As such, neither industry nor the U.S. government can fully realize market advantage.

As an industry focused on explosive weapons and propellants, government regulation over the production and sale of such items poses a barrier to entry and an overall administrative burden on participants. For example, foreign military sales (FMS) of missile defense systems are subject to U.S. Arms Export Control Act and International Traffic in Arms Regulations (ITAR), among other market restricting laws and regulations, limiting a company's ability to expand sales beyond the U.S. government.<sup>27</sup> Moreover, the formal rules and requirements associated with government contracting and working with classified weapons systems necessitate a particular skillset and acceptance of administrative overhead costs. As a relatively small and concentrated industry with few buyers, such costs, generalized economic effects of interest rates, supply chain disruptions and limitations, and frequently interrupted government funding induce significant risk to any company attempting to compete or enter the market.

The industry's structure drives how participant companies conduct their business and their resultant performance. The costs of developing and selling the MDS steer the industry toward mergers and acquisitions to access economies of scale and new technologies.<sup>28</sup> Consolidation within the industry further reduces competition in price and innovation.<sup>29</sup> With fewer companies working on a particular problem, it is less likely those companies will find innovative solutions and more likely they will control pricing to the buyer's detriment.

Notwithstanding the complications of operating in the missile defense industry, rising global threats and hostilities continue to spur growth.<sup>30</sup> Experts expect missile defense spending to grow and remain insulated from budget cuts due to the industry's vital role in national security.<sup>31</sup> Companies within the missile defense industry are profitable and continue to forecast growth.<sup>32</sup> This \$40 billion industry enjoys a 14.3% profit margin and expects greater than 3% growth for the next several years.<sup>33</sup> However, the risk of fundamental shifts in industry structure,

such as changing laws and regulations, including the availability of government funding or interference in mergers and acquisitions, induces volatility that will continue to impact the competitive landscape of the missile defense industry.

Out of the Big-5 defense industry competitors, four large prime contractors lead the U.S. missile defense industry: Lockheed Martin, Raytheon Technologies, Northrop Grumman, and Boeing. Annex C contains company profiles for the four companies dominating the missile defense industry and two of the prominent industry subcontractors, as well as an analysis of the industry using Porter's Five Forces.

### **Implications and Assumptions**

For the United States to defend itself against limited missile threats from any source as opposed to merely countering rogue nations' ballistic missile threats, the U.S. government must expand the requirements for the Next Generation Interceptor (NGI), continue to fund those efforts already underway to counter the threat from cruise missiles and HGVs, field products on time, and meet combatant commanders' operational needs for homeland and regional defense. Additionally, the federal government must make sufficient resources available to implement the recommended policy changes below, commensurate with the domestic and international assets it wishes to defend against missile threats.

### **How To Strengthen the U.S. Missile Defense Industry**

The U.S. government must make structural and policy changes to the missile defense enterprise to provide the modern, layered, homeland, and regional defenses the United States needs to deter and defeat adversaries. The following strategic framework offers solutions to the United States' lack of preparedness to face current missile defense challenges. The framework begins with a desired end state, which will solve this problem if achieved. The subsequent

policy recommendations target specific factors currently degrading the missile defense enterprise and hampering its achievement of the desired end state. These factors include a need to reallocate responsibilities amongst the entities involved with missile defense research, development, procurement, and sustainment, an updated U.S. missile defense strategy, increased speed and effectiveness of research and development, and a stronger and nimbler defense industrial base.

### **Desired End State and How To Get There**

Ideally, the United States can create an integrated missile defense enterprise with allies and partners that will incorporate the competence, innovation, and agility needed to develop an effective missile defense deterrent and respond to future threats. It will be a system to defend against any missile, although not every missile. To get there, the United States should shift the strategy behind U.S. missile defense, reform the MDA, and strengthen the U.S. Missile Defense Industry.

### **Shift the Strategy Behind U.S. Missile Defense**

*Expand the aims of the U.S. missile defense system and strategy to better defend the nation:* As previously stated, the U.S. government should be able to defend against any missile, although not every missile. Homeland ICBM defenses should complicate and deter peer adversaries' strike planning. They should also be able to defend against limited nuclear attacks from rogue nations credibly. Finally, the U.S.'s ability to defend the homeland from HGV and cruise missiles should deny an adversary's ability to disrupt U.S. force projection and defend critical infrastructure designated by the executive and legislative branches. At the regional level, the United States must be able to defend itself from any adversary's missile attacks long enough to counterattack effectively.

For threat ICBMs, homeland missile defenses need to be able to counter five to ten incoming missiles in order to “take the cheap shots off the table,”<sup>34</sup> The capability to intercept ICBMs from peer and rogue nations alike would provide deterrence by denial and an acceptable level of defense against adversary weapons (both peer and rogue) without endangering strategic stability or becoming too cost-prohibitive. The Next Generation Interceptor (NGI) will provide better defense against increasingly sophisticated rogue state intercontinental ranged ballistic missiles as currently envisioned. However, it needs to be capable of defending against a limited number of still more sophisticated Russian and Chinese ballistic missiles. The U.S. government should continue ongoing development efforts to counter cruise missile and HGV threats to the homeland, and Congress should fund MDA’s \$50.9 million unfunded requirement (UFR) for a homeland cruise missile defense demonstration in FY23.

The United States must continue to increase its regional missile defense capacity and capability against ballistic missiles, cruise missiles, and HGVs to counter the overall quantity of missiles, the duration of the attack, and the time spacing between missile attacks, which will vary by theater, necessitating theater-specific missile defense architectures. These systems should be able to defend the joint force, allies, critical logistic nodes, and critical offensive capabilities long enough to enable an effective counterattack and defeat the threat.

### **Reform the Missile Defense Agency (MDA)**

*Refocus the MDA on its original charter:* In 2002, the DoD established the MDA to develop and field missile defense capabilities. The Department of Defense granted the MDA the authority to diverge from traditional acquisition processes to enable rapid acquisitions.<sup>35</sup> Nevertheless, the DoD has canceled several of MDA’s programs over the years due to high costs and seemingly insurmountable technical challenges. The DoD is concerned with MDA’s

approach to requirements and its decision authorities, costs, risks, and poor track record of transferring programs to the military services in the production phase.<sup>36</sup> Holding on to sustainment programs distracts the MDA's attention and resources from its primary responsibility--innovation. The MDA is understandably wary of transferring systems to the military services, fearing that the military services will underfund sustainment.<sup>37</sup> Nevertheless, by law, the MDA must transfer ownership of these programs to the military services when the programs enter the production and deployment phase.<sup>38</sup> The military services are equally wary of accepting the systems unless they come with sustainment funding. The DoD and the U.S. Congress must enforce the transition to allow the MDA to focus on developing the next generation of MDS. Planned sustainment funding for the systems should transition to the military services when the systems transition, and the Secretary of Defense should direct the services to ensure that the systems' sustainment remains fully funded through the Defense Planning Guidance. The MDA might argue that the services lack the institutional knowledge necessary to sustain the systems. Undoubtedly, the services presently lack such knowledge. But, the fact they already sustain missile defense systems like Patriot suggests they have the capacity to learn.

The DoD must also ensure that the flaws uncovered by the Government Accountability Office regarding the MDA's grossly inaccurate cost estimates for its missile defense programs are corrected.<sup>39</sup> If it does not, the military services will have inadequate funding for the MDA's programs in sustainment. Although MDA policy directs the agency and military services to pursue an independent verification of the Joint Cost Estimate (JCE) by the Office of Secretary of Defense (OSD) Director of Cost Assessment and Program Evaluation (CAPE), the policy does not direct it to actually obtain this verification.<sup>40</sup> The DoD should change this policy to require

the verification to be completed and not just pursued. The DoD should provide close oversight of the cost estimate process and the transition of systems. It should also ensure that the military services are sufficiently funded to maintain the systems once transferred and then prevent the military services from using that funding for other priorities by including appropriate direction in the Defense Planning Guidance (DPG).

***Update the Missile Defense Agency’s research and development strategy to drive more innovation and increase risk tolerance:*** The U.S. missile defense enterprise lacks sufficient R&D to provide innovative missile defense solutions due to unbalanced R&D objectives, insufficient private sector research efforts, and no-fail testing policies. To improve the speed, quantity, and overall performance of R&D, the MDA should design and implement a more effective R&D strategy.

A successful R&D strategy must strike an appropriate balance between modernizing existing systems and developing future technologies. As the lead agency for missile defense, the MDA leads the missile defense R&D strategy. The MDA’s existing R&D strategy is unbalanced, focusing predominantly on incremental modernization of existing systems at the expense of developing leap-ahead future technologies. Of the MDA’s \$10.4 billion FY22 budget, only \$299 million, or 2.8% of its overall budget,<sup>1</sup> is dedicated to researching future technologies, with the remainder allocated to procurement, sustainment, testing, and improving existing systems.<sup>41</sup> This unbalanced resource allocation is wholly inadequate for an organization designed specifically to research and develop advanced technologies.<sup>42</sup>

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<sup>1</sup> MDA claims that up to 80% of its budget is allocated to R&D. However, the expenditures in MDA’s 80% statistic include upgrades of current systems and NGI, which is an evolution of existing hit-to-kill technology. \$299 million is the budget allocated to new and advanced technologies.



To achieve the first policy recommendation, the government should restructure the MDA to rebalance R&D and allow the MDA to redirect focus from sustainment and modernization of existing systems back to its core mission of developing advanced systems ready for procurement. Once restructured, the MDA must address its R&D resource imbalance by increasing the percentage of funding it applies to basic and applied research, especially in budget activities 01 (basic research) and 02 (applied research). The R&D allocated to developing and fielding advanced missile defense technology should be increased from its current level of 2.8% to as much as 90% of the MDA budget.<sup>43</sup> Although PACOM has requested funding for the proposed hypersonic glide-phase defense system for years, the proposal remains on MDA's unfunded requirements list; MDA could fund this technology in a strategically relevant timeframe if resources were reallocated.

In addition to more effectively balancing government R&D funds, a successful research strategy must unleash the defense industry's creativity while focusing its internal research efforts. The government could better focus industry's internal R&D and spur creativity by better advertising advanced technology needs and creating R&D competitions.

A portion of the MDA's R&D strategy must be a roadmap for industry that describes general capabilities, timelines, and estimated procurement budgets over the next several years. Creating this roadmap will allow industry to better focus its internal R&D (including independent R&D) on specific areas where the MDA perceives a future need.

Another method to spur industry creativity and innovation would be for the government to create small R&D competitions. These events, modeled after the Defense Advanced Research Projects Agency (DARPA) challenges, would invite teams from industry and educational institutions to compete by proposing solutions to existing capability gaps. This type of

competition offers several advantages over conventional R&D methods. Defining the problem as a capability gap unleashes creative thinking and can lead to novel solutions for existing scientific and engineering challenges instead of placing the teams into a predefined box. Incentive-based competitions also attract interest from outside the existing defense sector, potentially luring new and innovative companies or groups to the defense industrial base.<sup>44</sup> Based on congressional discussions, the MDA should contact the National Reconnaissance Office to see how it has successfully nurtured start-ups to harness more innovation in space and to learn best practices as it updates its R&D strategy.

Finally, the government must reform missile testing as part of its missile defense strategy. MDA appears risk-averse toward testing, fearing that any test failure will lead to Congressional funding cuts and perceptions of weakness abroad. However, the current testing paradigm's no-fail nature slows the pace of missile defense innovation and stifles the risk-taking that could lead to innovation. The MDA must develop a culture that accepts a degree of failure as an integral part of research, development, and engineering and then adapt its R&D strategy to test often and learn from failure when it happens. The MDA should adopt U.S. Special Operations Command (SOCOM) and Army Rapid Capabilities and Critical Technologies Office (RCCTO) acquisition culture as a template. Both SOCOM and RCCTO instill a culture willing to fail fast and early, then learn lessons and move on.<sup>45</sup> The MDA must adopt this same mindset, especially in the development of game-changing technology, to ensure overly bureaucratic testing requirements and the fear of failure do not stifle missile defense innovation. Congressional oversight committees and Department of Defense leadership must also support and encourage this cultural shift.

## **Strengthen the U.S. Missile Defense Industry**

### ***Improve government engagement with the U.S. missile defense industry to better guide***

***R&D investments:*** The U.S. government must improve its signaling to increase economic surety for the Missile Defense Industrial Base (MDIB). During discussions with the largest U.S. defense companies, industry representatives consistently repeated that the government needed to provide more information to focus missile defense R&D expenditures.<sup>46</sup> The U.S. government must clearly articulate what its missile defense priorities are now and over the coming years, and in what quantity, to drive the MDIB to invest in more capable systems while expanding and modernizing its infrastructure. The government also needs to provide economic surety to industry partners by providing clear government direction coupled with consistent funding. Thus, Congress and the DoD need to align themselves with a strategy and communicate it clearly to industry while providing stable, predictable funding. By not doing so, the defense industrial base's myriad challenges will continue to limit overall missile defense production capacity and fail to provide sufficient capacity against the spectrum of threats the joint and combined force will face in the future. Recently, the shortage of Stinger and Javelin missiles in Ukraine highlights that when the DoD focuses industry solely on great power competition threats, weapons needed to fight low-intensity conflicts are neglected. The U.S. government must engage industry effectively, including enumerating priorities for future capabilities, to ensure sufficient capacity exists to win in any type of conflict.

***Lower barriers to entering the U.S. missile defense industry to increase competition:*** As previously mentioned, the U.S. missile defense industry currently operates as an oligopoly, characterized as a market with a limited number of suppliers and high barriers to entry for new companies.<sup>47</sup> New entrants are also disincentivized by the defense industry's byzantine

regulatory environment and unpredictable federal budgets. The U.S. government should use legislation to reduce red tape for new entrants to the market, change continuing resolution (CR) rules to allow new starts without a congressional waiver, and protect missile defense funding in the budget to create stable and predictable funding for MDS. Ultimately, fewer demanding government requirements and more predictable government spending should ideally incentivize new companies to enter the missile defense market. Additionally, government outreach to nontraditional partners and support to new companies to help them understand processes, procedures, and regulations could further lower barriers to entry, resulting in greater competition.

***Expand international partnerships to facilitate innovation and competition and share costs:*** Another way to increase competition is to expand the missile defense market with greater contributions from international allies and partners. This can take the form of joint ventures between U.S. and foreign companies or direct purchases of foreign-made MDSs. A recent example of a joint venture between the U.S. and Japan is the SM-3 Block IIA, in which Raytheon Technologies and Mitsubishi Heavy Industries (MHI) co-developed and co-produced the mid-course interceptor.<sup>48</sup> The United States has also directly purchased systems from allies, including the Iron Dome MDS from Israel-based Rafael, intended as a stopgap for delayed efforts by the U.S. Army to get its own new IAMD system up and running.<sup>49</sup> These cases present a model in which the United States can expand the National Technology and Industrial Base (NTIB) for MDS, strengthen partnerships, and increase opportunities for competition.

The INDOPACOM Area of Responsibility (AOR) presents a unique opportunity to take advantage of our partners' industrial bases and to expand the NTIB. The NTIB consists of the people and organizations engaged in national security and dual-use R&D, production, maintenance, and related activities and was expanded to include the UK and Australia in 2017.<sup>50</sup>

The U.S. government could better integrate the UK and Australia into its missile defense strategy and create a similar organization of partners, such as Japan and South Korea, focused on the regional threat from China and North Korea. It could expand the NTIB to include Japan and South Korea to help strengthen the U.S. missile defense system while sharing the financial burden and strengthening the DIBs of partner nations—a win-win. Japan and South Korea purchase U.S. defense systems but also domestically produce MDS, such as the Japanese version of the Patriot missile and the South Korean L-SAM launcher.<sup>51</sup> An expansion of the NTIB, specifically for missile defense, would increase incentives for joint projects such as the SM-3 Block IIA and leverage foreign defense companies to increase the amount of competition in the missile defense market. Expanding information and technology sharing is not without risk. However, with sufficient protocols in place, such as anti-tampering technologies, this risk can be mitigated, as Raytheon Technologies has demonstrated with its partnership with Mitsubishi Heavy Industries.

An expansion of the NTIB in INDOPACOM presents an opportunity to enhance relationships with regional allies. In Europe, the European Phased Adaptive Approach (EPAA) successfully implemented regional missile defense systems to protect NATO partners from the Iranian BMD threat. The U.S. does not enjoy a similar multilateral collective defense treaty in the Pacific region but could develop a similar Indo-Pacific Phased Adaptive Approach (IPPAA) to enhance regional missile defenses and create a de facto missile defense treaty between Japan, South Korea, Australia, and the United States. This effort could include the implementation of a Pacific BMD Operations Center (BMDOC), similar to the NATO BMDOC in Germany, to improve collective defense against missile threats, share information and intelligence, and encourage foreign military sales of missiles defense systems.

***Increase foreign military sales (FMS) to provide greater economic certainty for the U.S.***

***missile defense industry:*** Washington uses FMS as a critical tool to advance national security objectives with allies and partners and sustain the defense industrial base that ensures America's military advantage. Better integration with allies and partners would share the burden and bolster joint protection, assurance, and deterrence across U.S. partners and allies.<sup>52</sup> The MDS 20-to-30-year life cycle will also ensure long-term, enduring partnerships. U.S. companies benefit from increased buyers. Increased sales reduce per-unit production costs, provide greater financial stability over time, and increase available funding to reinvest in research and development. Washington and industry must do more to address obstacles to increased FMS, including simplifying lengthy bureaucratic processes. The fact that Poland has only recently begun receiving Patriot FMS systems after it formally requested them in 2014 illustrates the scope of the problem.<sup>53</sup> Washington should also modify the extensive, outdated regulations dictated by the International Traffic in Arms Regulations (ITAR) and revise Missile Technology Control Regime (MTCR) restrictions while addressing MDS.

The U.S. government should begin by establishing a working group with industry to discuss viable, creative solutions and incorporate consultations with key purchasers like Japan and NATO Allies. Washington must also continue to examine the ITAR approval process, including the MTCR, and streamline it as well as the agencies involved. The MTCR, for example, has not been effective at limiting the spread of missile technology, yet it inhibits allies from improving their offensive and defensive capabilities. A sensible start would be to waive most of the approval processes for additional purchases of previously approved MDS sales and their parts. Furthermore, the extensiveness of the approval process needs to be more tailored to the sensitivity of the technology involved vice a one-size-fits-all approach.<sup>54</sup> Next, the U.S.

government must provide the U.S. DIB with more information up front on what will be required for exportability approval so that the DIB can incorporate it into systems at the outset of development. This would increase delivery speed and greatly reduce conversion costs.<sup>55</sup>

Government and industry must also address the overwhelming issue of the cost of U.S. MDS. The U.S. DIB should adapt some components using less expensive options (and admittedly somewhat less capable) to expand sales to countries incapable of purchasing such expensive systems. For example, some allies have shown interest in the SkyCeptor—a U.S. derivative of Israel’s David’s Sling Stunner missile—as a lower-cost interceptor compatible with the Patriot system.<sup>56</sup> Companies should also invest in expanded infrastructure to shorten system delivery timelines, partially supported by Defense Production Act funding. The Ukraine crisis has demonstrated the long-term need and likely sustained demand for regional MDS. Raytheon Technologies estimates that current orders are taking at least three years to complete and deliver, primarily due to the need for a new factory to expand production capacity.<sup>57</sup> To drive down costs, both industry and Washington should encourage more bulk purchases by countries in a shared region, such as the Gulf Cooperation Council, NATO, or the Baltic states. Finally, Washington should lift the post-Cold War ban on U.S. Export-Import Bank financing to help allies finance arms imports from the United States.<sup>58</sup>

***Improve the missile defense talent pipeline for the U.S. Defense Industrial Base (DIB):***

The U.S. DIB, from primes to sub-tier companies, regularly identifies hiring and retaining a skilled workforce as one of the top challenges to developing and producing missile defense weapons systems. DIB companies cite an aging workforce and shortage of qualified applicants due to insufficient interest in a career in the field, educational programs suffering from a teacher shortage, lack of practical skills needed by employers, and delayed processing of security

clearances. As a result, they compete for too few skilled workers and shuffle personnel from one defense program to another, to the detriment of the long-term sustainment of production and innovation in missile defense and other systems. The programs' resulting loss of institutional memory and experienced, skilled workers increases re-startup costs in time and money when the DoD needs more and/ or modernized systems.<sup>59</sup>

The U.S. government and industry must work together to strengthen the recruitment pipeline into the U.S. DIB for its long-term health and sustainment. Apprenticeships would be the most effective way to provide the hands-on experience and skillset industry wants to see in applicants, such as machinists. Students could spend one semester working full-time in industry during trade or technical education, gaining real-world experience for class credit at no cost to the hosting DIB company. The Biden Administration, through Department of Labor grants to state governments, increased federal funding for such apprenticeships, as well as their focus on recruiting underrepresented populations, and it should continue to do so.<sup>60</sup> Companies in the DIB should expand their ongoing small apprenticeship programs and become more involved in this Apprenticeship Building America Grant Program. Some remain unaware of the existing program and would benefit from informational outreach from federal and state government leads. Washington should provide more grants to community colleges and trade schools to recruit qualified teachers and continue their professional development, and the DIB should partner with local schools to help develop practical curricula, train instructors, and lend their own talent to teach students the practical skills they desire. The investment of a few hours of an employee's time each week would pay dividends in creating the skilled applicant pipeline they currently lack. Furthermore, public and private sector messaging that promotes college as the best solution for all Americans should shift to note that trade and technical schools can also



provide financial security and career satisfaction. Lastly, the DoD should create a security pre-clearance program to build a vetted pool of workers available to the defense industry immediately upon college or technical school graduation. This program would entail the DoD advertising degree areas in which it would pay for students' security clearances in exchange for their commitment to future employment in the DIB, significantly expediting hiring.

Finally, Washington should work with industry on retraining and upskilling programs focused on the DIB's hardest-to-fill jobs. The DIB could better leverage DoD's SkillBridge program, which funds Service members' full-time secondment to the private sector for training, apprenticeships, or internships in their last 180 days of service.<sup>61</sup> The DoD should also create an upskilling program modeled after its National Defense Science and Engineering Graduate Fellowship.<sup>62</sup> STEM workers whose jobs face termination due to new skill requirements or termination of government contracts could receive one- to two-year scholarships and living stipends to pursue a new certification or degree in an area of high DIB need, committing to DIB employment upon program completion.

### **Risks, Trade-offs, and Prioritization**

Some of these recommendations, particularly the top priorities, will require new monetary investments. As a result, the government will have to make difficult trade-offs in national security spending and possibly domestic spending. However, bolstering our nation's defenses and military advantage relies on dramatically shifting the approach and increasing investment in missile defense. Expanded collaboration with foreign partners and the commitment of industry to these recommendations, including industry's willingness to spend some of its own resources, would help with cost burden-sharing. For example, in the case of strengthening the talent pipeline, industry would gain exponentially over the long-term from the

small investments required now. In addition, these recommendations will require great political will and sustained commitment to strive for difficult change, as they call for revisions to laws, complex regulations, cultural biases, and entrenched bureaucracies. DoD, White House, and Department of State buy-in at the highest levels is necessary to advance progress. Many of these recommendations rely on legislation, authorization, and/or funding from Congress, which creates a sizeable risk to this approach, given the persistence of Congressional deadlock on most issues. However, the recent prevalence of bipartisan agreement on the need for strong missile defense and this year's National Defense Authorization Act's funding commitments present a unique opportunity to reach a consensus. The suggested budget process and CR reforms will be challenging to achieve, but their impact would be game-changing and, thus, a necessary part of this approach.

A primary risk associated with these recommendations is also how to enforce the proposed policy that the MDA transition MDS to the military services. If the DoD fails to do this correctly, the MDA will continue to spend more than half of its budget on Operations and Maintenance, not innovation. The shift, however, will face significant cultural and bureaucratic obstacles. Shifting systems to the military services risks the health of their sustainment due to their great cost and local competing priorities. This risk could be mitigated by improved oversight from the DoD (through the DPG) and Congress and the Hill's commitment to provide sufficient missile defense O&M funding to the military services without reducing their overall individual budgets.

Another major risk is that changes to the homeland defense strategy to include near-peer adversaries could trigger an arms race. That said, the stabilizing effects of homeland missile defense outweigh this risk. Nevertheless, U.S. adversaries likely will continue to strengthen their

offensive countermeasures as the United States modernizes its capabilities to counter them. Similarly, advancing U.S. capabilities in space to support missile defense could drive U.S. adversaries to do the same and develop new ways to counter the United States' advantages, spurring a race that requires infinite investment in insufficient defenses. Critics argue that the mere pursuit of a robust space-based sensor layer capable of mitigating adversary missile threats will only encourage would-be aggressors to develop their capabilities further by developing kinetic and non-kinetic anti-satellite weapons. While this may be true, it is inevitable regardless. Throughout history, adversaries have continued to play a game of "one-upmanship" as warfare technology has advanced from swords to arrows to gunpowder to lasers. The United States must stay ahead of its adversaries and cannot afford to refrain from investing in next-generation technology out of fear of spurring their weapons advancement; it is already happening.

## **Conclusion**

The current U.S. missile defense architecture is poorly suited to counter threats posed by near-peer and rogue nations alike. Russia's and China's long-range missiles threaten the United States' ability to deploy its forces in a conflict, and U.S. homeland missile defenses are mostly incapable of intercepting them. The United States' longstanding reliance on its nuclear deterrent to dissuade a Russian or Chinese nuclear attack is ill-matched to counter conventional cruise missile or HGV attacks against the homeland -- a more likely scenario. Meanwhile, rogue nations are incorporating advanced technologies into their ICBMs that will eventually render current homeland missile defenses obsolete. At the regional level, U.S. and allied forces face the prospect of missile barrages that overwhelm the MDS's intercept capacity.

To better protect the United States and its allies, the United States must change its strategy. Though homeland and regional missile defenses will never be able to intercept every

missile, they must be capable of intercepting any type of missile. Homeland defenses capable of intercepting limited ICBMs, cruise missiles, and HGVs will complicate adversaries' nuclear strike planning and lessen their ability to interfere with our deployment of forces. Regional defenses capable of intercepting high volumes of missiles for short durations will buy U.S. forces time to counterattack. To build and deploy the missile defense capabilities the United States needs, it must reorient the Missile Defense Agency toward basic and applied research that will yield breakthrough technologies and shift the burden of sustaining legacy systems to the military services. The United States must also strengthen the missile defense industry by improving its engagement with industry, encouraging competition and innovation, expanding international partnerships and FMS, and better sourcing and managing talent within the defense industrial base. These goals will take additional resources and a shift in priorities. Although expensive, the cost would pale in comparison to the cost of the loss of American lives and vital infrastructure should U.S. adversaries choose to exploit the United States' current vulnerabilities and missile defense gaps. It is not too late to catch up, but the clock is ticking.

## **Annex A: Support to Ukraine**

The United States seeks to create an environment in which the development, acquisition, deployment, and use of ballistic missiles by adversaries and competitors, such as Russia and China, can be deterred, principally by decreasing their confidence in the effectiveness of a missile attack. The conflict in Ukraine brings this aspiration into focus. The United States should continue to use its full range of security assistance tools to achieve three primary objectives: enable Ukraine to continue to defend its territorial integrity, expel Russia, and deter Russia from invading its neighbors—especially NATO countries—in the future. The United States cannot allow Russia to undermine the rules-based international order and norms that Washington has shaped since World War II. It must stand up for democratic values and come to the aid of Ukraine. It might be too late for the United States to provide direct missile defense assistance that would deter Russian aggression. However, working through allies, the United States could indirectly provide Ukraine with enough missile defenses to turn the tide in Ukraine’s favor. With more broad and longer-term policy changes toward Ukraine’s security, the United States, NATO members, and other regional security partners could facilitate the development of organic European missile defense systems.

### ***Assistance to Ukraine***

More so than most U.S. partners lacking state-of-the-art missile defense capabilities, Ukraine needs a medium-range, technologically advanced system to counter Russia’s invasion. However, at this point in the conflict, the United States would be challenged to train the Ukrainian Armed Forces quickly to use and maintain a complex system like Patriot without operating inside Ukrainian territory.

Additionally, Washington must avoid providing new game-changing, long-range, offensive capabilities or sophisticated weapons systems to Kyiv that Russia might deem so provocative or escalatory that they trigger direct retaliation against the United States. Defensive aid should focus on systems Ukrainians are already familiar with so that the Ukrainian Armed Forces can integrate them quickly and effectively—particularly given that the United States cannot risk direct entanglement by deploying troops to train, support, or maintain them. The United States should continue to maximize the DoD’s Ukraine Security Assistance Initiative, redirect defense articles previously allocated for Afghanistan, and prioritize Ukraine in the Excess Defense Articles program.<sup>63</sup> The S-300 air and missile defense system has proven its utility. Recognizing that missile defense systems are expensive and scarce, the United States should consider deploying additional Patriot missile defense systems to allow NATO Allies, such as Slovakia or Greece, to send Ukraine S-300s that the Ukrainian armed forces already know how to operate.<sup>64</sup>

The United States and its NATO Allies must ensure they do not provide weapons that cross Putin’s red lines and trigger direct confrontation with Russia, which is especially likely if Russia’s position erodes. To mitigate such a risk, the United States must maintain direct communication with Russia about U.S. and NATO intentions. In the near term, the United States should focus on delivering defensive systems to Ukraine that provide an effective deterrent, coupled with shorter-range offensive weapons—munitions that do not directly enable Ukrainian attacks into Russian territory but effectively contribute to Ukraine’s ability to defeat Russia without risking further escalation.

After termination of hostilities or a ceasefire, Ukraine could improve its defensive posture with missile defense capabilities and deter future Russian attacks. Direct medium-term

assistance should include an integrated tracking and fire control system akin to Northrop Grumman's Integrated Air and Missile Defense Battle Command System, which draws on data from multiple aircraft- and ground-based air defenses and enables commanders to engage air targets at greater range than Patriot. The United States could upgrade Ukraine's fighter aircraft with sensors that would feed into a similar network. Even without aerial integration, Ukraine's air defenses would increase their coverage, range, and effectiveness.

Additionally, as NATO begins to phase out Patriot systems in the next few years and replace them with next-generation systems, the United States could permit the transfer of the older Patriot systems to Ukraine. By employing Patriot batteries around strategic locations in Eastern Ukraine and neighboring countries that border Russia, the United States can help create a buffer to deter future Russian aggression. However, integrating legacy units into this new network would take time. Ukraine has proven a valuable asymmetric partner in great power competition. By helping Ukraine build a resilient and layered network of air defenses, the United States would not just assist Ukraine but expand NATO's defensive buffer in Eastern Europe and help deter future aggression.<sup>65</sup> An additional long-term option would be for NATO and European countries to develop organic European missile defense systems to deter further Russian incursion into Ukraine or NATO territory.

#### ***Assistance to Eastern European NATO members and partners***

The United States must coordinate a long-term plan for weapons supply and sustainment with U.S. allies to share the burden, demonstrate solidarity with a vast coalition, and leverage the global resources available most effectively and speedily. To assist in a longer-term buildup of defensive systems in Eastern Europe, the United States needs to reexamine its security assistance packages with Ukraine's neighbors and NATO members in the Baltic region and countries on

Russia's periphery. European partners should use these assistance packages to bolster their defenses, increase European strategic autonomy, and free up limited U.S. resources needed elsewhere. The more united Europe and NATO Allies and partners are, the less likely Russia is to divide Europe and undermine the current rules-based international order.

Advanced weapons systems often take years to produce. The export control process regulating FMS and military assistance, including security and technology transfer checks, is lengthy and designed to protect U.S. interests. These regulations cannot be eliminated but can be shortened and streamlined. The United States should expedite Foreign Military Sales (FMS) and Foreign Military Financing (FMF), mandate faster and more streamlined decisions, and expand the list of preapproved countries to help vulnerable European nations, especially those adjacent to Russia's territory, bolster their defenses and build a stronger deterrent to prevent Russia from attacking another of its neighbors the future. It is time to enable Europe to modernize its forces and take the lead in its defense.<sup>66</sup> Our processes should match our priorities and support our strategic objectives. The Baltic States—Estonia, Latvia, and Lithuania—and Poland, a critical supply route into Ukraine, are particularly vulnerable. Their prioritization should fall only below Ukraine.<sup>67</sup>

### ***Conclusion***

The United States must deploy its complete toolkit of defensive aid, financing, leases, and sales to Ukraine and its neighbors to help stop Russia's offensive, restore Ukraine's territorial integrity, and deter future aggression by Moscow. It must coordinate closely with allies to send Moscow a clear message that the world will not stand by while it violates international law and order. The United States must navigate this carefully to avoid entangling itself directly in a war with Russia and risk a nuclear incident. The United States and its allies



are enabling Kyiv to contain Russia's offensive. The United States missed a pre-war opportunity for a robust direct U.S. investment in Ukrainian missile defense that might have deterred the conflict. However, this conflict may not be the last. More advanced defensive systems—including our highly capable theater missile defense systems—could help Ukraine deter future Russian aggression. Additionally, by reforming FMS processes and providing more significant assistance to Eastern European NATO members and partners, the United States can better enable Europe to protect its territory and people.

## **Annex B: Porter's Five Forces**

### **Porter's Five Forces Analysis**

With this baseline understanding of the missile defense industry, one can apply Porter's Five Forces to more precisely analyze variables to pinpoint strengths and threats, identify power dynamics, and understand risk. High barriers to entry translate into financial security for existing companies. The threat of new entrants is low, given entry requires increased capital investment, and contracts are generally long-term with slow return on investment. Established companies within the industry possess proprietary technology, established brand identities, and cumulative experience making it difficult for smaller companies to compete.<sup>68</sup>

The industry has trended toward consolidation, reducing from thirty prime contractors three decades ago to merely five prime companies today, with only four competing in the missile defense industry. Typically, well-positioned firms will purchase smaller firms with distinctive competencies, and those without unique competencies exit the market. This consolidation trend is even more evident within the hypersonic weapon systems sector.<sup>69</sup> As hypersonic technologies begin to grow, many prime companies and first-tier material suppliers will position themselves to acquire lower-tiered hypersonic contractors and material suppliers, ultimately resulting in vertical integration.<sup>70</sup> This acquisition may reduce or eliminate competition, creating high barriers to entering the market, resulting in limited competition and capacity issues.

The supplier base primarily consists of several large defense contractors, placing the bargaining power of suppliers in the industry at moderate. Suppliers in a dominant position can decrease prime contractors' margins. Additionally, some suppliers patent their products, which might prevent the prime contractor from switching suppliers. Some highly specialized suppliers of niche components, such as rocket motors, have considerably more bargaining power than

others. With the current supply chain challenges, increased inflation, and tariffs, elevated manufacturing costs will be levied on the prime contractors and, depending on contract type, may carry over to customers, primarily the U.S. government.<sup>71</sup>

The bargaining power of buyers (the U.S. Government and limited foreign governments) is low due mainly to a lack of choice between companies that manufacture missile defense products. Prime contractors are in an advantageous position over the buyers, who rely on their unique competencies. In addition, trade regulations place a strain on buyers due to the lengthy approval process. A buyer dependent on missile defense products for its national security loses leverage in the marketplace; even if prices increase, the need for the systems remains, raising the supplier's bargaining power and lowering that of the buyer.

The growing global security threat promotes industry growth,<sup>72</sup> making it very competitive. Rapidly increasing advanced technology has played a significant role in the industry's advancement. Substitutes are available only through select vendors; therefore, the overall threat of substitution is low to moderate. The largest defense contractors continue to innovate to keep up with current needs; thus, the companies would need to develop new, differentiated products to compete with those already available in the market.<sup>73</sup> Missile defense products are highly specialized and customized, raising switching costs and lowering the likelihood that buyers will change from one supplier to another once product development has begun. To an extent, passive missile defenses, such as hardened bunkers and dispersion, are a substitute for active missile defenses. Still, there is little evidence that the United States would seriously consider passive defenses in lieu of active.

With relatively few firms competing for a small number of large contracts, rivalry between firms is moderate. Consolidation has improved corporate efficiency, product quality,

and internal costs, but it has also reduced competition to the detriment of the U.S. government.<sup>74</sup>

As a result, the remaining companies have greater market power to potentially shut out new competitors, reduce customer choices, limit innovation, charge higher prices, and team up on big projects.

## Annex C: Company Profiles

### Prime Contractors:

- **Lockheed Martin** - Headquartered in Bethesda, MD. Lockheed Martin is one of the larger companies with approximately 115,000 employees. Lockheed Martin manufactures Aegis, Command and Control Battle Management Communications (C2BMC), and Terminal High Altitude Area Defense (THAAD) products and services. Its most recent Return On Invested Capital (ROIC) was 17.1% versus a Weighted Average Cost of Capital (WACC) of 6.1%. Its net worth has increased over the past few years. These factors show that Lockheed Martin's stakeholders have benefited from the past few years of growth, and it is a company creating value.
- **Raytheon Technologies** - Headquartered in Waltham, MA. Raytheon is one of the larger companies with 70,000 employees. Raytheon manufactures the AN/TPY-2 and SPY-6 radars, SM-3, SM-6, and Patriot missiles. Its most recent ROIC was 4.6% versus a WACC of 7.8%, which has improved but not yet rebounded to pre-COVID numbers. It shows a net worth gain but does not show value creation based on the current ROIC versus WACC.
- **Northrop Grumman** - Headquartered in Falls Church, VA. NG is one of the larger companies with 90,000 employees. Northrop Grumman provides boosters for the Ground-based Midcourse missile Defense (GMD). Its most recent ROIC was 21.2% versus a WACC of 5.4%, which has increased in the past few years along with its net worth and a strong order backlog. These factors show that Northrop Grumman's stakeholders have benefited from the past few years of the company's growth and that this company has strong value creation.

- **Boeing** - Headquartered in Chicago, IL. Boeing is one of the larger companies with 141,582 employees. Boeing manufactures Aegis, Ground-based Midcourse missile Defense (GMD), and PAC-3 missile defense products and expertise. It has struggled financially over the past few years. It has also encountered supply chain issues and setbacks from aircraft mishaps that have cost the company, including the infamous 737 Max. Its most recent ROIC was 7.6%, with a WACC of 7.8%, a decline from previous years. These factors and setbacks do not bode well for the company's stakeholders. It has not shown a net profit in a few years and is not generating value.

Prominent Industry Subcontractors:

- **Aerojet Rocketdyne** - Headquartered out of El Segundo, CA. Aerojet is one of the smaller companies with approximately five thousand employees. Aerojet manufactures solid rocket propulsion for most products in the missile defense industry. Its net sales, free cash flow, and funded backlog have increased in recent history. Its most recent ROIC was 9.5% versus a WACC of 4.15%, an increase from prior years. These factors show that Aerojet is doing great for its stakeholders and creating value.
- **Mitsubishi Heavy Industries (MHI)** - Headquartered in a suburb of Tokyo, Japan. MHI is a larger company with around 86,000 employees. It is unique in that it co-develops with Raytheon Technologies the Standard Missile-3 (SM-3) MDSs for the United States and Japan, sharing costs, production efficiencies, and innovation. Its most recent ROIC was 4% versus a WACC of 3.54%, which shows value creation on a smaller scale, though at a far lower profit margin than U.S. industry. Japan is one of Washington's closest allies on missile defense. Its steady annual defense spending increases over the past decade and clear signals about future defense investments provide MHI stability and

security over time. This also highlights the importance of partnerships with foreign allies in this industry.

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<sup>41</sup> Jen Judson, “Missile Defense Agency Seeks \$9.6 Billion in FY23 Budget” (Defense News, March 2022), <https://www.defensenews.com/congress/budget/2022/03/29/missile-defense-agency-seeks-96-billion-in-fy23-budget/#:~:text=The%20budget%20includes%20%247.9%20billion,Dee%20Dee%20Martinez%2C%20MDA's%20comptroller.>

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<sup>42</sup> Jen Judson, “Missile Defense Agency Needs to Get Back to Its Advanced Tech Roots, Top US General Says” (Defense News, February 2021), <https://www.defensenews.com/pentagon/2021/02/25/missile-defense-agency-needs-to-get-back-to-its-advanced-tech-roots-top-us-general-says/>.

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<sup>44</sup> “Prize Challenges” (Defense Advanced Research Projects Agency, No Date), <https://www.darpa.mil/work-with-us/public/prizes>.

<sup>45</sup> “United States Special Operations Command Acquisition Authorities” (Congressional Research Service, July 2018), 10, <https://crsreports.congress.gov/product/pdf/R/R45252/4>.

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