R&D Vision

Toward the Realization of a Multi-Domain Defense Force and Beyond

Explanatory Documentation

Stand-off Defense Technologies

March 31, 2020

Acquisition, Technology & Logistics Agency

What is the "R&D Vision?"

The R&D vision is a document which presents the principles on Research & Development (R&D), technological challenges, and roadmaps of the technologies required to realize our future defense capability for the purpose of strategically conducting advanced R&D from the viewpoint of the mid-to-long term.

The Ministry of Defense (MOD) has formulated *R&D vision concerning Future Fighter Aircraft* in 2010, and *R&D vision of Future Unmanned Vehicles* in 2016 based on *Strategy on Defense Production and Technological Bases and Defense Technology Strategy*. According to the direction shown in *National Defense Program Guidelines for FY 2019 and beyond* (approved by the National Security Council and Cabinet on December 18, 2018), the MOD has formulated the new R&D vision. They are leading to encouragement to acquisition and enhancement of the capabilities required for cross-domain operations such as "Electromagnetic spectrum (EMS) technologies", "Technologies for Persistent ISR including Space", and "Cyber defense technologies" as well as leading to that in traditional domains such as "Underwater warfare technologies" and "Stand-off defense technologies" in order to contribute to realization of Multi-domain Defense Force and to realize technological innovation required for further enhancement of future defense capability.

According to the R&D vision, the MOD will hereafter strategically foster technologies that become necessary in the future and conduct R&D effectively and efficiently.

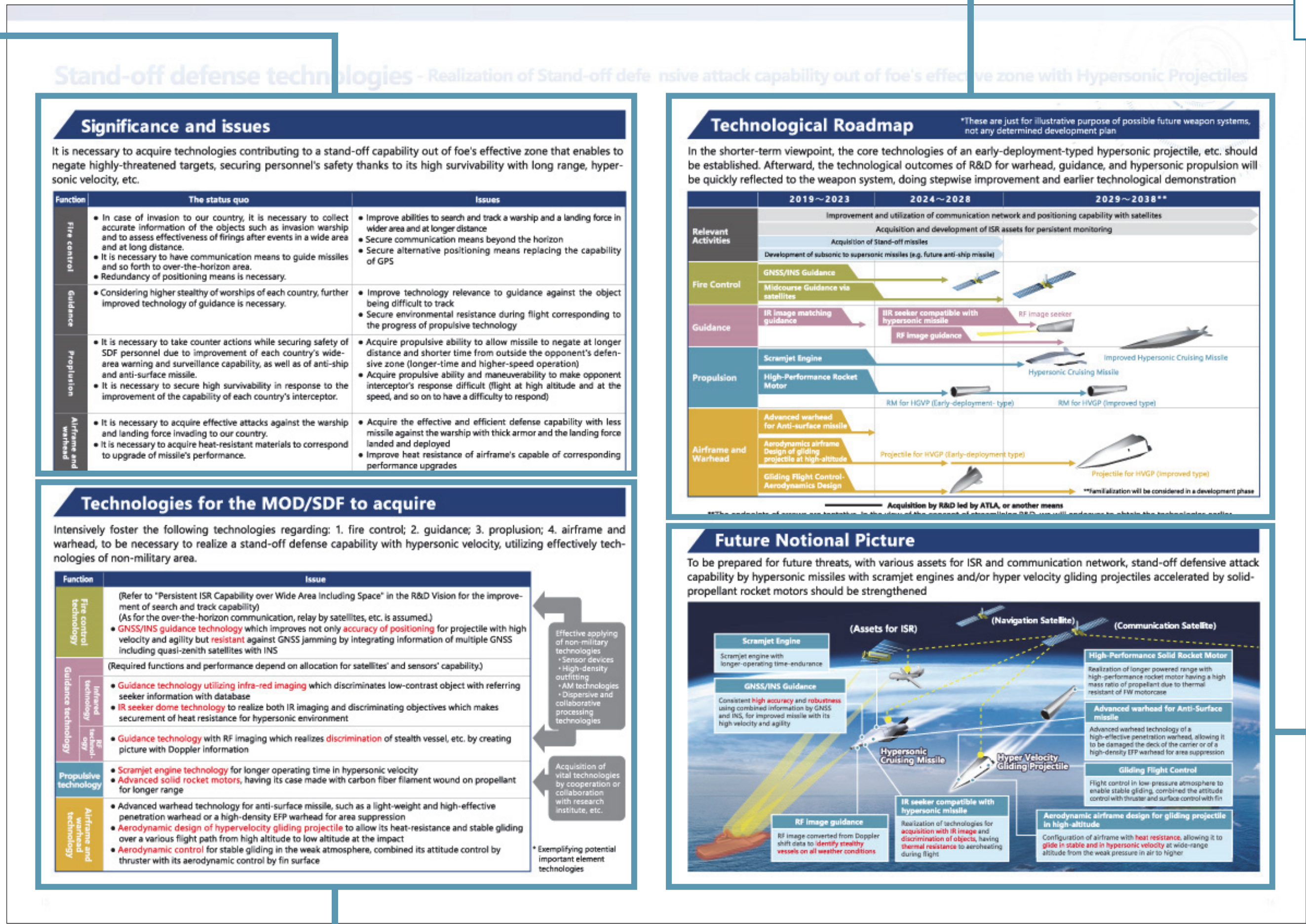
Remarks: A decision-making whether to initialize a development for a deployment or not is comprehensively done by the perspective of defense program on various then-conditions including progresses of researches conducted depicted on the R&D vision, a latest national security environment, an availability of procuring a foreign weapon system, etc.

Table of Contents

Correspondence with the R&D Vision Document

R&D Vision

P15-16



Stand-off defense technologies - Realization of Stand-off defensive attack capability out of foe's effective zone with Hypersonic Projectiles

Significance and issues

It is necessary to acquire technologies contributing to a stand-off capability out of foe's effective zone that enables to negate highly-threatened targets, securing personnel's safety thanks to its high survivability with long range, hypersonic velocity, etc.

Function	The status quo	Issues
Fire control	• In case of invasion to our country, it is necessary to collect accurate information of the objects such as invasion warship and to assess effectiveness of firings after events in a wide area and at long distance. • It is necessary to have communication means to guide missiles and so forth to over-the-horizon area. • Redundancy of positioning means is necessary.	• Improve abilities to search and track a warship and a landing force in wider area and at longer distance • Secure communication means beyond the horizon • Secure alternative positioning means replacing the capability of GPS
Guidance	• Considering higher stealthy of worships of each country, further improved technology of guidance is necessary.	• Improve technology relevance to guidance against the object being difficult to track • Secure environmental resistance during flight corresponding to the progress of propulsive technology
Proplusion	• It is necessary to take counter actions while securing safety of SDF personnel due to improvement of each country's wide-area warning and surveillance capability, as well as of anti-ship and anti-surface missile. • It is necessary to secure high survivability in response to the improvement of the capability of each country's interceptor.	• Acquire propulsive ability to allow missile to negate at longer distance and shorter time from outside the opponent's defensive zone (longer-time and higher-speed operation) • Acquire propulsive ability and maneuverability to make opponent interceptor's response difficult (flight at high altitude and at the speed, and so on to have a difficulty to respond)
Airframe and warhead	• It is necessary to acquire effective attacks against the warship and landing force invading to our country. • It is necessary to acquire heat-resistant materials to correspond to upgrade of missile's performance.	• Acquire the effective and efficient defense capability with less missile against the warship with thick armor and the landing force landed and deployed • Improve heat resistance of airframe's capable of corresponding performance upgrades

Technologies for the MOD/SDF to acquire

Intensively foster the following technologies regarding: 1. fire control; 2. guidance; 3. proplusion; 4. airframe and warhead, to be necessary to realize a stand-off defense capability with hypersonic velocity, utilizing effectively technologies of non-military area.

Function		Issue
Fire control technology		(Refer to "Persistent ISR Capability over Wide Area Including Space" in the R&D Vision for the improvement of search and track capability) (As for the over-the-horizon communication, relay by satellites, etc. is assumed.) • GNSS/INS guidance technology which improves not only accuracy of positioning for projectile with high velocity and agility but resistant against GNSS jamming by integrating information of multiple GNSS including quasi-zenith satellites with INS
Guidance technology		(Required functions and performance depend on allocation for satellites' and sensors' capability.)
	Infrared technology	• Guidance technology utilizing infra-red imaging which discriminates low-contrast object with referring seeker information with database • IR seeker dome technology to realize both IR imaging and discriminating objectives which makes securement of heat resistance for hypersonic environment
	RF technology	• Guidance technology with RF imaging which realizes discrimination of stealth vessel, etc. by creating picture with Doppler information
Propulsive technology		• Scramjet engine technology for longer operating time in hypersonic velocity • Advanced solid rocket motors, having its case made with carbon fiber filament wound on propellant for longer range
Airframe and warhead technology		• Advanced warhead technology for anti-surface missile, such as a light-weight and high-effective penetration warhead or a high-density EFP warhead for area suppression • Aerodynamic design of hypervelocity gliding projectile to allow its heat-resistance and stable gliding over a various flight path from high altitude to low altitude at the impact • Aerodynamic control for stable gliding in the weak atmosphere, combined its attitude control by thruster with its aerodynamic control by fin surface

Effective applying of non-military technologies
・Sensor devices
・High-density outfitting
・AM technologies
・Dispersive and collaborative processing technologies

Acquisition of vital technologies by cooperation or collaboration with research institute, etc.

* Exemplifying potential important element technologies

Technological Roadmap

*These are just for illustrative purpose of possible future weapon systems, not any determined development plan

In the shorter-term viewpoint, the core technologies of an early-deployment-typed hypersonic projectile, etc. should be established. Afterward, the technological outcomes of R&D for warhead, guidance, and hypersonic propulsion will be quickly reflected to the weapon system, doing stepwise improvement and earlier technological demonstration

Future Notional Picture

To be prepared for future threats, with various assets for ISR and communication network, stand-off defensive attack capability by hypersonic missiles with scramjet engines and/or hyper velocity gliding projectiles accelerated by solid-propellant rocket motors should be strengthened

Future Notional Picture (p. 11)

Current state of stand-off defense capability

Stand-off defense capability which balance countermeasures from outside the opponent's threat zone with a high survivability are required in order to ensure the safety of SDF personnel and to effectively deter naval vessels, landing forces, etc. from invading Japan and its minor islands. Guided weapon systems consisting of guided weapons and communication systems are the core of stand-off defense capability. Currently, Japan is promoting the research and development of hyper velocity gliding projectiles for minor island defense, new anti-ship guided missiles for minor island defense, and hypersonic guided missiles in addition to the improvement of stand-off missiles.

Capability improvements in various foreign countries

Large-scale military power is concentrated in the areas around Japan. China is promoting the enhancement of its naval and aerospace military capabilities against a backdrop of increases in its high level of national defense spending. In addition to promoting a build-up of new torpedo boat destroyers and frigates with superior capabilities as well as fourth and fifth-generation fighters, China appears to be emphasizing "A2/AD" (Anti Access/Area Denial) capabilities and deploying multiple long-range cruise missiles in addition to anti-ship ballistic missiles. Russia has announced the development of new missile systems and weapons which can penetrate existing defense networks. In addition, both China and Russia appear to be promoting the development of hypersonic weapons which will enable them to penetrate missile defense networks.

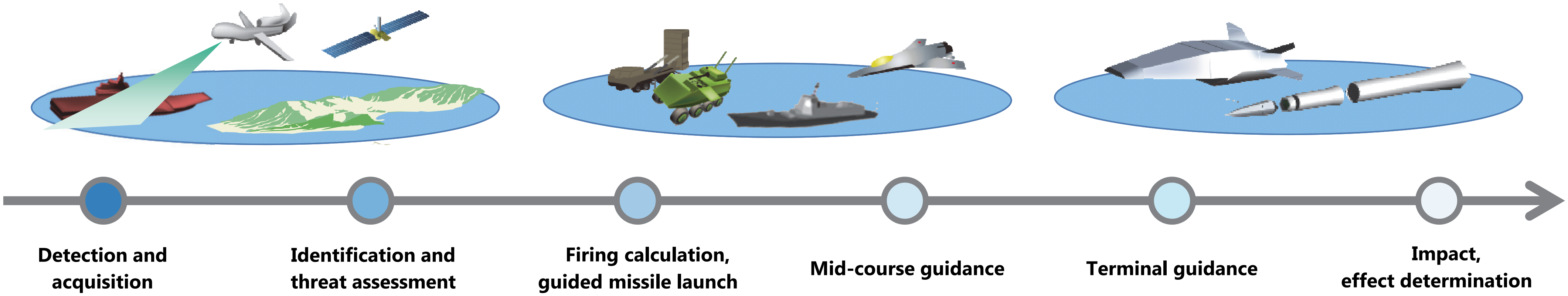
Future directions according to the "NATIONAL DEFENSE PROGRAM GUIDELINES for FY 2019 and beyond"

As the early warning control capabilities and the performance of various missiles are significantly improving in each country, there is a need to ensure the safety of SDF personnel and effectively deter attacks against Japan. Therefore, in addition to acquiring the stand-off firepower and other capabilities required to respond to naval vessels, landing forces, etc. which attempt to invade Japan and its minor islands from outside the opponent's threat zone, we will rapidly and flexibly strengthen related technologies including comprehensive research and development to be able to appropriately cope with the advances in military technologies.

In view of the large-scale concentration of military power in the areas around Japan and the performance improvements of various countries, stand-off defense capability which balance countermeasures from outside the opponent's threat zone with a high survivability are required in order to ensure the safety of SDF personnel and to effectively deter invasions. Going forward, there is a need to advance the comprehensive research and development of technologies related to stand-off defense capability to be able to appropriately cope with the advances in military technologies, and <u>the Ministry of Defense will clarify the technological issues which it should resolve with respect to the technologies required for stand-off defense capability and promote various policies by developing an executable roadmap to steadily ensure technological superiority.</u>

Classifications of Technologies Relating to Stand-off Defense Capability

Series of steps required to demonstrate stand-off defense capability



Technology	Examples of technologies which should be acquired
Fire control technologies	● Technologies for detecting and acquiring (detection and tracking) threats using persistent ISR sensors* ● Technologies including detection and acquisition via radar, etc. for firing, firing calculations based on identification and threat assessment, and guided missile launches and mid-course guidance as well as effect determination* ● Technologies relating to guided missile navigation during mid-course guidance
Precision guidance technologies	● Technologies which use radio waves and light wave sensors and match images with a database to detect and track targets which are difficult to acquire and to perform terminal guidance
Propulsion technologies	● Technologies for achieving the propulsive force to launch and maneuver guided missiles
Airframe and warhead technologies	● Technologies relating to guided missile airframes ● Technologies for implementing attitude control ● Warhead and fuse-related technologies for destroying or disabling targets

* These related technologies are described in detail in the "R&D Vision for Persistent ISR Including Space"

Issues Concerning Stand-off Defense Capability

Issues relating to stand-off defense capability in Japan	
Issues relating to fire control technologies	● To ensure the safety of SDF personnel and handle threats, the ability to search for and acquire naval vessels, landing forces, etc. across a wider area and at a greater distance is required ● To handle long-distance targets which are below the radio wave horizon, over-the-horizon communication measures must be secured to update the target information, etc. ● Redundant positioning measures must be secured due to the risk that specific satellite positioning systems may stop functioning due to interference or the disabling of positioning satellites
Issues relating to precision guidance technologies	● Terminal guidance technologies must be further improved due to the possibility that terminal guidance may become difficult as the naval vessels of each country employ stealth measures ● Seeker domes which can withstand hypersonic flight and other related technologies are required due to the advances in propulsion technology
Issues relating to propulsion technologies	● Based on the improvements in persistent ISR capabilities and the performance of interceptor missiles in each country, propulsion technologies which enable difficult-to-track high altitude flight and flight at high speeds are required
Issues relating to airframe and warhead technologies	● Warhead technologies which are able to effectively and efficiently handle naval vessels and landing forces that are unloading and deploying to invade Japan using a smaller number of warheads are required ● Based on the shift to hypersonic and other flight conditions for guided missiles, heat resistance and other improvements to the environmental worthiness of airframes are required

Advanced Technologies Required by Stand-off Defense Capability

Advanced technologies which are key to the realization of stand-off defense capability	
Fire control	● ISR systems, distributed/cooperative processing technologies utilizing over-the-horizon radar information, and communications technologies are required to detect threats across a wide area and at a great distance* ● GNSS/INS composite guidance technologies are required to improve the mid-course guidance precision and to ensure the ability to withstand GNSS interference ● Analysis technologies using long-distance communication technologies and artificial intelligence, etc. are required to ascertain the results of an attack*
Precision guidance	● Radio wave seeker technology (radio wave image guidance technology) and light wave seeker technology (infrared image matching guidance technology) are required for guidance to targeted stealth vessels and small vessels as well as land-based targets. (Signal processing acceleration and further improvements in radio wave image guidance capabilities are required for ground attacks under all weather conditions)
Propulsion	● To achieve hypersonic flight, technologies to protect the airframe from aerodynamic heating during flight, stable supersonic combustion technologies for scramjet engines, and regenerative cooling technologies to realize long-term operation are required
Airframes and warheads	● Airframe technologies and control technologies which can stably glide at a wide range of altitudes are required to achieve gliding projectiles which fly at hypersonic speeds ● Advanced anti-ship and anti-surface warhead technologies with penetration force according to the flight speed and threat characteristics are required to destroy or disable threats

To prepare for future threats, utilize satellite communication networks and various assets for persistent ISR and enhance stand-off defense capability through hypersonic guided missiles equipped with scramjet engines and gliding projectiles which use high-performance solid rocket motors to accelerate.

* These technologies are described in detail in the "R&D Vision for Persistent ISR"

Effectively utilize technologies from the public sector and intensively cultivate the following technologies from among the (1) fire control technologies, (2) precision guidance technologies, (3) propulsion technologies, and (4) airframe and warhead technologies required to achieve hypersonic stand-off firepower

Function		Examples of technologies which should be acquired
Fire control technologies		(The improvement of detection and acquisition capabilities are described in the "R&D Vision for Persistent ISR Including Space") (It is presumed that over-the-horizon communication methods will be secured through satellites and other relays) GNSS/INS composite guidance technologies which integrate multiple GNSS information and INS systems including quasi-zenith satellites to balance positioning accuracy corresponding to high speed and high mobility with the ability to withstand GNSS interference
Precision guidance technologies		(Achieve the required functions and performance depend on the distribution of the capabilities between the satellites and sensors)
	Light waves	● Infrared image matching guidance technology which compares seeker information with a database to identify low contrast targets ● Light wave seekers for hypersonic guided missiles which possess heat resistance to the aerodynamic heating associated with hypersonic flight and achieve light wave image capture and target identification
	Radio waves	● Radio wave image guidance technologies which image doppler information and identify stealth vessels, etc.
Propulsion technologies		● Scramjet engine technologies which can operate for long periods of time at hypersonic speeds ● High-performance solid rocket motors which improve the heat resistance of direct winding FW motor cases and the propellant loading mass fraction to achieve an extended firing range
Airframe and warhead technologies		● Advanced anti-ship and anti-surface warhead technologies such as a light-weight and highly effective penetration warhead or a high-density EFP warhead for area suppression ● High altitude gliding airframe shape technologies which achieve heat-resistant airframe shapes that can stably glide at supersonic speeds across a wide range of altitudes from high altitudes down to low altitudes near the target ● Composite gliding control technologies such as gas jet based attitude control and aerodynamic steering blades which are required for stable gliding flight in regions where the air is thin

Effective utilization of technologies in the public sector

- Sensor element technologies
- High density packaging technologies
- AM technologies
- Distributed coordination processing technologies

Acquire core technologies through research collaboration/joint research with research institutions

* Illustrates potentially important component technologies

Direction of R&D Initiatives

Operational environment construction perspective

- With the shift toward the long-range firing of guided weapons, networking, as well as the increasing coordination and system integration with unmanned aircraft and other defense equipment which provide target information across a wide area, due to the growing complexity of domestic equipment, there is a need to continue empirical initiatives in actual operating environments which establish the safety and reliability of new defense equipment and definitively resolve high risk issues in stages.
- On the one hand, we currently depend on overseas ranges to conduct testing and training for long-range guided weapons. In order to conduct demonstrations and future training in a sufficient and safe manner in operating environments which include other Japanese equipment, the necessary examinations must be carried out in domestic testing evaluation and training environments which include targets that simulate growing threats such as stealth and high-speed targets.

Efficient technology establishment perspective

- In order to handle the expected future increases in speed and long-range firing as well as the improvements in target detection and interception capabilities by threats, Japan's guided missile systems must also be system optimized through network cooperation along with further improvements in hypersonic speed, long-range firing, and survivability.
- In order to respond from outside the opponent's threat zone, a satellite communication network which utilizes sensor information from persistent ISR assets and provides over-the-horizon communication is essential, and sensor networks and other support environments must be maintained to sufficiently demonstrate the guided missile functionality.
- An unprecedented level of advanced technology is required to develop guided missiles with sufficient capability to handle future threats, and it is imperative that technologies which are not an extension of conventional guided missile-related technology be acquired in a staged and efficient manner.
- Therefore, in order to establish these technologies, various methods including the utilization of technologies from joint research partners must be effectively and efficiently combined to acquire the technologies.

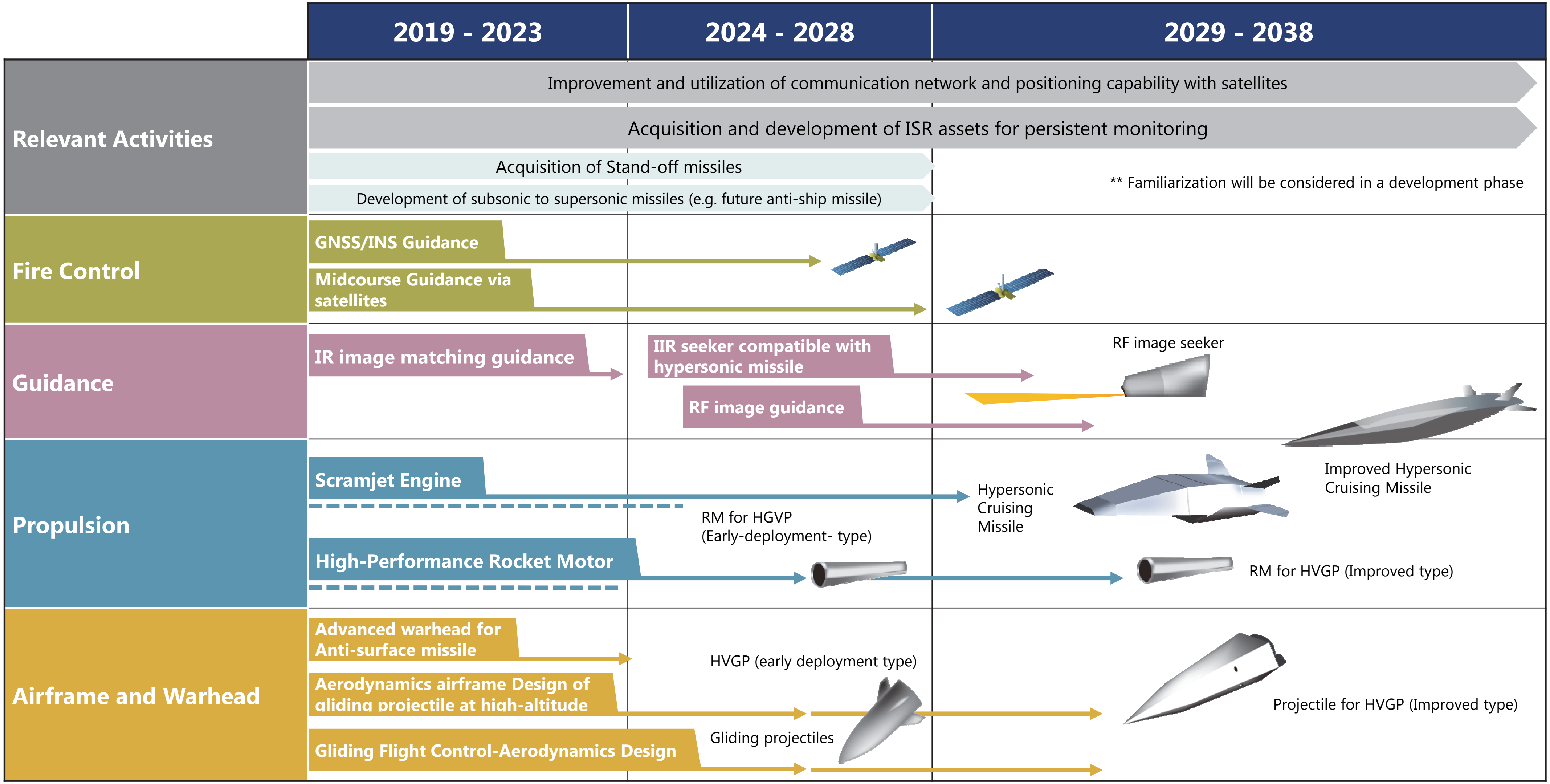
In order to ensure a high survivability from outside the opponent's threat zone and effectively handle high threat targets, various methods must be effectively and efficiently combined to acquire the technologies which achieve hypersonic stand-off firepower.

Leading Technological Issues Which Should be Addressed

Carry out efficient research and development which utilizes Japan's technological advantages according to the characteristics of individual technologies and the technological maturity in regard to the technological issues which should be addressed in order to achieve the hypersonic stand-off defensive firepower of the future.

Important component technologies		Technology overview	Technological issues	Expected results
Fire control technologies	(The improvement of the detection and acquisition capability is described in the "R&D Vision for Persistent ISR Including Space" (It is presumed that over-the-horizon communication methods will be secured through satellites and other relays)			
	GNSS/INS composite guidance	Integrate multiple GNSS information and INS systems to a high degree to improve the robustness and resistance to interference	● GNSS beam formation to avoid the direction of interference ● Ultra-precise coupling of the satellite frequency tracking filter and inertial system	● High-precision mid-course guidance ● Ensure the ability to withstand satellite interference
Precision guidance technologies	Infrared image matching guidance technology	Compare seeker information with a database to identify low contrast targets	● Extract and identify targets (low contrast target) with a low temperature gradient against the background	● Low contrast target identification
	Light wave seekers for hypersonic guided missiles	Image acquisition and target identification during hypersonic flight, ensure resistance to the hypersonic environment and a high visual range through the use of a dome cover	● High frame rate image processing ● Establish resistance during hypersonic flight	● Ensure the operability and performance of the light wave seeker in a hypersonic environment
	Radio wave image guidance	Imaging technology using radar. Enable target identification and guidance capabilities for anti-ship attacks in all weather conditions	● Radio wave image technologies established through previous research must be applied, and optimization based on target setting specific to individual equipment, etc. is required	● Stealth vessel identification
Propulsion technologies	Scramjet engines	Achieve an extremely high survivability and responsiveness by cruising at high altitudes and hypersonic speeds	● Stable supersonic combustion ● Cooling technology which enables long periods of operation	● Reach the target in a short period of time ● Firing range extension ● Improved guided missile survivability
	High-performance solid rocket motors	Improve the heat resistance of direct winding FW motor cases and the propellant loading mass fraction to achieve an extended firing range	● High heat resistance and curing of resin materials ● Environmental worthiness and aging-resistant maintenance improvements	● Extended firing range for gliding projectiles
Airframe and warhead technologies	Advanced anti-ship and anti-surface warheads	Penetration warheads which can destroy the flight deck of an aircraft carrier, etc. or a high-density EFP warhead for area suppression of a ground target	● Standardization of anti-ship and anti-surface warheads ● Shock resistant function for the fuse section ● Design methods which enable lightweight warheads that are still powerful	● Destroy and disable naval and land-based threats with a small number of warheads
	High-altitude gliding airframe shapes	Heat-resistant airframe shapes that can stably glide at supersonic speeds across a wide range of altitudes from high altitudes down to low altitudes near the target	● Airframe shape technology for stable gliding flight in regions where the air is thin ● Heat resistant technology that can withstand aerodynamic heating up to a maximum of 2000°C	● Ensure the operability of gliding projectiles ● Improved survivability through the implementation of gliding flight at various altitude ranges
	Gliding control	Composite controls such as gas jet based attitude control and aerodynamic steering blades which are required for stable gliding flight in regions where the air is thin	● Composite control technologies such as gas jet based attitude control and aerodynamic steering blades	

Establish early deployment gliding projectiles and other core technologies over the short term. Take the results of R&D into warhead, precision guidance, and propulsion (scramjets) technologies and rapidly apply them to armaments through staged capability improvements and early technology demonstrations

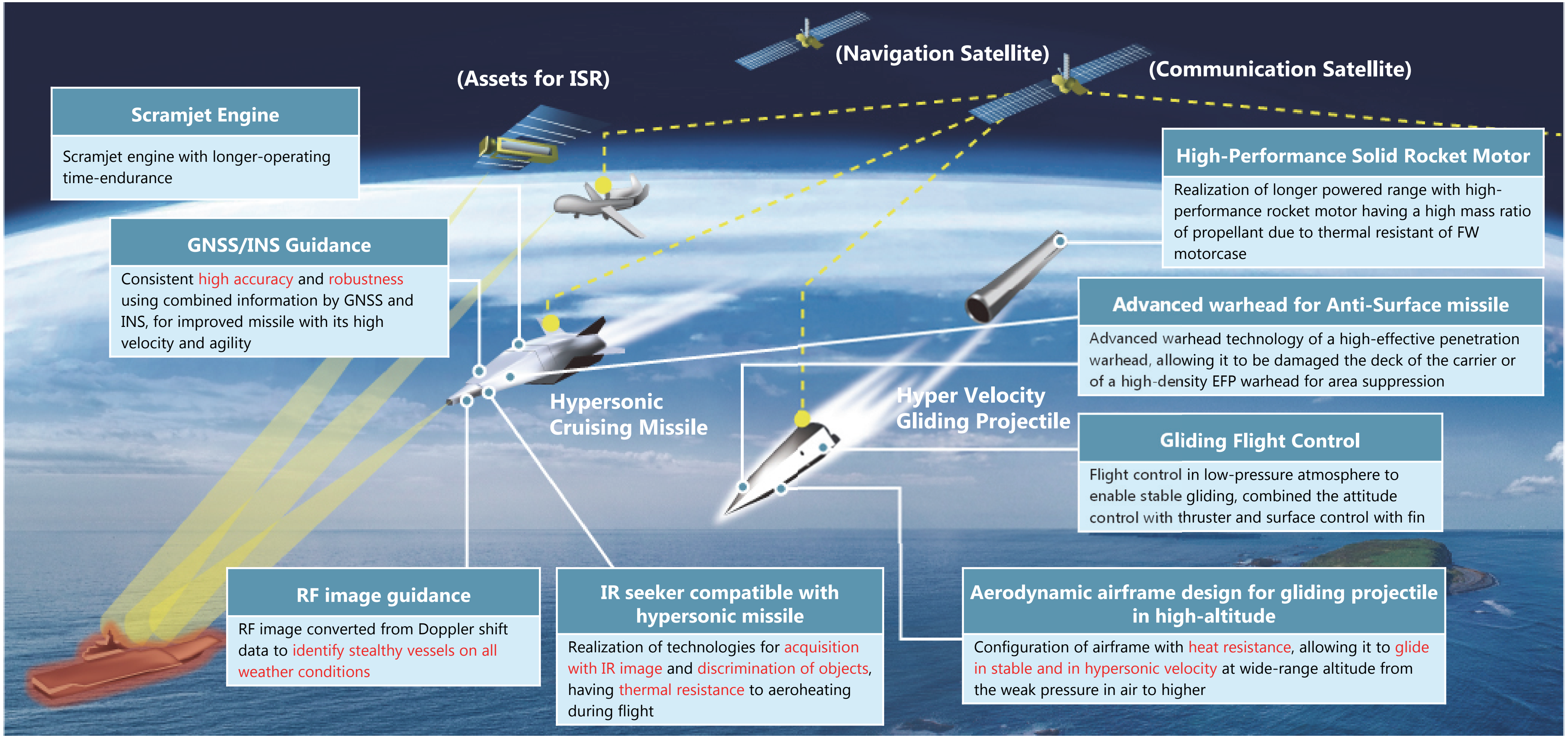


Primarily acquire through research and development
Acquire through joint research
Acquire through new civilian technologies

Note 1 Sufficiently examine the operational, technology, and cost aspects of establishing a specific research and development project.
Note 2 This slide illustrates future equipment which could conceivably be realized and does not indicate a development schedule.
Note 3 The endpoints of the arrows are only tentative. In light of the rapid R&D approach, we will strive for early technology acquisition.

Future Notional Picture

To be prepared for future threats, with various assets for ISR and communication network, stand-off defensive attack capability by hypersonic missiles with scramjet engines and/or hyper velocity gliding projectiles accelerated by solid propellant rocket motors should be strengthened



Conclusion

Primary method of advancing research and development

- The realization of hypersonic guided missile systems requires research into heat-resistant materials and propulsion units, etc. for hypersonic flight as well as the steady advancement of the entire system from fire control and other comprehensive technologies to high resolution seekers, system optimization controls, and other component technologies in order to make guided missiles possible.
- In particular, the promotion of joint research into fundamental technologies for hypersonic flight with research institutions can be expected to not only produce results in technology for defense but also have ripple effects across industries and the entire economy including transfers to civilian technologies.
- Artificial intelligence, quantum computers, sensing, communication, and other quantum technologies which are potentially game-changing technologies in the future are becoming borderless and dual-use. Because the speed of progress in the civilian sector is unusually fast, we will strive for continuous technology improvement and apply the latest technologies according to the progress of domestic and overseas technologies.

Expected results

- Acquiring the capability to effectively strike remote targets through long-range firing can be expected to ensure a broader defensive range.
- High mobility and improved survivability will make it possible to penetrate the opponent's air defense network and efficiently remove threats.
- Acquiring technologies and capabilities which foreign countries, including the advanced nations, do not sufficiently possess will ensure technological superiority and demonstrate Japan's stand-off defense capability as being a deterrent to invasion by other countries.

Proposed vision for stand-off defense technologies

- Improvements in hypersonic speed, long-range firing, and survivability
- Designs which combine mountability on various platforms with ease of maintenance (ensure commonality as much as possible)
- The ability to organically coordinate the guided missile system with fire control equipment and various other platforms as well as the entire defense system to handle threats in order to sufficiently demonstrate their functions as stand-off defense capability

Reference

Previous Initiatives and Foreign and Domestic Trends in Stand-off Defense Capability

Fire control technologies

- Conducted research into GPS/INS composite guidance equipment from FY 2003 to FY 2005. Performed research into GPS/INS composite guidance technologies in high-speed and high-mobility missiles to improve the guidance precision.
- Conducted research into future fire control technologies from FY 2014 to FY 2019. Performed research into component technologies required to realize fire control radar for handling high-speed targets.
- Currently developing the Type 12 anti-ship guided missile (revised) incorporating a feature which sends information to the guided missile from land-based equipment via a satellite as a new component from FY 2017 to FY 2022.

Precision guidance technologies

- Conducted research into active radio wave image guidance methods from FY 2010 to FY 2014. Verified the principles of guidance using radio wave images.
- Conducted research into the light wave dome for the acceleration of anti-aircraft guided missiles from FY 2012 to FY 2017. Performed research into light wave dome and dome cover heat resistance, etc. during hypersonic flight.
- Conducted research into ground target extraction technologies from FY 2015 to FY 2017. Performed research into methods which use brightness gradients as a feature quantity to extract and identify infrared stealth targets, etc.

Propulsion technologies

- Performed research into scramjet engine combustion chambers and other component technologies and gained insight into their operation from FY 2017 to FY 2018. Conducted research into hypersonic guided missile engine system construction from FY 2019.
- Conducting research into high heat resistance technologies for CFRP rocket motor cases since FY 2018.

Airframe and warhead technologies

- Research prototypes of advanced anti-ship and anti-surface warhead standardization technologies are scheduled to be implemented from FY 2020.

✓ Regarding fire control technologies and precision guidance technologies, we only have experience with component technologies for subsonic to supersonic guided missiles, and component technologies for hypersonic speeds will be addressed going forward.

Fire control technologies

- Japan is advancing preparations to establish a system of seven quasi-zenith satellites to enable continuous positioning.
- In Russia, the GLONASS global satellite positioning system is already in operation.
- China is advancing the construction of its own BeiDou system, because it does not rely on GPS for national security reasons and plans to provide a global satellite positioning system starting in 2020.

Precision guidance technologies

- Since FY 2018, Japan has been researching new image processing algorithms and evaluation methods to enable the detection and identification of targets from low contrast infrared images.
- It is known that light wave domes and dome covers (shrouds) have been adopted for use in SM-3 and THAAD in the US. In addition, according to published documents, the AGM-158 uses technology which compares and recognizes infrared images of the target collected through intelligence logistics support.
- According to published documents, the JSM (Joint Strike Missile) developed in Norway is said to use guidance based on comparisons with landforms and other topographical features and automatic target recognition technology based on dual wavelength infrared images.

Propulsion technologies

- The US, China, Russia, and India are performing research into projectiles equipped with scramjet engines to achieve hypersonic cruising and long-range firing.
- Scramjet engine technologies are being researched not only in the field of defense but also in the aerospace field.

Airframe and warhead technologies

- In Japan, JAXA is gaining technological knowledge concerning high altitude aerodynamic characteristics and thermal protection technologies through a hypersonic experimental aircraft project.
- Outside of Japan, Russia, China, and the US are advancing research into hypersonic gliding vehicles.

✓ While each country appears to have initiatives for each component technology, there are no confirmed cases in which the systems have reached the development level or practical level.