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STRENGTHENING JAPAN'S DEFENSE IN RESPONSE TO RUSSIA'S AGGRESSION AGAINST UKRAINE

A STUDY FROM THE PERSPECTIVE OF INTEGRATED AIR AND MISSILE DEFENSE CAPABILITIES

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Executive summary

Japan's 2022 National Security Strategy emphasizes the importance of maintaining sovereignty, ensuring territorial integrity, and securing the safety of its citizens. To achieve these ends, Japan aims to strengthen its defense system, enhance the Japan-U.S. alliance's deterrence and response capabilities, and reinforce cooperation with like-minded countries. Given that Japan is an island nation, air and maritime transport capabilities for rapid deployment and supply are crucial.

However, the Japan Self-Defense Forces (SDF) faces several challenges in its current state of readiness. If ground-deployed missile defense systems or medium-range air defense missiles are subjected to concentrated enemy attacks, the destruction of fire control systems could render them inoperable, even if ammunition remains. Additionally, the lack of compatibility between systems makes it difficult to repair damaged units using parts from other units or to supplement ammunition supplies from other sources within the arsenal. Furthermore, challenges related to rapid production raise concerns about Japan's ability to sustain weapon and ammunition supplies during prolonged conflicts.

This paper proposes three measures to address these challenges. The first is to develop combined offensive and defensive systems to enhance operational flexibility and strengthen sustained combat capabilities under concentrated enemy attacks. The second is to invest in low-cost, mass-produced interception systems such as short-range surface-to-air missiles and man-portable air defense systems to counter large numbers of low-end aerial threats. The third is to utilize 3D-printing (also known as "additive manufacturing," or AM) technology to ensure a rapid and stable supply of weapons and ammunition, thereby overcoming the limitations of traditional supply chains.

However, implementing these measures involves several challenges, including ensuring system compatibility, developing a strategy for AM technology, and addressing policy and budgetary constraints. In order for integration to run smoothly, any new systems must be compatible with existing SDF equipment. Additionally, a comprehensive AM technology strategy must be in place to address potential disruptions in the supply chain. Overcoming policy and budgetary constraints requires obtaining approval and securing funding for new defense projects not included in the current Defense Buildup Program. Though these challenges are significant, they can be overcome if addressed in the right way.

The recommendations put forth in this paper to enhance the SDF's combat sustainment capabilities align with Japan's national security interests and are crucial for maintaining regional peace and stability. Implementing these recommendations would not only improve Japan's defense capabilities but also strengthen the Japan-U.S. alliance and, potentially, further advance Japan's overall industrial and technological progress. By addressing new threats and preparing for prolonged conflicts, Japan can ensure its peace and stability in an increasingly uncertain world.

Introduction

Japan's security environment has become increasingly complex and severe due to Russia's aggression against Ukraine and the military advancements of countries neighboring Japan, such as China and North Korea. This situation underscores the urgent need to enhance the combat sustainment capabilities of Japan's Self-Defense Forces (SDF), in the interest of maintaining peace and stability in Japan and the Indo-Pacific region.

This paper argues that strengthening the SDF's combat sustainment capability is crucial for Japan's national security. Three primary recommendations are made to achieve this end: the first is to develop combined offensive and defensive ground systems, the second is to enhance low-end interception measures, and the third is to establish a rapid and stable supply system using 3D-printing (also known as "additive manufacturing" technology).

The development of combined offensive and defensive ground systems will result in greater operational flexibility and will enable the SDF to sustain combat capabilities even under concentrated enemy attacks. Enhancing low-end interception measures, such as short-range surface-to-air missiles and man-portable air defense systems, will allow the SDF to effectively counter large numbers of low-end aerial threats. Finally, the use of additive manufacturing (AM) technology, which is not subject to the limitations of traditional supply chains, will ensure a rapid and stable supply of weapons and ammunition.

These recommendations are supported by the outcomes of recent conflicts in which the effectiveness of integrated air and missile defense (IAMD) systems, the importance of low-end interception measures in countering mass aerial threats, and the advantages of AM technology in maintaining a resilient supply chain have been made clear. By addressing these key areas, Japan can significantly enhance its defense capabilities and contribute to regional stability.

Japan's security environment

MILITARY TRENDS IN NEIGHBORING COUNTRIES AND REGIONS

As described in Japan's 2022 National Security Strategy, China's external stance, military activities, and other nonmilitary actions have become a matter of serious concern for Japan and represent an unprecedented strategic challenge to the international community.[1] Backed by substantial increases in defense spending, China is rapidly enhancing its military capabilities across a broad spectrum, focusing on sea power, air power, and nuclear and missile capabilities. The Chinese navy is the world's largest, comprising over 370 ships and submarines, including more than 140 major surface combatants. The Chinese navy is rapidly strengthening its power: it is currently building its fourth amphibious assault ship and commissioning its third aircraft carrier.[2] The Chinese air force has over 3,150 aircraft, of which approximately 2,400 are combat aircraft (including bombers), and is rapidly enhancing its air power. Recent advancements include the deployment of the J-20 fifth-generation fighter.[3] The U.S. Department of Defense estimates that the People's Liberation Army (PLA) already possesses over 500 operational nuclear weapons and projects that it will probably have more than 1,000 operational nuclear warheads by 2030.[4] The U.S. Department of Defense also estimates that the PLA has 2,850 ballistic missiles and 300 ground-launched cruise missiles (GLCMs) with ranges exceeding 1,500 km.[5]

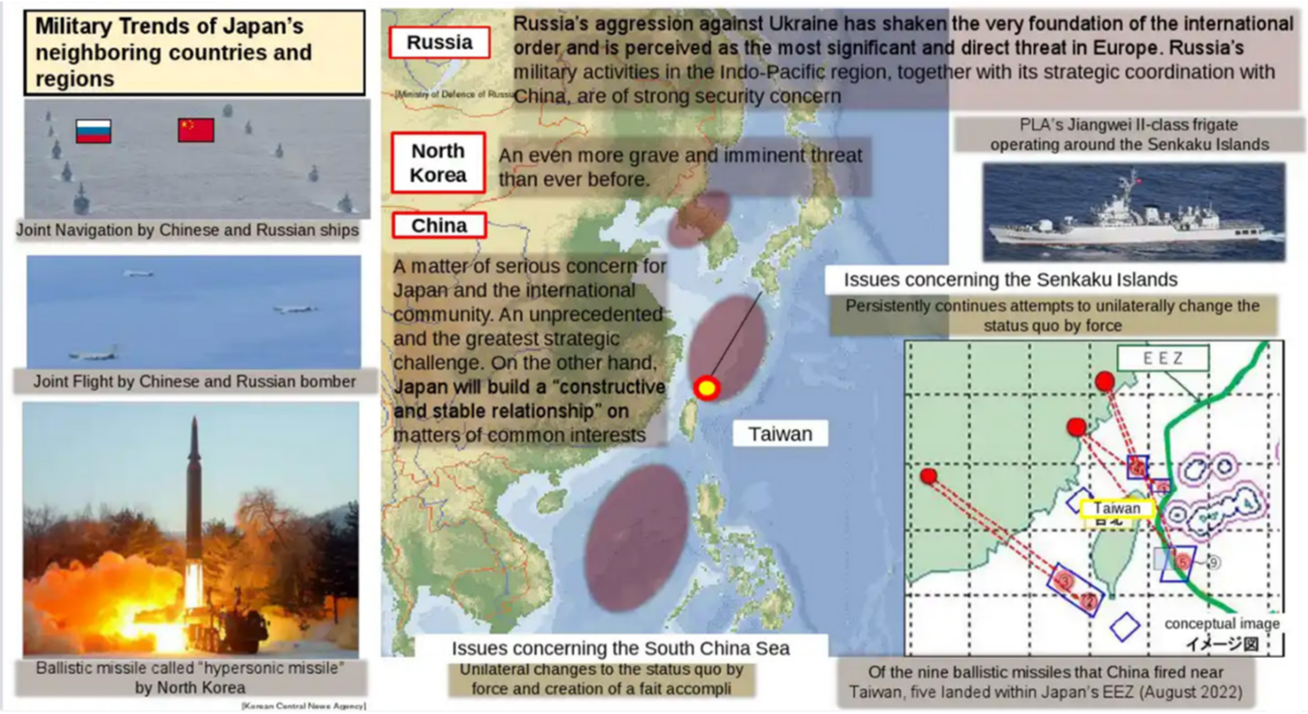
China has intensified the activities of its naval and air forces in the seas and airspace around Japan and the Western Pacific and has used force to unilaterally change the status quo in the East and South China Seas. In August 2022, when U.S. House Speaker Nancy Pelosi visited Taiwan, China launched a total of nine ballistic missiles into the waters around Taiwan, five of which landed in Japan's exclusive economic zone (EEZ). Since 2020, the number of Chinese military aircraft crossing the Taiwan Strait median line has significantly increased, particularly after Pelosi's visit.[6] While China maintains a policy of peaceful unification with Taiwan, it has not ruled out the possibility of using force. In October 2022, during the 20th National Congress of the Chinese Communist Party, President Xi Jinping stated that "we will continue to strive for peaceful reunification with the greatest sincerity and utmost effort, but we will never promise to renounce the use of force."[7] Against this backdrop, in testimony to Congress on March 20, 2024, Admiral John Aquilino, former commander of the Indo-Pacific Command, stated, “All indications point to the PLA meeting President Xi Jinping’s directive to be ready to invade Taiwan by 2027.”[8] In 2023, the Center for Strategic and International Studies, a U.S.-based think tank, released the results of a Taiwan Strait contingency simulation,[9] and the Japan Institute of International Affairs conducted a similar simulation of its own.[10] These trends indicate that China’s external posture and military actions are heightening tensions around the Taiwan Strait, causing significant concern for the international community, including Japan.

North Korea’s military activities pose a graver and more imminent threat to Japan’s national security than ever before. Over the past decade, North Korea has rapidly advanced its nuclear and missile development. In 2022 alone, North Korea conducted an unprecedented number of missile tests, launching at least 59 missiles in total on 31 occasions. The Japan Ministry of Defense (JMOD) estimates that one of the missiles flew approximately 4,600 km over Japan.[11] The launch patterns of North Korean ballistic missiles have become more diverse and complex, indicating a steady improvement in their missile capabilities. It is anticipated that North Korea will continue to focus on the research, development, and operational enhancement of various weapons, including nuclear weapons and missiles, based on the “five-year plan for the development of the defense science and the weapon system” announced at the 8th Congress of the Korean Workers Party in January 2021.[12]

Even amid its aggression against Ukraine, Russia continues its military activities elsewhere, which include large-scale exercises in the Far East. These actions, coupled with strategic coordination with China, pose strong security concerns for the Indo-Pacific region, including for Japan. In fact, Russia has been enhancing its military presence around Japan. Over the past decade, it has deployed and modernized various weapons systems, such as the Bastion and Bal coastal defense missile systems and Su-35S fighters, in the Far East, including in the Japanese Northern Territories. At the same time, joint activities with China have increased in frequency and scale. Russia and China have been strengthening their cooperation through annual joint flights of bombers and joint naval operations near Japan’s waters.[13] This trend is expected to continue.

FIGURE

Military trends in Japan's neighboring countries and regions[14]



EMERGING WAYS OF WARFARE: NEW DOMAINS AND TECHNOLOGIES

Russia's approach to warfare in its aggression against Ukraine has significantly shifted from traditional methods. Prior to its aggression against Ukraine, Russia had relied on a fairly conventional methodology, focusing on air, sea, and land invasions. As described in Japan's National Defense Strategy, Russia's new approach incorporates not only these traditional modes but also large-scale missile attacks, using ballistic and cruise missiles with enhanced precision-strike capabilities; hybrid warfare, involving information-warfare tactics such as false flag operations; utilization of the space, cyber, and electromagnetic domains; and asymmetric attacks using unmanned assets. This new approach also incorporates actions and rhetoric that could be interpreted as threats of nuclear force.[15]

In 2015, China established the Strategic Support Force to enhance its capabilities in the domains of space, cyber, and electromagnetic warfare. In April 2024, this force was disbanded, and a new Information Support Force was created. The space and cyber divisions previously under the Strategic Support Force were reorganized into the Aerospace Force and Cyberspace Force, respectively.[16] This move appears to be an attempt to further strengthen capabilities in space, cyber, and electromagnetic domains. Additionally, China has proposed the concept of "intelligentized warfare."[17] This involves conducting an integrated war not only across land, sea, air, and space but in the electromagnetic, cyber, and cognitive domains as well, using intelligentized weapons and equipment and operational methods based on IoT information systems. The aim of this approach is to enhance integrated operational capabilities by combining traditional and new methods of warfare.[18]

Acquiring the capability to respond to these new warfare methods is a major challenge in building future defense capabilities.

RUSSIA'S INVASION OF UKRAINE

Prior to its full-scale invasion of Ukraine in February 2022, Russia conducted cyberattacks and waged information warfare, while also threatening the use of nuclear weapons.[19] Shortly after the invasion began, Russia executed a concentrated offensive involving space, cyber, and electromagnetic attacks, alongside information warfare, massive missile barrages with ballistic and cruise missiles, aerial assaults, and rapid ground incursions.[20] This intense blitzkrieg aimed to defeat Ukraine without leaving time for other countries to intervene, thereby forcing Ukraine into early submission. Drawing on the success of the 2014 Crimea annexation, Russia likely estimated that pairing hybrid warfare with a blitzkrieg-style offensive could quickly subdue the Zelenskyy administration.

Russia's new method of warfare, characterized by concentrated attacks, inflicted significant damage on Ukraine's operational bases and air defense systems immediately after the invasion began. Consequently, Russian aircraft were able to operate freely in Ukrainian airspace and conduct attacks.[21] However, Ukrainian surface-to-air missiles that survived the initial onslaught posed a substantial threat to Russian air power, significantly reducing the frequency of medium- and high-altitude incursions by Russian aircraft into Ukrainian airspace.[22] Russian ground forces advanced to within 30 kilometers north of Kyiv[23] but faced fierce resistance from Ukrainian forces. Their difficulties were compounded by logistical issues such as fuel shortages, which ultimately led to the failure of Russia's ground assault on Kyiv.[24]

Russia's aggression against Ukraine continues and has become prolonged. One reason for the prolonged invasion is that Western countries, in response to repeated nuclear threats from Russian President Vladimir Putin, have provided restrained support to Ukraine to avoid nuclear escalation, and the Ukrainian military has also had to conduct restrained operations.[25] In this prolonged invasion, both Ukraine and Russia are compensating for conventional manpower shortages by employing an unprecedented number of unmanned aerial vehicles (UAVs). For both sides, the effective deployment of large numbers of UAVs and the ability to counter the opponent's UAVs are increasingly critical.[26] Additionally, in a prolonged military confrontation, the ability to mass-produce and procure weapons and ammunition, including UAVs, plays a critical role in determining the outcome. The Ukrainian military, while receiving Western support, is also mass-producing its own FPV (first-person view) drones. Meanwhile, Russia continues to receive substantial weapons and ammunition support from Iran and North Korea,[27] in addition to producing missiles and UAVs at its own facilities.[28] Ultimately, the side with the superior weapons and ammunition supply holds the advantage.

Considerations for Japan's defense

Since Japan is an island nation, access to Japanese territory must be by air or sea. If an adversary were to invade Japan, it would have difficulty conducting a ground invasion using land-based forces. The enemy would first need to degrade the SDF's operational bases and capabilities, then gain temporary regional air and sea superiority, and then launch invasion forces by air or sea.

Japan's territory consists of approximately 14,000 islands and stretches about 3,000 km in all directions.[29] Therefore, when Japan recognizes an armed attack or existential crisis and responds, the SDF will deploy units and accumulate supplies as necessary. Particularly when conducting maneuver deployments to islands or transporting supplies, air or water transport is required. Additionally, islands generally have a limited number of airports and harbors, and those that do exist are often small, making it difficult for large aircraft to land or for naval vessels to dock.

As for transport between islands, the SDF is unable to provide land transportation except when bridges are built between islands. Otherwise, Japan relies heavily on air and water transport for importing goods. In the event of an armed attack against Japan, the SDF may have to supply weapons and ammunition by air and sea while under missile attack.

As described above, while threats from the outside need to cross the ocean, by air or by water, to invade Japan, Japan itself faces constraints in supplying arms and ammunition due to the high possibility of being forced to rely on air and water transport under enemy attack. Given these circumstances, the SDF needs to build the capacity and readiness to continue fighting tenaciously in an island region to achieve a desirable end state for Japan.

Enhancing SDF combat sustainment capabilities: IAMD systems

In light of Russia's aggression against Ukraine, it is crucial for the SDF to be able to continue fighting tenaciously even when subjected to concentrated attacks employing new combat styles and to avoid running out of weapons and ammunition in the event of a prolonged conflict. In other words, enhancing the SDF's combat sustainment capability is key.

Based on the current status of the SDF's IAMD systems, three specific measures can be taken to strengthen the SDF's combat sustainment capability. The first is to increase operational flexibility by developing combined offensive and defensive ground systems. The second is to address quantitative threats by enhancing low-end interception methods. The third is to ensure a rapid and stable supply of materials through 3D-printing technology. The first two are short-to-medium-term measures, while the third is a medium-to-long-term measure.

THE CURRENT STATUS OF THE SDF'S IAMD SYSTEMS

The High-End Air Defense System

The SDF's current ballistic missile defense (BMD) protocol utilizes a multilayered defense system that integrates upper-tier interceptions by Aegis ships (SM-3) and lower-tier interceptions by Patriot systems (PAC-3 and PAC-3 Missile Segment Enhancement, or MSE) through the Japan Aerospace Defense Ground Environment (JADGE) automated warning and control system. This system includes eight Aegis ships operated by the Maritime Self-Defense Force (MSDF) and Patriot units under the purview of the Air Self-Defense Force (ASDF)—specifically, four air defense missile groups and 24 air defense missile fire units. The ASDF's air defense units are widely distributed across Japan, from Hokkaido to Okinawa, and all units can launch PAC-3 MSE missiles. This deployment allows for rapid maneuvering and interception readiness as the situation demands. Additionally, the ASDF operates 28 fixed warning and control radar sites across Japan, 17 of which can detect and track ballistic missiles.[30]

In terms of air defense systems beyond BMD, the ASDF's Patriot systems can also intercept aircraft and cruise missiles using Guidance Enhanced Missiles and PAC-3 MSEs.[31] The Ground Self-Defense Force (GSDF) has a similar capability with its Type 03 medium-range surface-to-air missile (SAM). The GSDF will operate a total of 14 Type 03 medium-range SAM units (improved version) by the end of FY 2032.[32] Furthermore, the ASDF and GSDF jointly possess the Type 11 short-range SAM as a successor to the older Type 81 system, with recent upgrades including the ability to intercept cruise missiles. The ASDF and GSDF are currently replacing Type 81 short-range SAMs with Type 11 short-range SAMs,[33] and several units have already commenced operations with these new systems.[34]

Regarding sensors, the ASDF possesses 11 radar units from the aforementioned 28 fixed warning and control radar sites that are not designated for ballistic missile defense,[35] as well as J/TPS-102A mobile warning and control radar units as backups for the fixed warning and control radar.[36] Additionally, the ASDF operates E-767 airborne warning and control system aircraft, both E-2C and E-2D, ensuring a robust surveillance posture.[37]

The low-end air defense system

The SDF has been in possession of the so-called legacy SAM for decades. Particularly, the GSDF has long been in possession of the modified Hawk and the Type 93 short-range SAMs, and they are currently in operation, but the decision was made to suspend their use in the FY 2024 budget.[38] The successor to the improved Hawk is the Type 03 medium-range SAM, while the successor to the Type 93 short-range SAM is the new short-range SAM.[39] The new short-range SAM will undergo further development, with the aim of improving its ability to counter cruise missiles while also reducing costs. The Acquisition, Technology & Logistics Agency (ATLA) plans to conduct practical tests of the new short-range SAM until FY 2026.[40] In addition, the GSDF possesses the Type 91 mobile surface-to-air guided missile (MANPAD).[41]

The following section outlines, based on the above information, three specific means for strengthening the SDF's joint warfighting capability from an IAMD perspective.

THREE SPECIFIC MEASURES FOR STRENGTHENING THE SDF'S JOINT WARFIGHTING CAPABILITY

#1: Developing combined offensive and defensive ground systems for operational flexibility

Possible combat scenarios

At the onset of Russia's invasion of Ukraine, Russia aimed to capture Kyiv early by launching attacks in the space, cyber, and electromagnetic domains; conducting saturation attacks with ballistic and cruise missiles; and executing cross-domain, concentrated airstrikes. These efforts were intended to destroy the Ukrainian military's operational bases, forces, and communication networks. One hour before the aggression against Ukraine began, Russia initiated cyberattacks on the KA-SAT satellite and other communication networks to disrupt Ukraine's information systems.[42] In the electromagnetic domain, Russia used aircraft-mounted electronic jamming devices and E-96M aerial decoys to disrupt Ukraine's air defense capabilities.[43]

Russia's saturation attacks with ballistic and cruise missiles primarily targeted Ukraine's long-range early warning radars, SAM sites, command centers, airfields, and ammunition depots. The resulting damage rendered the Ukrainian Air Force unable to detect Russian aircraft and launch missiles from the SAM sites in the country's southern regions that are relatively close to Russian territory.[44] In total, Russia launched 2,154 missiles at Ukrainian cities and regions within the first two months of the invasion.[45]

The Russian Air Force deployed Su-34 fighter jets approximately 140 times per day immediately after the invasion began, conducting over 100 attacks in the first three days alone. These strikes targeted Ukraine's long-range early warning radars, bases, ammunition depots, and mobile SAM units.[46] Concentrating its forces across all domains at the outset, Russia aimed to destroy the operational bases, forces, and communication networks of the Ukrainian military.

China has adopted a similar approach to warfare: its concept of intelligentized warfare centers on the integration of traditional and new warfighting methods with the goal of heightening the country's capability to conduct concentrated, effective attacks. In light of China's developments in this area, the Center for Strategic and International Studies has anticipated in its aforementioned Taiwan simulation that the operational bases and forces of Japan, the United States, and Taiwan would suffer significant damage from large-scale attacks by Chinese ballistic missiles, cruise missiles, and aerial assaults.[47]

Current challenges facing the SDF

One issue facing the SDF is the lack of redundancy in ground-based the systems such as SAMs and SSMs. In the event of cross-domain concentrated attacks by the enemy, it would be extremely difficult to keep all the SDF's assets intact. The SDF's Patriot systems and medium-range SAM systems are particularly vulnerable in this regard. As seen in the example of Russia's aggression against Ukraine, the enemy tends to conduct large-scale attacks on operational bases, air defense systems, and airpower to gain air superiority.

Ground-based assets such as SAMs and Type 12 SSMs are expected to be deployed to operational fronts, including island areas, due to Japan's defense requirements. If the Patriot missile fire control system deployed on an island were destroyed by concentrated enemy attacks, even if there were plenty of PAC-3 MSE ammunition remaining, that fire unit would be unable to operate. The same applies to the Type 03 medium-range SAM and Type 12 SSM.

If units with the same systems are deployed in contiguous areas, damaged units can be repaired using components, missiles, and personnel from other units, thus enabling them to remain in operation. If this is not the case, damaged units cannot continue combat until air- or sea-based support arrives from outside the island. In such a challenging environment, with the enemy continuing missile and air attacks and naval invasions, personnel on the ground would have no choice but to request support from higher command and wait for air or sea transport while conserving remaining components and ammunition.

Another issue is the lack of compatibility between systems. The Patriot systems, Type 03 medium-range SAMs, and Type 12 SSMs are not compatible with each other and have different operational procedures. Thus, if components of one system are damaged, units cannot reconfigure components, ammunition, or personnel with other systems to continue operations. Even if the components themselves are not damaged, any unit that runs out of missiles must wait for ammunition supplies from outside the island to arrive before resuming operation. In sum, the lack of compatibility among these systems makes them insufficient for sustained operations.

Necessary SDF capabilities

Given the above, it is imperative that the SDF is able to flexibly reorganize and persistently continue combat operations even if damage is sustained from the enemy's cross-domain concentrated attacks. To achieve this end, the SDF should strive for operational flexibility and sustained combat capability that go beyond the framework of IAMD, including standoff defense capabilities.

In particular, as long as SAM systems remain operational, it is possible to restrict enemy aircraft operations and protect operational bases and units. In March of 2022, about a week into Russia's invasion of Ukraine, Ukrainian SAMs, which had survived the initial attacks, became a significant threat, heavily reducing the Russian Air Force's incursions into Ukrainian airspace at medium and high altitudes.[48] As a result, the Russian military found it difficult to gain air superiority, which is one of the reasons why its blitzkrieg-style advance on Kyiv was unsuccessful. Furthermore, SAMs can protect operational bases and units from enemy air and missile attacks. This capability contributes to the success of Japan-U.S. agile combat operations, temporarily dispersing and withdrawing fighter jets, and supporting counterattacks through standoff defense capabilities. Improving the sustained combat capabilities of SAM units can thus heighten the effectiveness of SDF integrated operations and Japan-U.S. joint operations.

SSM units can prevent the approach of enemy forces from the sea by destroying vessels before they land. As long as the SDF prevents enemy forces from landing, Japan's territory will not be captured, and the enemy's war objectives can be thwarted. It is therefore highly desirable to enable SSM units to persistently continue combat operations.

Strengthening the sustained combat capabilities of SAM and SSM units will allow the SDF to repeatedly intercept enemy attacks, regardless of how many are launched; this, in turn, will lower the odds of success for a blitzkrieg-style landing invasion. Repelling enemy attacks in this manner would allow SDF ground forces to reorganize according to the situation and to continue fighting persistently, breaking the enemy's will and securing the time and foundation needed for counterattacks by Japan-U.S. air forces. Ultimately, the SDF will be able to prevent enemies from achieving their war objectives and enhance deterrence against invasion.

Recommendations

This paper proposes the development of combined offensive and defensive ground systems, with both offensive and defensive capabilities, is proposed. This would enhance the effectiveness of the SDF's standoff defense and IAMD capabilities. This is not about developing something entirely new but, rather, about developing a platform that utilizes a multi-mission fire control system and launchers capable of firing Patriot missiles, Type 03 medium-range SAMs, and Type 12 SSMs. In other words, the goal is to operate three types of missiles within a single system.

Achieving this goal would significantly change the way in which the SDF conducts combat operations. If, for example, the SDF were to deploy three of the multi-mission ground units described above on one of the southwestern islands, it would be able to continue combat even if the fire control system for one unit were destroyed because parts and ammunition from the other two units would be compatible. Furthermore, because all personnel would have been trained to operate the same system, personnel rotation between units could be carried out flexibly.

Another advantage of the multi-mission ground system is that ground forces would be able to flexibly switch between offense and defense in response to the enemy's invasion posture. For example, if a heavy enemy air offensive were expected, the SDF could use all three units to fire SAMs. If the aim were to destroy enemy vessels, all three units could fire SSMs.

Additional standoff defense technologies, such as the HVGP, for the defense of remote islands, and hypersonic missiles, are currently under development.[49] If these can be integrated into the aforementioned ground system, it is believed that operational flexibility and sustained combat capability could be further enhanced, making this a matter worth considering.

#2: Addressing quantitative threats by enhancing low-end interception measures

Possible combat scenarios

Throughout Russia's aggression against Ukraine, both sides are operating drones and unmanned aerial vehicles on an unprecedented scale. These UAVs, which are cheap and able to be mass-produced, can be used for tracking, targeting, and bombing enemy forces.[50]

At the beginning of the invasion, Ukraine successfully operated Turkish-made Bayraktar UAVs with a range of about 300 km to destroy Russian armored vehicles and air defense systems.[51] In the summer of 2022, as Russia began to experience a shortage of ballistic and cruise missiles and faced a Ukrainian counteroffensive, Moscow purchased a large number of Shahed UAVs from Iran.[52] Russia has extensively used the Shahed, a long-range autonomous UAV with a range of approximately 1,000 to 1,500 km, to exhaust Ukraine's air defense missiles. By December 2023, Russia had launched 3,700 Shahed attacks on Ukraine,[53] and even now, Ukraine continues to face hundreds of Shahed attacks each month.[54]

To counter this large-scale offensive, Ukraine has used FrankenSAMs as well as Western-supplied anti-aircraft guns and MANPADS to shoot down Russia's Shahed UAVs.[55] Additionally, Ukraine has independently developed and deployed long-range UAVs, such as the UJ-26, with a reported maximum range of 800 km, to strike infrastructure within Russia.[56]

Both Ukraine and Russia are also deploying large numbers of inexpensive first-person view (FPV) drones. In January 2024, Ukraine launched the so-called People's Drones Project, which mobilized the public to begin manufacturing FPV drones.[57] Although it is unclear whether the goal was achieved, this initiative aimed to produce one million FPV drones by the end of 2024 to compensate for the country's severe ammunition shortage. Ukraine is currently using many FPV drones, each costing around $500, in combination with reconnaissance drones equipped with high-performance cameras, which cost between $1,500 and $3,000, to destroy high-value Russian equipment such as tanks—these tactics have allowed the Ukrainian military to hold its ground in the battle. While the range of FPV drones is only about 5 to 20 km and their destructive power is less than that of artillery shells, their precise guidance makes them highly effective. Russia is also using FPV drones to attack Ukraine. These drones are a threat to front-line soldiers on both sides and have become a factor in the current stalemate.[58]

Thus, in the prolonged Russia's aggression against Ukraine, it has become clear that UAVs can be effective in compensating for shortages and inferiority of conventional weapons. It is expected that in future wars, invading countries will use not only high-end conventional weapons but also many UAVs.

China, a neighboring country of Japan, possesses a wide variety of UAVs for both military and civilian use, and their long-range UAVs are already conducting air activities in the vicinity of Japan.[59] A situation similar to the one in Russia and Ukraine is by no means out of the question for Japan.

Current challenges facing the SDF

The SDF has a world-class capability to counter ballistic missiles, second only to that of the United States. In particular, the SDF's theater-level BMD capability in the vicinity of Japan is highly developed in terms of C2 systems, sensors, and shooters. Furthermore, plans are in place to steadily enhance capabilities against emerging threats such as hypersonic glide vehicles.

It is crucial to equip the SDF with high-end air defense systems to counter high-end threats from the enemy because the SDF would be powerless against enemy attacks without such systems. However, high-end equipment generally comes with high costs and long production and procurement times, making it difficult to maintain in large quantities. For example, as of July 2023, the annual production of PAC-3 MSE missiles in the United States was 550 units, with Lockheed Martin aiming for 650 units by 2027.[60] These numbers fall far short of the number of Shahed UAVs launched by Russia. If the SDF were to use high-end air defense missiles to counter a large number of low-end threats from the enemy, the stockpile of air defense missiles would quickly be depleted. This would leave the SDF unequipped to deal with further low-end, as well as any high-end, threats from the enemy.

Currently, most of the SDF's low-end air defense systems are being replaced, under development, or slated for decommissioning. It is unlikely that Japan, surrounded by the sea, will suffer significant damage from FPV drones so long as the enemy cannot land because these drones have very short ranges. However, long-range UAVs would be problematic because they could reach Japanese territory from a number of different launch points. Therefore, a shortage of low-end countermeasures could put Japan in a difficult situation were it to face a large-scale attack utilizing long-range UAVs.

Necessary SDF capabilities

In addition to having the capability to intercept high-end threats from the enemy, the SDF must be able to counter quantitative low-end threats. Given that the Ukrainian forces are successfully and reliably intercepting Shahed UAVs using FrankenSAMs, anti-aircraft guns, and MANPADS, intercepting long-range UAVs is not likely to pose a technical challenge. The key factor is ensuring a sufficient quantity of low-end interception measures to address quantitative threats.

Recommendations

The paper proposes the establishment of a defense posture that combines high-end and low-end interception means by increasing investment in interception measures against low-end threats. This is intended to strengthen IAMD capabilities.

The requisite supply of low-end interception missiles could be secured using several means. The first is to accelerate the replacement of the Type 81 short-range SAM with the Type 11 short-range SAM. This would not only enhance the SDF's ability to counter UAVs but would also improve response against saturation attacks by cruise missiles. Although mass production of the Type 11 short-range SAM began about 14 years ago,[61] the process has been slowed by strict budget constraints; there is a need to accelerate the pace at which these missiles are replaced.

The second means is to promote the acquisition of Type 11 short-range SAMs. It goes without saying that the first step must be to enhance the existing equipment. The SDF has allocated approximately 10.8 billion JPY (approximately $700 million) for the acquisition of Type 11 short-range SAMs in the 2024 budget.[62] As with the first strategy, the pace of missile acquisition must be further accelerated.

The third means is to make steady investments in the development of new short-range SAMs. The new short-range SAM, which will succeed the Type 93 short-range SAM, is an improved version of the Type 11 and is expected to present fewer technical hurdles than developing interception capabilities through non-kinetic means. Additionally, the new short-range SAM is expected to be more effective in responding to saturation attacks by cruise missiles compared to the Type 11 short-range SAM and aims to reduce cost burdens by reducing the unit production cost per missile. It is therefore in the SDF's best interest to make steady investments in the development of the new short-range SAM and to ensure its deployment to units.

The fourth means is to make steady investments in the development of non-kinetic interception means, despite technical and operational hurdles. Establishing non-kinetic interception means, such as laser weapons, can significantly reduce supply concerns, as long as resources such as electricity remain available. While laser weapons have not yet been fully operationalized, the U.S. military has begun limited operations in the Middle East,[63] and the U.K. plans to provide Ukraine with laser weapons, whose development is scheduled for completion by 2027, ahead of schedule.[64] Although it takes time to establish the technology, it is making steady progress, and its practical application is in sight, which is important.

The fifth means is investment in MANPADS and anti-aircraft guns. Their effectiveness in intercepting Shahed UAVs has already been demonstrated in Russia's aggression against Ukraine, but they are similarly effective against large numbers of low-end UAVs. Furthermore, these weapons consume less electricity and fuel, making them potentially extremely effective for low-end countermeasures in island defense. Regarding MANPADS, the SDF has long possessed the Type 91 mobile SAM. It is necessary to thoroughly consider whether to increase the number of Type 91s or to develop new MANPADS. Outdated anti-aircraft guns were scrapped in FY 2021, but successor equipment has not been introduced.[65] Considering Russia's aggression against Ukraine, the introduction of new anti-aircraft guns is certainly worth considering.

In conclusion, it is important to strengthen the SDF's combat sustainment capabilities by combining high-end and low-end interception means and enhancing readiness to respond to a large number of low-end threats.

#3: Establishing a quick and stable supply chain with 3D-printing technology

Possible combat scenarios

One of the most influential factors in Russia's invasion of Ukraine has been the supply of weapons and ammunition. As previously mentioned, after Russia failed to capture Kyiv early on, Ukraine counterattacked with weapons and ammunition support it received from the United States and other Western countries.

Within the first two months of the invasion, Russia launched 2,154 ballistic and cruise missiles against Ukraine.[66] Having to fend off Ukraine's counterattack while dealing with a depleted missile supply pushed Russia to the verge of a disadvantage. However, around September 2022, Russia began purchasing and deploying large numbers of Iranian Shahed UAVs,[67] which it used in saturation attacks to deplete Ukraine's air defense missiles. Additionally, around the summer of 2023, Russia began receiving large quantities of weapons and ammunition from North Korea and established a system to produce missiles and other munitions using its own production base.[68]

Due to a temporary stagnation of U.S. support and restrained support from other Western countries, Ukraine's supply of weapons and ammunition was depleted during this time.[69] This created a significant disparity in munitions stockpiles between Russia and Ukraine and allowed Russia to regain momentum, not only thwarting Ukraine's counteroffensive attempts but also beginning to expand the front lines within Ukrainian territory again.[70] The domestic production of Shahed UAVs further strengthened Russia's supply system. Ukraine managed to hold out during this period by mass-producing FPV drones. In April 2024, the U.S. Congress passed a bill that included support for Ukraine,[71] causing the supply of U.S. military weapons and ammunition to Ukraine to resume. This will potentially improve Ukraine's situation.

The takeaway from Russia's invasion of Ukraine is that in a prolonged military confrontation, differences in the supply of weapons and ammunition can have a great effect. What is more, it is highly likely that Russia's strategy of launching large quantities of missiles and ammunition immediately after the start of hostilities will be emulated at some point. The SDF must therefore be prepared to intercept such attacks and to similarly counterattack with large numbers of missiles and ammunition. It must also prepare for warfighting scenarios in which both sides' stockpiles are significantly depleted.

Japan needs to be prepared for a long-term war. Conflicts with outside actors attempting to change the status quo by force are often drawn out in order to deter nuclear escalation. Much as Russia and Ukraine have done, the SDF may need to engage in long-term warfare with depleted missile and ammunition stockpiles, and under such circumstances, it is conceivable that the SDF would need to continue fighting while producing and procuring weapons and ammunition.

Current challenges facing the SDF

There are two primary methods for supplying weapons and ammunition. One is to produce them domestically, and the other is to purchase or receive them from other countries. This discussion will focus on the former, given the latter's dependence on international circumstances, which can be unpredictable.

The challenges of domestic production lie in the supply system's limited ability to respond to long-term demand—specifically, the difficulty of rapid production and supply and the lack of resilience in the supply chain for unexpected situations.

Concerning rapid production and supply, both the SDF and the supply industry face challenges. The Japanese Ministry of Defense determines the quantity of weapons and ammunition to be procured based on the annual defense budget. Generally, defense companies adjust the scale of production lines, technicians, and facilities according to the fluctuations in procurement quantity, but maintaining these production bases involves costs. During peacetime, they do not establish production lines with long-term warfare in mind. Moreover, it takes time to train technicians and invest in facilities, which means it is difficult to achieve rapid production increases when situations necessitating them arise. Furthermore, in an emergency, the SDF must carry out air and sea transport of weapons and ammunition to areas under enemy attack; this takes time and carries the risk of transport assets being shot down and supply becoming impossible.

The main difficulties in maintaining supply-chain resilience during unexpected situations lie on the industry side. In Japan, as in other countries, many vendor companies are involved in production under prime contractors. The cessation of production by key parts manufacturers can lead to a halt in the supply of weapons and ammunition. Some companies are withdrawing from the defense business due to a decrease in procurement volume.[72] If this trend continues, the SDF may face difficulties in procuring weapons, ammunition, and parts in the future, potentially leading to reduced equipment operational rates and delays in ammunition production. Additionally, there have been many instances in which production had to be halted due to large-scale natural disasters in Japan.[73]

Necessary SDF capabilities

The SDF must establish a system that enables the rapid and stable supply of weapons and ammunition in emergencies. Achieving this goal requires enhancing the supply capabilities of the defense industry. While some progress can be made on the industry side—technological development and increased production volume, for example—the JMOD and the SDF must take the lead in driving policy. Sole dependence on industry efforts will not produce the desired result.

Recommendations

Although additive manufacturing technology is still developing, it is steadily expanding its range of applications, and military forces around the world have begun investing in it. In recent years, AM technology has even shown promise in more complex projects, such as producing high-performance components in the space sector.[74]

In the United States, former President Joe Biden had been promoting an initiative known as AM Forward, which encourages large corporations to place AM-related orders with small and medium-sized enterprises.[75] In January 2021, the U.S. Department of Defense formulated an AM strategy and has been promoting the use of AM technology in each branch of the military.[76] Notably, the U.S. Air Force has been using AM technology to produce parts for fighter jets and transport aircraft.[77] In 2024, the U.S. Air Force Academy's Blue Horizon Rocketry Club successfully used 3D printers to manufacture and fly a small UAV within 24 hours.[78]

In September 2023, Japan's GSDF signed a contract with an Australian company that manufactures 3D printers. The contract includes two types of printers: one is a large metal 3D printer capable of quickly producing large metal parts in minutes to hours, and the other is a rugged and deployable unit that has been integrated into a transport container and includes all necessary auxiliary equipment. These systems provide groundbreaking opportunities to produce metal parts on-site and on demand. Additionally, the contract includes comprehensive training, support, maintenance, and in-the-field exercise programs using the printers, ensuring that the GSDF can fully utilize the potential of this technology in combat and on base.[79] This partnership will enhance the sustained combat capabilities of units deployed in island areas and further strengthen the existing supply chain. The advantages of AM technology can be summarized as follows:

- 3D printing offers a dramatic reduction in production time.
- With design data available, production capacity can be significantly increased simply by adding more 3D printers.
- Since 3D printing can be carried out inside containers such as vehicle shelters, it can be used on the front lines in island areas and can significantly contribute to the sustained combat capabilities of frontline units. (However, parts manufactured on-site may have inferior functionality, precision, and quality compared to those manufactured off-site due to material and equipment limitations.)
- Since it is possible to produce parts on demand and on a smaller scale, the risk of vendor companies withdrawing due to insufficient demand is reduced. Small-scale production also reduces storage costs incurred by the SDF.
- Because the same 3D printers can be utilized in multiple locations, damage to one production site will not cause production to be halted.
- The ability to share production data digitally will enhance joint production capabilities with allies and strengthen joint operational capabilities.

Given these advantages, it is clear that AM technology contributes to the supply chain's rapidity and resilience, and there is no doubt that it will benefit the SDF's sustained combat capabilities.

TABLE

Effects and limitations of SDF capability-enhancement measures

MEASURE	EFFECTS	CONSTRAINTS
Development of combined offensive and defensive ground Systems	■ Builds an integrated platform for both offensive and defensive operations, enabling flexible operational deployment ■ Allows rapid reconstitution by sharing parts and ammunition, even when damaged ■ Enhances sustained combat capabilities under concentrated enemy attacks	■ Creates potential for disputes over system management responsibilities between the (GSDF) and ASDF ■ Allows only limited cooperation from the U.S. Army, especially regarding modifications to the Patriot system ■ Is subject to budgetary constraints under the current Defense Buildup Program
Enhancement of low-end interception measures	■ Effectively counters small UAVs and low-cost aerial threats ■ Reduces consumption of high-cost interceptors by utilizing short-range SAMs and MANPADS ■ Establishes a sustainable air defense system against mass attacks	■ Could cause delays related to the development and deployment of non-kinetic interception means (e.g., laser weapons) ■ Incurs costs associated with upgrading existing systems and developing new ones ■ Could lead to temporary vulnerability due to shortages of low-cost interceptors
Establishment of a quick and stable supply system with 3D-printing technology	■ Significantly reduces production time for parts ■ Enables rapid production sharing with allies via digital data ■ Enhances resilience against attacks by dispersing production sites	■ Brings challenges related to manufacturing quality and consistency (machine difference) ■ Requires additional facilities for manufacturing equipment with electronic components ■ Is vulnerable to cyberattacks, including data tampering and theft ■ Has limited applicability to U.S.-made equipment due to the lack of domestic design modification authority

Limitations and responses to implementing specific measures

There are, of course, several limitations to the strategies proposed thus far. The following provides an analysis of them.

LIMITATIONS TO DEVELOPING A COMBINED OFFENSIVE AND DEFENSIVE GROUND SYSTEM

Because the combined offensive and defensive ground system can be operated cross-sectionally between the Ground and Air Self-Defense Forces, there is a risk that debates may arise over which service it should belong to, potentially hindering the system's development. If these debates do not reach a resolution, there is a risk that development plans will never come to fruition.

However, the SDF has dealt with such issues before. In the 1960s, following years of debate, the Nike SAM held by the GSDF was transferred to the ASDF,[80] proving that mature and thorough discussions can yield positive results.

Additionally, since the Patriot system, which constitutes part of the combined offensive and defensive ground system, is domestically produced under license,[81] its modification requires cooperation from the U.S. Army, the original licensor. Because the United States may not see a clear incentive to support the development of a combined offensive and defensive ground system, which is a technology unique to Japan, it may be difficult to secure the necessary cooperation to integrate the Patriot system. However, in preparation for a contingency in the Western Pacific, enhancing the combat sustainment capabilities of SDF's GSDF—making it capable of stopping maritime invasions by an aggressor nation on the frontlines and defending Japan-U.S. bases from large-scale missile attacks—should benefit the overall U.S. joint forces. In addition, if the U.S. Army's Patriot system deployed in Japan during wartime were damaged, the combined offensive and defensive ground system would be able to fire the U.S. Army's remaining missiles, thereby improving U.S.-Japan interoperability and resilience. In other words, Japan's combined offensive and defensive system can be considered an important asset for the U.S. military as well. Japan may gain U.S. cooperation in this matter by explaining that both parties stand to benefit.

Finally, the development of the combined offensive and defensive ground system is not included in the current Defense Buildup Program, meaning that, at the moment, it lacks budgetary backing. However, while using the Defense Buildup Program as a basis, the Ministry of Defense makes flexible budget requests depending on the circumstances at the time. Furthermore, expanding the SDF's planned modifications to the Patriot system to incorporate systems such as the Type 12 SSM could result in more efficient development.[82] Explaining this and other advantages clearly will significantly increase the project's chances of approval.

LIMITATIONS OF ADDRESSING QUANTITATIVE THREATS THROUGH ENHANCED LOW-END INTERCEPTION MEASURES

It is possible that the development of non-kinetic interception means will take longer than expected to complete and that, consequently, deployment will be delayed. The SDF plans to test prototypes of high-power lasers by FY 2025 and research and demonstration tests for high-power microwave irradiation technology are scheduled to continue until FY 2027.[83] In both cases, it is expected to take some time before mass production can commence, and development may be further delayed depending on test results. Until non-kinetic interception means are established, efforts to gradually increase the stockpile of kinetic interception means—namely, low-end weapons and ammunition—are advisable. Additionally, as soon as signs of an enemy invasion become apparent, a response can be mounted by urgently procuring weapons and ammunition from other countries and rapidly training personnel.[84]

There is an additional risk that an invasion might occur at a point when the supply of low-end interception means is low. As previously mentioned, the SDF's short-range SAM arsenal is undergoing partial replacement, and new short-range SAMs and non-kinetic interception means are under research and development. However, just as the FrankenSAM intercepted the Shahed UAV,[85] the SDF's legacy SAMs could intercept UAVs of similar levels. By establishing operational procedures for legacy SAMs as a stopgap measure until newer and more efficient interception means are established, the situation can be managed in the meantime.

Finally, investments in the aforementioned MANPADS and anti-aircraft guns are not currently included in the Defense Buildup Program, which could make it difficult to obtain project approval. As was the case for the combined offensive and defensive ground system, it will be necessary to carefully explain these technologies' necessity and effectiveness in repelling anticipated large-scale UAV attacks. It is also important to emphasize that these weapons are generally inexpensive.

LIMITATIONS OF ESTABLISHING A QUICK AND STABLE SUPPLY CHAIN WITH 3D-PRINTING TECHNOLOGY

One of the foremost challenges of implementing AM technology on a military-wide scale is machine variability. Manufacturing variations can and do occur in 3D printing, even when using the same materials, data, maintenance protocols, and printer model—resolving this issue is essential for stable production. Defects in weapons and ammunition that result from machine variability could put users in danger. For this reason, it is not expected that AM technology will be capable of efficiently and economically producing missiles in the near future. However, by creating an AM technology strategy early, investing proactively in it, and standardizing technical verification and certification processes and risk assessment standards, the JMOD will be able to overcome this issue, and the technological capabilities of the defense industry will be enhanced as a result. It is particularly important for the JMOD to set as specific a goal as possible for the development of AM technology (e.g., that 30% of parts of equipment will be manufactured using AM technology by 2040) and steadily make efforts toward realizing that goal. The publication of clear objectives can also provide the impetus for industries to switch to digital supply chains.

Another limitation of AM technology is that it is currently able to produce only a limited range of products. Equipment that includes electronic components, for example, must be assembled after the individual parts are printed. This means that while equipment components, protective barriers, and decoys can be made solely with 3D printers, complete products such as missiles and drones cannot be created without additional metal-processing equipment. This is particularly true for drones. However, utilizing vehicle-mounted 3D printers in tandem with vehicle-mounted secondary processing facilities would allow products that include electronic components to be manufactured on-site. An alternative solution would be to pre-install secondary processing facilities at bases likely to become front lines. Whatever the specific circumstances are, a production system that includes secondary processing equipment must be established when incorporating AM technology.

Furthermore, because much of the AM supply chain is digital, there is a risk of data theft or tampering. Defense capabilities in this area can be strengthened by establishing a cybersecurity policy for AM technology and by sharing information with existing cyber departments.

Budgetary demands, which are significant, present another challenge for AM technology. Since the JMOD must simultaneously invest in many areas, it may be prevented from investing sufficiently in AM technology. However, the widespread use of AM technology could also ameliorate financial strain by making it less necessary to maintain parts stockpiles. It would also prevent future cost increases due to the sudden withdrawal of analog supply chains. Investment in AM technology is an economical measure in the long run.

Finally, much of the SDF's latest equipment is made in the United States, and Japan does not have the authority to make design changes to this equipment domestically, potentially limiting the application of AM technology to domestically produced equipment. One reason for this is that Japan does not yet have a strategy for AM technology and has not reached the technical level necessary to implement such a strategy. This challenge can be overcome by Japan formulating a strategy early and building a framework for cooperation with the United States regarding AM technology in the future. The Japan Ministry of Defense could obtain cooperation from the U.S. Department of Defense by explaining that advances in Japanese AM technology could be shared with Japan's allies and would strengthen U.S.-Japan interoperability and resilience.

Conclusion

The three strategies for enhancing the SDF's sustained combat capability discussed in this paper—the development of combined offensive and defensive ground systems, the enhancement of low-end interception methods to address quantitative threats, and the establishment of a quick and stable supply system using 3D-printing technology—are all measures that serve Japan's national interests as outlined in its 2022 National Security Strategy.[86] They are key to peace and stability in Japan and the Indo-Pacific region. The combined offensive and defensive ground systems are particularly desirable for their suitability to situations in which resources are limited and efficiency is paramount. They also constitute a very achievable goal, as the technology for such systems already exists.[87] The enhancement of low-end interception methods will have a direct, positive effect on the SDF's ability to respond to large-scale, prolonged attacks. Implementing AM technology will enhance the sustainability of Japan's warfighting operations by stabilizing the supply chain and increasing production capability. Moreover, Japan's implementation of these initiatives would undoubtedly benefit the United States, its ally. Developments such as the ones outlined in this paper not only enhance the SDF's integrated operational capabilities but also improve Japan-U.S. joint operational capabilities, significantly contributing to the shared interest of deterring and responding to unilateral attempts to change the status quo by force.

Finally, a few additional factors warrant consideration in this context. Japan has been facing a rapid decline in birthrate and an aging population for three decades—termed the "silent emergency"—this is considered a serious national issue. Japan's working-age population (15-64 years old) was 75.6 million in 2020, but it is projected to decrease to 45.35 million by 2070.[88] The SDF is working to address the decline in applicant numbers by extending the retirement age of current SDF personnel[89] and raising the upper age limit of recruitment.[90] The aforementioned combined offensive and defensive ground systems integrate three systems into one, allowing for the consolidation of personnel engaged in maintenance, supply, system capability enhancement, and project management. A combined system eliminates the need to maintain separate unit formations, thereby enabling better allocation of personnel resources. AM technology, which can be operated with fewer personnel, and which does not rely on individual skill, could also compensate for the manpower shortage in the analog supply chain.

Furthermore, AM technology is already used in the aerospace sector for manufacturing precision components, and its significance is highlighted by its application in many pieces of U.S. military equipment, which is the result of focused technological investment. Using AM technology allows for rapid prototyping, which accelerates innovation and has the potential to create game-changing defense equipment. AM technology can also be utilized for camouflage, concealment, decoys, and hardening to enhance the viability of critical assets. Therefore, it is crucial for the JMOD to promptly develop, publish, and implement a strategy for this important technology, as it can significantly enhance the SDF's mission capabilities. Additionally, initiative on the part of government agencies like the JMOD will lead to greater motivation for AM technology investment across Japan's industrial sector, significantly contributing to the widespread adoption and technological advancement of AM technology in the country. There are many technological hurdles to be cleared—not only for AM technology but also for non-kinetic means of interception. However, investment in emerging technologies itself constitutes a national defense capability. If Japan were to give up such investments due to challenges and barriers, it would never again be able to compete with other countries in that area. That is why it is important for the SDF not to give up easily on investing in emerging technology.

In sum, these three proposed measures not only contribute to strengthening Japan's defense capabilities but also bring benefits to its ally, the United States, and hold great potential for fostering the advancement of Japan's entire industrial sector and technological prowess.

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