R&D Vision

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

Explanatory Documentation

Persistent ISR Including Space

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.

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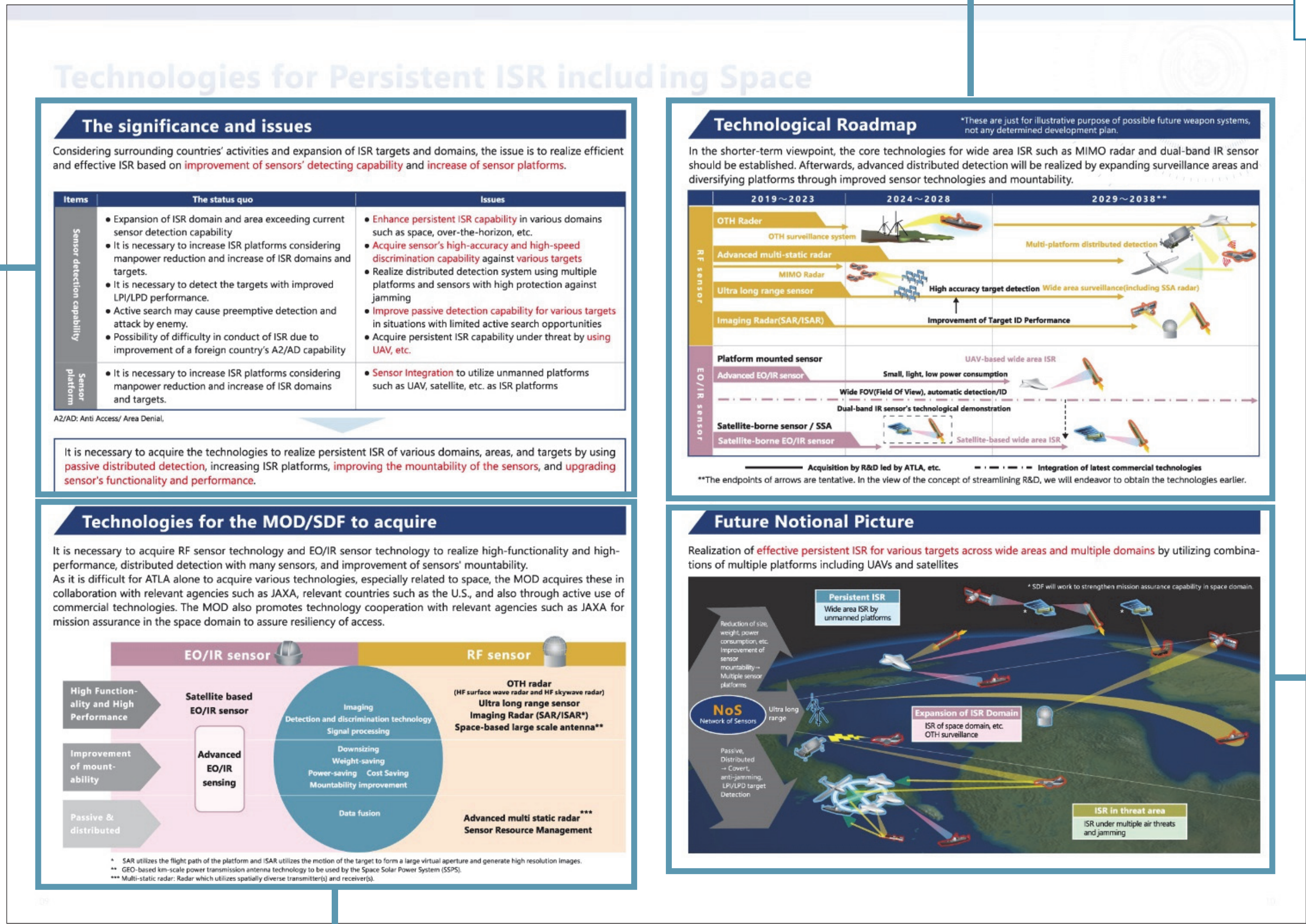


Technologies for Persistent ISR including Space

The significance and issues

Considering surrounding countries' activities and expansion of ISR targets and domains, the issue is to realize efficient and effective ISR based on improvement of sensors' detecting capability and increase of sensor platforms.

Items	The status quo	Issues
Sensor detection capability	• Expansion of ISR domain and area exceeding current sensor detection capability • It is necessary to increase ISR platforms considering manpower reduction and increase of ISR domains and targets. • It is necessary to detect the targets with improved LPI/LPD performance. • Active search may cause preemptive detection and attack by enemy. • Possibility of difficulty in conduct of ISR due to improvement of a foreign country's A2/AD capability	• Enhance persistent ISR capability in various domains such as space, over-the-horizon, etc. • Acquire sensor's high-accuracy and high-speed discrimination capability against various targets • Realize distributed detection system using multiple platforms and sensors with high protection against jamming • Improve passive detection capability for various targets in situations with limited active search opportunities • Acquire persistent ISR capability under threat by using UAV, etc.
Sensor platform	• It is necessary to increase ISR platforms considering manpower reduction and increase of ISR domains and targets.	• Sensor Integration to utilize unmanned platforms such as UAV, satellite, etc. as ISR platforms

A2/AD: Anti Access/ Area Denial.

It is necessary to acquire the technologies to realize persistent ISR of various domains, areas, and targets by using passive distributed detection, increasing ISR platforms, improving the mountability of the sensors, and upgrading sensor's functionality and performance.

Technologies for the MOD/SDF to acquire

It is necessary to acquire RF sensor technology and EO/IR sensor technology to realize high-functionality and high-performance, distributed detection with many sensors, and improvement of sensors' mountability.
As it is difficult for ATLA alone to acquire various technologies, especially related to space, the MOD acquires these in collaboration with relevant agencies such as JAXA, relevant countries such as the U.S., and also through active use of commercial technologies. The MOD also promotes technology cooperation with relevant agencies such as JAXA for mission assurance in the space domain to assure resiliency of access.

* SAR utilizes the flight path of the platform and ISAR utilizes the motion of the target to form a large virtual aperture and generate high resolution images.
** GEO-based km-scale power transmission antenna technology to be used by the Space Solar Power System (SSPS).
*** Multi-static radar: Radar which utilizes spatially diverse transmitter(s) and receiver(s).

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 for wide area ISR such as MIMO radar and dual-band IR sensor should be established. Afterwards, advanced distributed detection will be realized by expanding surveillance areas and diversifying platforms through improved sensor technologies and mountability.

**The endpoints of arrows are tentative. In the view of the concept of streamlining R&D, we will endeavor to obtain the technologies earlier.

Future Notional Picture

Realization of effective persistent ISR for various targets across wide areas and multiple domains by utilizing combinations of multiple platforms including UAVs and satellites

Trends in activities, etc. by foreign countries surrounding Japan

Nations which possess qualitatively and quantitatively superior military power are concentrated around Japan, and the further strengthening of that military power and the increasing frequency of military activities is becoming pronounced.

China is extensively and rapidly strengthening the quality and quantity of its military power with a focus on nuclear and missile forces as well as naval and air forces. In doing so, China is focusing on ensuring dominance in new domains by continuing to strengthen its capabilities in the space domain including the development and testing of anti-satellite weapons. In addition, China is expanding and increasing the frequency of military activities in maritime and air spaces such as the East China Sea by carrying out constant activities by public and naval vessels in the area around Japan's indigenous territory in the Senkaku Islands and advancing the military fortification of the South China Sea by frequently expanding into the Pacific Ocean through a variety of routes and unit configurations.

In recent years, North Korea has launched ballistic missiles with an unprecedented frequency and is rapidly strengthening its simultaneous launch capabilities and surprise attack capabilities, etc. While announcing its intentions to completely denuclearize, North Korea's nuclear and missile capabilities are essentially unchanged.

Russia is strengthening its military posture by continuing initiatives to modernize its military power with a focus on its nuclear forces and is also stepping up its military activities in the Far East including the Northern Territories.

Japanese initiatives relating to ISR and space

As indicated in the "NATIONAL DEFENSE PROGRAM GUIDELINES for FY 2019 and Beyond," Japan's policies pertaining to ISR and space are as follows.

Regarding ISR, it states that the "SDF will leverage its capabilities in all domains to conduct wide-area, persistent intelligence, surveillance and reconnaissance (hereinafter referred to as “persistent ISR”) activities around Japan" and appropriately respond to gray zone situations during peacetime.

In contrast, the priority items for strengthening defense capabilities with regard to space indicate that the "SDF therefore will further improve various capabilities that leverage space domain including information-gathering, communication and positioning capabilities. SDF will also build a structure to conduct persistent ground and space-based space situation monitoring" to undertake the strengthening of capabilities to ensure space utilization superiority including the construction of a Space Situational Awareness (SSA) as part of conventional initiatives.

The current status of ISR research and development at the Ministry of Defense

In the past, the Ministry of Defense has engaged in the research and development and practical application of radio wave, light wave, and other sensors required for Japanese ISR, and such initiatives will be required going forward due to the increase in space and other ISR domains, the increase in drones (miniature UAVs) and other ISR targets, and the improvements in low-observability and other capabilities.

(1) Regular and continuous ISR (hereinafter, "Persistent ISR") across a wide area around Japan is important
(2) Information gathering utilizing the space domain and regular and continuous ISR of space is required
(3) Research and development initiatives are required to improve ISR capabilities according to the increase in the ISR domain and the improvements in equipment performance. Given the reasons stated above, Ministry of Defense will promote various policies by clarifying the technological issues in research and development and developing an executable roadmap to steadily ensure Japan's technological dominance to realize persistent ISR including space

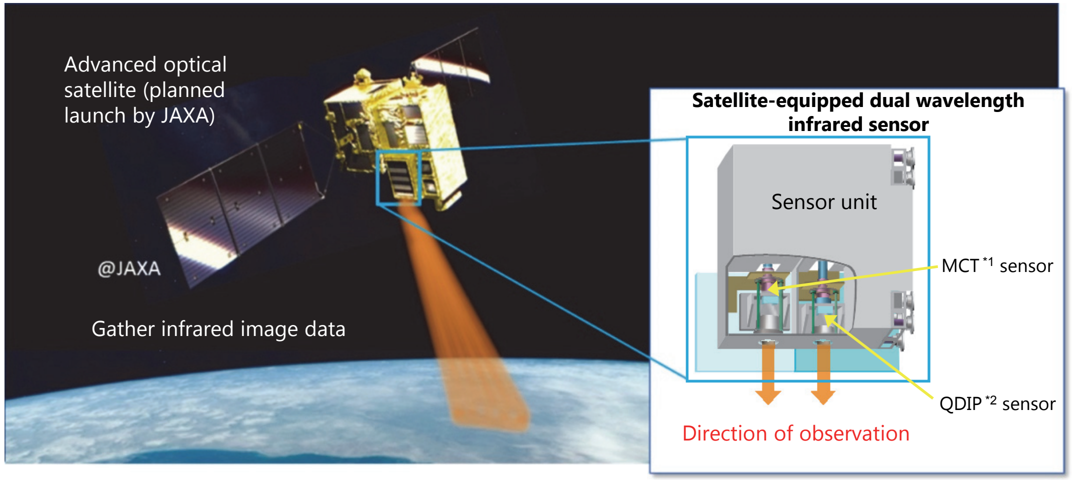
Issues with persistent ISR in Japan

Improvements in sensor detection and identification capabilities

- In addition to the expansion in space and over-the-horizon monitoring domains and the increase in the number of targets, in order to handle the ISR challenges due to the improvements in A2/AD capabilities by foreign countries, MOD must utilize Japan's superiority in semi-conductor technologies over foreign countries to improve the detection capabilities of sensors used in ISR.
  A2/AD: Anti-Access/Area Denial
- In particular, the acquisition and improvement of space monitoring capabilities, expansion of the ISR domain, and improvements in the ability to detect targets with limited radiation opportunities and enhanced low-observability characteristics as well as improvements in the passive, wide area detection of a variety of targets and high-precision and high-speed identification are required.

Sensor platform expansion

- From the perspectives of efficient ISR according to the monitoring domain and the target expansion as well as reducing manpower and labor for continuous ISR, the types of sensor platforms must be expanded and applied to ISR, especially various types of unmanned aircraft, satellites, and other unmanned platforms. Therefore, miniature, high-performance, low power consumption, and low cost sensors which can be equipped on various unmanned platforms must be developed.
- With the expansion in the number of sensor platforms, distributed remote detection, information merging, and composite sensor technologies across multiple platforms must be improved to conduct ISR while ensuring robustness amidst electronic attacks from presumed threats.
- Because it is challenging for the Acquisition, Technology & Logistics Agency to acquire various space-related technologies on its own, such technologies must be acquired through coordination with JAXA and other relevant institutions and the U.S. and other concerned countries as well as the proactive application of civilian technologies.



"Satellite-equipped dual wavelength infrared sensor" illustration

*1 MCT: Mercury Cadmium Telluride
*2 QDIP: Quantum Dot Infrared Photodetector

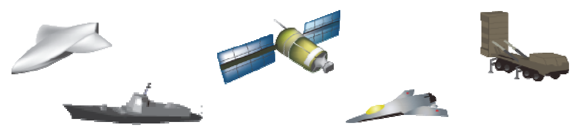
Technologies required to realize persistent ISR by the Ministry of Defense and the SDF

Issues	Technology	Light wave sensors		Radio wave sensors
Improvements in detection and identification capabilities	High functionality and high performance	Satellite-equipped light wave sensor technologies	Imaging technologies Detection and identification technologies Signal processing technologies	Over-the-horizon radar technologies (Short wave band surface waves and ionospheric reflection radar technologies) Ultra long range sensor technologies Image radar (SAR/ISAR*1) technologies Large-scale antenna technologies installed in space*2
Platform expansion	Mountability improvements	Advanced detection technologies	Miniaturization technologies Weight reduction technologies Power-saving technologies Cost-reducing technologies Mountability improvement technologies	
	Passive and distributed		Data merging technologies	Advanced multistatic radar technologies*3 Sensor resource management technologies

Information sharing technologies

Examine in a separate vision document

Platform technologies



Examine individually

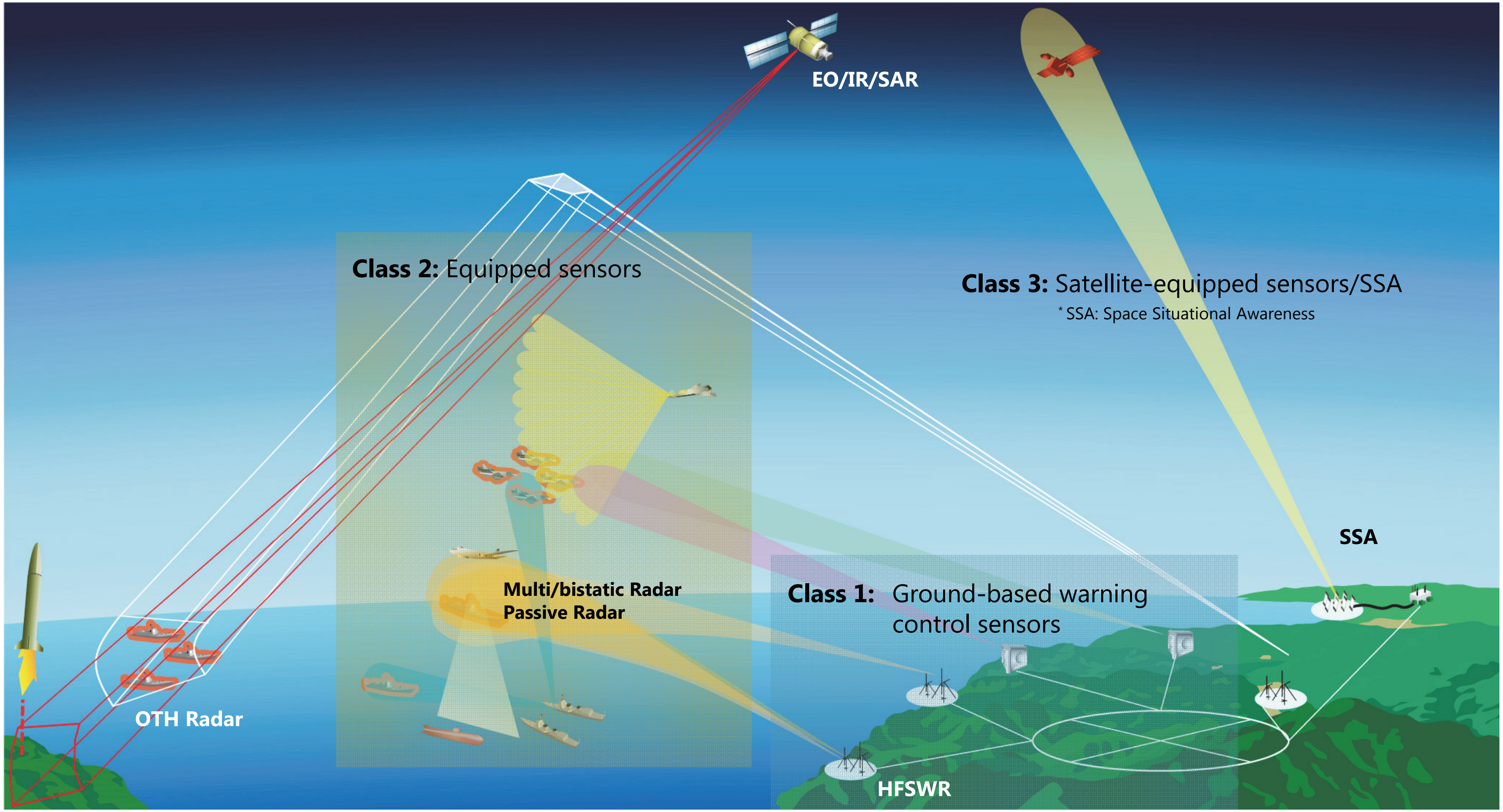
*1 SAR (Synthetic Aperture Radar)/ISAR (Inverse SAR): creates a virtually large antenna through movement to increase the high resolution. SAR uses the movement on the sensor side while ISAR uses the movement on the target side.

*2 Technologies related to a massive, kilometer-sized power transmission antenna installed in orbit and used in the Space Solar Power System (SSPS).

*3 Multistatic radar: uses one or more transmitters and receivers in different locations.

Scope of the R&D Vision for Persistent ISR Including Space

Classifications of Persistent ISR Functions (Radio Waves and Light Waves)

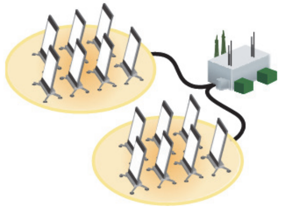


Classification	Description
Class 1 (Ground-based warning control sensors)	Ground-based equipment which possesses functions for continuous monitoring of territorial air space and waters
Class 2 (Equipped sensors)	Equipment mounted on unmanned aircraft and other aircraft, ships, vehicles, and other platforms which possesses functions to search for targets on the installed platform
Class 3 (Satellite-equipped sensors/SSA)	Satellite-equipped sensors, space monitoring sensors, and other space-related equipment

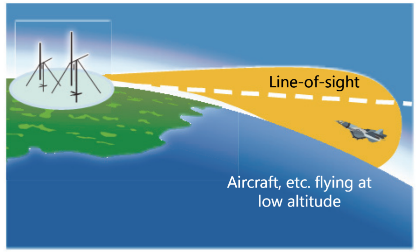
Technological advances in persistent ISR functions (radio waves)

- The Acquisition, Technology & Logistics Agency is implementing multiple radar systems operated from various platforms including ground-based radar as well as systems mounted on aircraft, ships, and vehicles to act as ISR radar systems. In recent years, research into warning control radar systems which introduced MIMO* technology was completed (transitioned to development in FY 2018)
- In addition, short wave band surface wave radar is being researched as a new system for conducting non-line-of-sight, continuous ISR from the ground
- The NATIONAL DEFENSE PROGRAM GUIDELINES for FY 2018 and Beyond describe the "building of a structure for the continuous monitoring of space-based conditions from the ground and space," and it is expected that the Acquisition, Technology & Logistics Agency's knowledge concerning warning control radar related technologies will be put to effective use
- In the private sector, research and development is advancing in the semi-conductor and signal processing technologies which are the foundation of radar systems. Japan's semi-conductor related technologies in particular are highly superior when compared to foreign countries

MIMO*: Multi-Input Multi-Output



Warning control radar



Over-the-horizon radar
(Short wave band surface wave radar)

Direction of future development

- Continuous ISR capabilities across a vast region which includes space in addition to Japan's territory, waters, and air space must be improved
- Among the improvements to wide area ISR capabilities, continuous over-the-horizon ISR capabilities which are newly required by conventional assets and long distance satellites and other identification capabilities must be acquired
- In the area of mobile platforms, since it is presumed that the opportunities for radio wave emission are limited from the perspective of low-observability, the capability to instantaneously search across a wide region must be acquired, and the shift to bi/multistatic technologies is necessary
- Devise ways to proactively utilize civilian technologies for semi-conductors and other fundamental technologies which are superior to foreign countries
- Verify the suitability and if necessary find ways to utilize artificial intelligence and other revolutionary technologies to identify targets detected via radar with high precision and speed.

Advanced technologies which are key to achieving wide area ISR (radio waves)

- In order to realize continuous ISR, short wave band transceiving technologies, surface wave radar signal processing technologies, surface wave radar target integration technologies, and ionospheric sounding estimation technologies are required to ensure continuous ISR capabilities via over-the-horizon radar.
- In order to realize wide area ISR, improvements in reception sensitivity through thermal noise reduction, additional power-saving as well as discrimination technologies through high resolution in a limited bandwidth, and consideration of the use of artificial intelligence, etc. are required to acquire ultra long range target searching and high-precision, high-speed identification capabilities
- In mobile platforms, element DBF* for instantaneous searching across a wide region and wideband support as well as bi/multistatic technologies which use those technologies are required

* DBF: Digital Beam Forming

Requires the most advanced and long-term technology development to achieve persistent ISR
Strategically acquire the advanced technologies to ensure Japan's technological dominance by systematically promoting the research and development of over-the-horizon radar, space surveillance and other ultra long range sensors, and Element DBF

Direction of R&D Initiatives (Radio Waves)

Operational environment construction perspective

- Regarding the ground-based warning control network, a development prototype which applies past research results is also planned, and steady functional enhancements are being devised. However, regarding the realization of continuous, over-the-horizon ISR, there are remaining issues which should be resolved to reach the practical application stage.
- While sensors for platform-mounting use are required for instantaneous wide area searching in an environment with limited radio wave usage due to stealth, the technologies for realizing passive operation (including bi/multistatic search) which does not emit its own radio waves is not at the practical application stage. In addition, anti-jamming characteristics must be improved to ensure efficient search capabilities.
- Regarding the realization of ultra long range, continuous surveillance functions for space, high-precision and high-speed identification technologies must be established through imaging radar to improve identification capabilities in addition to research and development to ensure long range target detection capabilities. In addition to such research and development, continuous research must be carried out to improve capabilities for equipping functions in space. Furthermore, cooperation with relevant foreign and domestic institutions must be proactively promoted and research and development must be efficiently carried out when it comes to realizing these initiatives.

Efficient technology establishment perspective

Class 1 Ground-based warning control sensors: at the current stage, the transition to development of MIMO radar and other research results is being prioritized. Introducing power-saving and other general requirements for electronic devices as needed based on the results of private sector technologies is an efficient approach. There are overseas examples of the practical application of over-the-horizon radar, but short wave band radar technologies for targeting over-the-horizon aircraft and ships have not yet been established in Japan at the current time, and research and development based on the environment and conditions in Japan is required

Class 2 (Equipped sensors): instantaneous wide area search in a future environments with limited radio wave use and other component technologies required in the future must be researched

Class 3 (Satellite-equipped sensors/SSA): there are overseas examples of practical application, but ultra long range target detection including space and high-precision identification technologies have not yet been established in Japan at the current time, and research and development based on the environment and conditions in Japan is required

Of the wide area ISR technologies (radio waves) which belong to Classes 1, 2, and 3, it is appropriate to prioritize the assignment of resources to the necessary research and development

Apply and utilize the acquired technologies as needed to other applications

Technological Issues Which Should be Addressed (Radio Waves)

Red: technologies which must be researched and developed primarily by the Ministry of Defense
Gray: technologies acquired through joint research with other institutions
Blue: technologies which can utilize the results of other equipment
Light blue: technologies awaiting progress in the civilian sector

Class	Important component technologies		Technology overview	Technological issues	Expected results
Class 1	Over-the-horizon radar	Short wave band transceiving technologies	Modulation and antenna technologies suited to surface wave radar using a short wave band	Short wave band transceiving technologies	Early detection of ships, aircraft, etc. in over-the-horizon waters
		Surface wave radar signal processing technologies	Technologies for suppressing Bragg scattering and other types of clutter specific to surface wave radars」	Surface wave radar signal processing technologies	
		Surface wave radar target integration technologies	Data integration technologies for target detection information from short wave band radar (including bistatic radar)	Short wave band radar target integration technologies	
		Ionospheric sounding estimation technologies	Technologies for monitoring the ionospheric conditions required for transmission control of ionospheric reflection radar	Ionospheric sounding estimation technologies	
Class 2	Advanced multistatic radar	Element DBF technologies	Technologies which digitize the received signal for all antenna components to enable instantaneous wide area search through beam forming technologies based on signal processing. Any wide area beam forming contributes to passive operation and anti-jamming improvements in bi/multistatic radar, etc.	Element DBF technologies which can realize instantaneous wide area search	Instantaneous detection of reflected radar waves from the target across a wide area and wide band Improvements in anti-jamming characteristics due to the realization of bi/multistatic radar, etc.
		Dual-band wideband technologies	Antenna technologies which support a wide frequency band ranging from the L or S-band to the X-band, etc.	Dual-band wideband technologies which can support a wide frequency band	
Class 3	Ultra long range sensors	Band supplementation technologies	Technologies which supplement a limited radio wave band and create an artificially wide band to improve the resolution in order to identify a detected target	Technologies which can achieve a high resolution in an actual environment using a limited frequency band	Accurate, ultra long range detection and tracking of high-speed targets
		Receiver thermal noise reduction technologies	Low noise technologies through receiver cooling	Receiver low noise technologies	
		Power-saving technologies	Power-saving technologies through high efficiency transmission amplifiers	Power-saving technologies	
		Information supplementation technologies through composite sensors	Technologies which use multiple sensors to supplement the information on both sides and improve detection capabilities	Information supplementation technologies through composite sensors which improve target detection capabilities in an actual environment	
	Imaging radar radar technologies	SAR/ISAR high resolution image technologies	Technologies which create high resolution SAR/ISAR images through the adoption of new signal processing methods to improve identification performance	Extended array technologies	High-precision and high-speed target identification using imaging radar
		SAR automatic image identification technologies	Technologies which perform a conversion suitable to learning and identify targets amidst restrictions on the amount of images gathered and the observation azimuth, etc.	Technologies which identify radar images when data is scarce or the view of the target changes significantly due to the target azimuth	
		ISAR automatic image identification technologies	Identification technologies which automatically extract the best shot according to an identification algorithm based on synchronous processing and integration processing	Identification technologies which extract the best shot from radar image video	

Advanced Technologies Required for Persistent ISR (Light Waves)

Technological advances in persistent ISR (light waves)

- On a global level, both visible and infrared sensors are trending toward high-sensitivity and multi-pixels (pixel size reduction), but there are limits to pixel size reduction with long wavelength infrared due to the diffraction limit. In addition, SWaP-C* reductions through high-temperature operation are also popular, and sensor devices including read circuits are becoming more intelligent

*SWaP-C: Size, Weight, and Power-Cost

- In contrast to defense applications, civilian applications primarily focus on short-range sensing
- Japan maintains globally high standards in the following fields
  - Semi-conductor manufacturing technologies (design, crystal growth technologies)
  - Micro-fabrication technologies (meta-material technologies)
  - Optical technologies (wave optics, precision machining)

IRST*

*IRST: Infrared Search and Tracking

Personal infrared night vision equipment

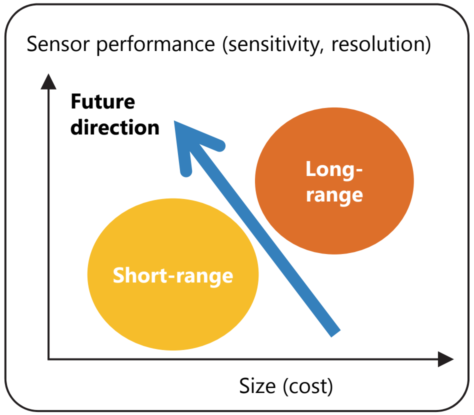
Direction of future development

- With advances in miniaturization, weight reduction, and cost reduction, the monitoring area will be expanded due to an increase in the number of sensors as well as developments in sensor networking, mounting on unmanned platforms, and applications to personal equipment
- Long-range and short-range visibility improvements which take into account all-weather environmental resistance can be expected in wide area ISR functions as a result of optical and quantum technologies, etc.
- There have been significant technological advances overseas, and Japan's sensor device development technologies must respond by taking such advances into account
- Sensor technologies required for IoT, self-driving, etc. have made rapid progress in the consumer field, and civilian technologies must be proactively applied to defense applications going forward to prevent equipment obsolescence

Technological advances in persistent ISR (light waves)

- High sensitivity, low cost, miniaturization and weight reduction
  [New principles, materials, and structures (mechanisms)]
  - Detector elements (graphene, etc.)
  - Optical (lensless, etc.)
  - Detection methods (quantum EPR*1, etc.)

  [Development of existing technologies]
  - Detector elements (T2SL*2)
  - Optical (DOE*3, GRIN*4, etc.)
  - Detection methods (LIDAR, super-resolution technologies, multiband technologies)



*1 EPR: Einstein-Podolsky-Rosen
*2 T2SL: Type II Super Lattice
*3 DOE: Diffractive Optical Element,
*4 GRIN: Gradient Index Lens

Strategically acquire advanced technologies to ensure Japan's technological dominance by first of all systematically promoting the research and development of the wide area ISR functions which require the most advanced and long-term technology development

Operational environment construction perspective

- In some cases, light wave sensors have an inferior detection distance compared to radio wave sensors. However, due to their vastly superior low power consumption, covert characteristics (during passive use), and high resolution, it would be desirable to apply such features to equipment (including unmanned aircraft). Therefore, sensors must become more highly sensitive, miniature and lightweight, and low cost, which will require the proactive absorption of civilian technologies and the modification and optimization for defense applications.
- Revolutionary light wave propagation technologies which can counter the effects of atmospheric attenuation are required. Moreover, in order for a country such as Japan with no actual combat experience to develop highly practical sensors, data must be accumulated through the use of simulation and close field testing with users. In particular, it is believed that initiatives are required to examine the effects of changes in propagation characteristics according to weather and environmental conditions (including underwater) within the wavelength band of each atmospheric window from visible to infrared rays and how such effects can be overcome.
- The role of light wave sensors, which are not affected by radio wave jamming, within the EM domain is extremely large. On the one hand, even if light wave sensors are jammed, it can be avoided through multispectral and other detection methods, so these technologies need to be improved going forward.
- Regarding the realization of ultra long range, continuous surveillance functions for space, high-precision and high-speed identification technologies must be established in addition to research and development to improve long range target detection capabilities. In addition to such research and development, continuous research and study must be carried out to improve capabilities for equipping functions in space. Furthermore, cooperation with relevant foreign and domestic institutions must be proactively promoted and research and development must be efficiently carried out when it comes to realizing these initiatives.

Efficient technology establishment perspective

Class 1 (Ground-based warning control sensors): revolutionary light wave propagation technologies which can counter the effects of atmospheric attenuation are required

Class 2 (Equipped sensors): research into low SWaP-C solutions, multiwavelength, multi-pixels, high sensitivity, active sensing, and other technologies is needed according to the operational situations required in the future

Class 3 (Satellite-equipped sensors/SSA): there are overseas practical application examples, but ultra long range target detection including space and high-precision identification technologies have not yet been established in Japan at the current time, and research and development based on the environment and conditions in Japan is required

Because there are multiple technologies in common to the research and development of the wide area ISR functions (light wave) belonging to Classes 1, 2, and 3, it is appropriate to prioritize the assignment of resources to the technologies belonging to Classes 2 and 3

Apply and utilize the acquired technologies to all sensors including those in Class 1

Passive (1/2)

Red: technologies which researched and developed primarily by the Ministry of Defense
Blue: technologies which can utilize the results of other equipment
Gray: technologies acquired through joint research with other institutions
Light blue: technologies awaiting progress in the civilian sector

Class	Item	Important component technologies		Technology overview	Technological issues	Expected results
Class 2	Advanced detection technologies	Detector element technologies	High sensitivity SW infrared detector element (type-2 superlattice model) technologies	Able to achieve SW detector elements capable of high sensitivity and high temperature operation.	Element structures for achieving high-sensitivity Element structures for achieving low noise	Instantaneous detection of targets within the field of view
			Advanced optical detector element (graphene) technologies which are high-sensitivity, wideband, low-cost, and uncooled	Uncooled optical detector elements with high sensitivity and a low cost which may be able to cover the visible to LW range	Detector element high-sensitivity and array configurations	
			High sensitivity LW infrared detector element (type-2 superlattice model) technologies	Able to achieve LW detector elements capable of high sensitivity.	Element structures for achieving high-sensitivity Element structures for achieving low noise	Improvements in target detection and identification capabilities
			Multiband infrared detector element (type-2 superlattice model) technologies	Able to achieve dual wavelength/single element MW/LW detector elements with high sensitivity and effective anti-jamming characteristics	Element structures for achieving high-sensitivity Element structures for achieving low noise	
		Optical technologies	Wideband, high transmittance optical technologies	Able to achieve optical systems through optical materials which cover the visible to LW range with a high transmittance.	Lensification of candidate materials (large aperture), high transmittance (absorption wavelength optimization)	Achieve high resolution images through an expansion of the detectable wavelength range
			Miniature and light weight optical technologies	Able to achieve optical systems that are applicable to personal equipment.	Miniaturization and weight reduction, adoption of DOE, GRIN and other optical elements, cost reduction	Eyewear and other miniature personal equipment
			Miniature display technologies	Able to achieve displays that are applicable to personal equipment.	Miniature displays for defense use that do not feel uncomfortable from the user's perspective, low cost, low power consumption, multi-pixel support	
		Detection method technologies	Multiband processing technologies	Processing (opto-thermal sensor) which utilizes multiband detection features that also has effective anti-jamming characteristics	Image fusion processing	Detection and identification improvements in poor environments
			Active sensing technologies	Able to use light sources and operate in a manner suitable to missions.	Development of extended near-infrared light sources	
			Quantum sensing technologies	Able to achieve active sensing (imaging) which resists environmental effects.	Development of quantum EPR and other light sources, signal processing technologies, verification in an actual environment, long-range	
		Mountability improvement technologies	Miniature, lightweight, low power consumption technologies	Miniature, lightweight, low power consumption technologies mountable on unmanned and personal equipment	Issues with detector element technologies and optical system technologies Miniaturization of coolers for cooled sensors	Further miniaturization of personal infrared night vision equipment
			General-purpose (common modules) technologies	Able to easily replace and update sensors at low cost.	Module units, targets	Improved sensor maintainability, LCC reduction

SW: ShortWave
LW: LongWave
GRIN: GRaded-INdex
MW: MicroWave
DOE: Diffractive Optical Element
EPR: Einstein-Podolsky-Rosen

Leading Technological Issues Which Should be Addressed (Light Waves) (2/2)

Passive (2/2)

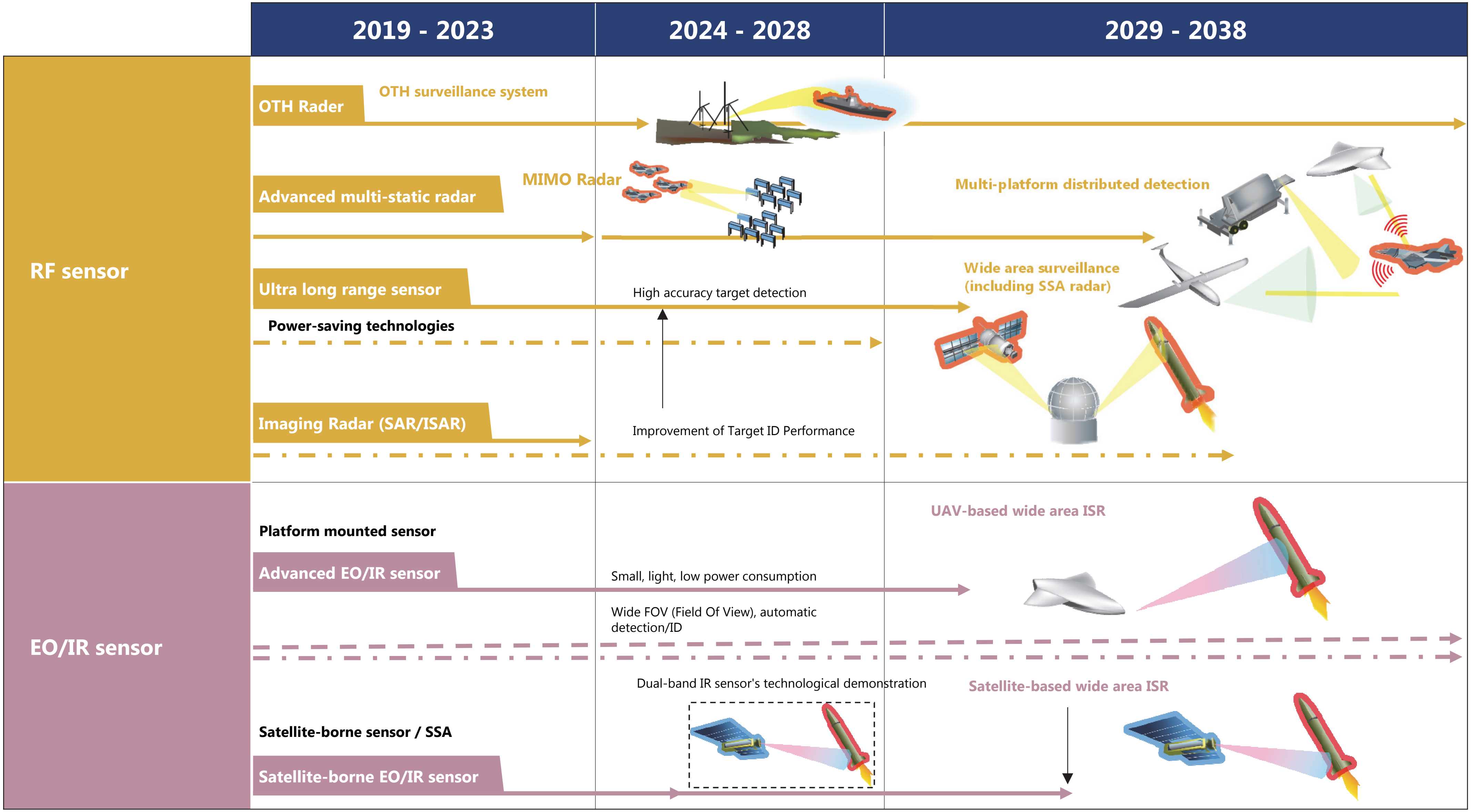
Red: technologies which researched and developed primarily by the Ministry of Defense
Gray: technologies acquired through joint research with other institutions
Blue: technologies which can utilize the results of other equipment
Light blue: technologies awaiting progress in the civilian sector

Class	Item	Important component technologies		Technology overview	Technological issues	Expected results
Class 3	Satellite-equipped light wave sensor technologies	Detector element technologies	High sensitivity LW infrared detector element (type-2 superlattice model) technologies	Able to achieve LW detector elements capable of high sensitivity.	Element structures for achieving high-sensitivity Element structures for achieving low noise	Improvements in target detection and identification capabilities
			Multiband infrared detector element (type-2 superlattice model) technologies	Able to achieve dual wavelength/single element MW/LW detector elements with high sensitivity and effective anti-jamming characteristics	Element structures for achieving high-sensitivity Element structures for achieving low noise	
		Optical technologies	Wideband, high transmittance optical technologies	Able to achieve optical systems through optical materials which cover the MW to LW range with a high transmittance.	Lensification of candidate materials (large aperture), high transmittance (absorption wavelength optimization)	• Achieve high resolution images through an expansion of the detectable wavelength range • Field-of-view expansion
			Wide-field optical technologies	Able to achieve optical systems with a wider field of view than conventional dioptrics.	Technologies for inserting optical systems inside the detector dewar to ensure a wide field of view Adoption of DOE, GRIN, and other optical elements Wide-field optical design	
			Anti-environmental optical window material technologies	Able to achieve optical windows with a high environmental resistance and support for dual wavelengths.	Further improvement of the MW transmittance is an issue	
		Detection method technologies	Multiband processing technologies	Processing which utilizes features based on multiband detection (able to remove sunlight clutter and improve anti-jamming capabilities).	Improvements in target identification performance	• Target discrimination • Launch site identification
		Mountability improvement technologies	Miniature, lightweight, low power consumption technologies	Miniature, lightweight, low power consumption technologies mountable on unmanned equipment, etc.	Issues with detector element technologies and optical system technologies Miniaturization of coolers for cooled sensors	Improved sensor maintainability, LCC reduction ISR on medium-sized unmanned aircraft
			General-purpose (common modules) technologies	Able to easily replace and update sensors at low cost.	Module units, targets	

Active

Class	Item	Important component technologies		Technology overview	Technological issues	Expected results
Class 2	Advanced detection technologies	Miniature high-power output laser technologies	Miniature high-power output visible laser technologies	Able to achieve miniaturization and high-power output for visible lasers.	Miniaturization (miniature cooling equipment, etc.)	• Underwater monitoring of aircraft including unmanned aircraft • Increased detection distance
			Miniature high-power output technologies for near-infrared lasers	Able to achieve miniaturization and high-power output for near-infrared lasers.	High-power output, low power consumption Miniaturization (miniature cooling equipment, etc.)	
		Dual wavelength processing technologies for visible and near-infrared lasers	False alarm reduction technologies	Able to reduce false alarms from the ocean surface and from underwater.	Dual wavelength processing (differential processing, etc.)	• Accurate identification of detected underwater targets
			Wave surface and flow speed measurement technologies	Able to assess the wave surface and flow speed conditions using Doppler LIDAR technologies.	Wave surface and underwater light propagation characteristics (reflection, diffusion, transmission, absorption)	
			LIDAR imaging technologies	Able to possess target identification functions through imaging.	Ensuring the necessary resolution	

Research and Development Roadmap



Primarily acquire through research and development

Acquire through joint research

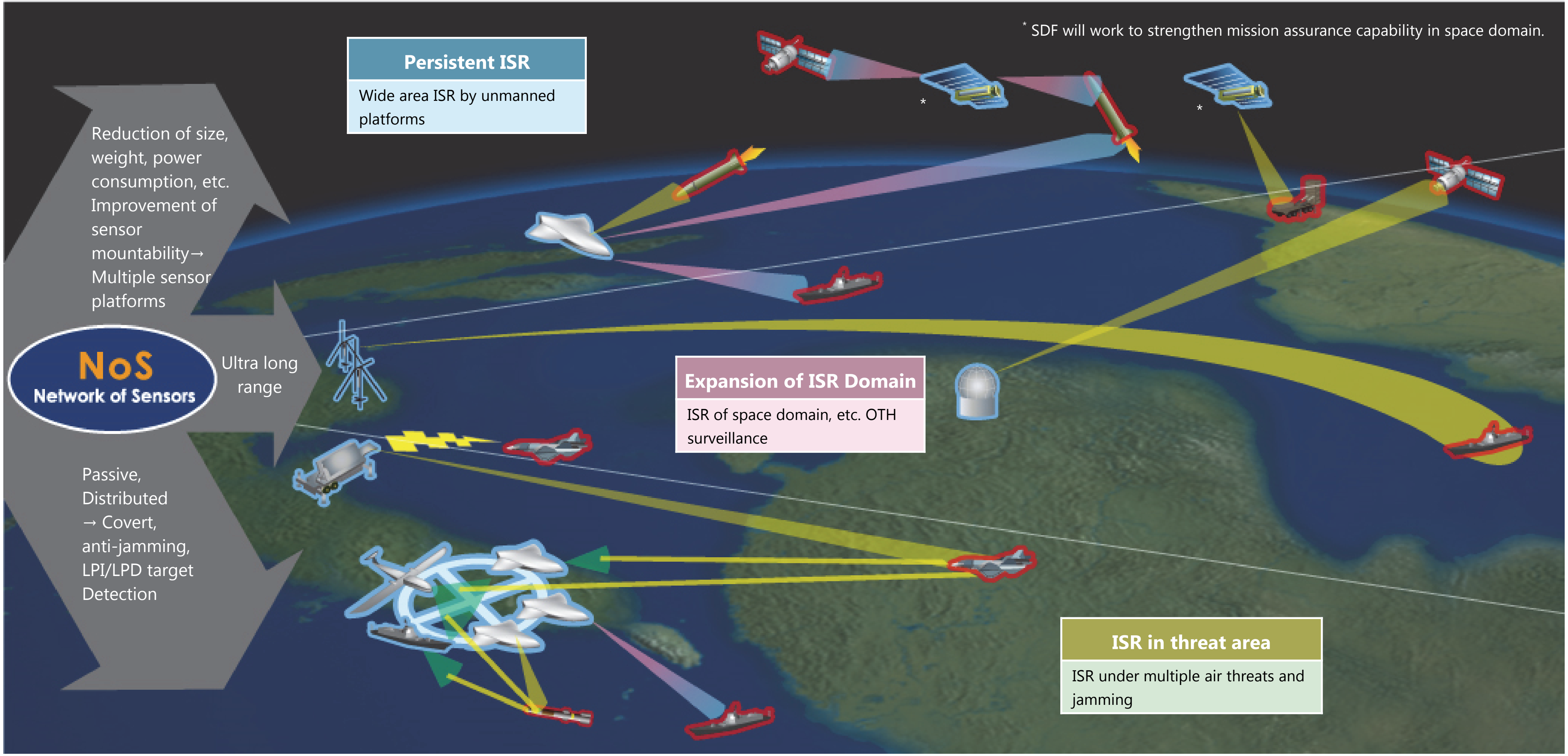
Acquire through new civilian technologies

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 research and development approach, we will strive for early technology acquisition.

Realization of effective persistent ISR for various targets across wide areas and multiple domains by utilizing combinations of multiple platforms including UAVs and satellites



Reference

Previous Ministry of Defense Initiatives and Foreign and Domestic Trends

Primary method of advancing research and development

- Because the elements, devices, signal processing and other technologies relating to radio wave and light wave sensors are rapidly advancing, the concepts and road map indicated in this R&D vision shall be revised as necessary according to technological progress, etc. It is expected that the latest research and development in strategically important technology fields will lead to the cultivation and strengthening of Japan's technology foundation as well as the invention of superior equipment.
- In order to achieve efficient and effective persistent ISR, sensor technologies must be acquired in conjunction with the promotion of technologies for configuring sensor-equipped platforms as well as command and control communication technologies for integrating, sharing, and accumulating the obtained sensor information along with an examination of search methods using sensors and other operational items. Therefore, research and development into sensor technologies shall be implemented in concert with the progress of research in related technology fields and operational examinations.
- 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.

Close observation of trends in governments and foreign countries concerning space

- Because there are no provisions concerning prohibitions on the destruction of space objects or the avoidance of actions which may lead to space debris within the "Space Treaty" and other existing frameworks regulating space exploration and use, in recent years international initiatives have been advanced to formulate a code of conduct for space activities and guidelines for the "long-term sustainability of space activities." However, a final agreement has not been reached due to political opposition and different opinions about how to adopt the guidelines. Such international initiatives must be closely observed when implementing persistent ISR in space. In addition, regarding maritime monitoring using artificial satellites (MDA: Maritime Domain Awareness), we will be involved in an examination by the entire government and contribute to MDA capability enhancement and policy promotion.
- The United States Army has created technical standards based on open architecture and modularization approaches for electronic devices that use EM waves such as radar and other sensors, communication devices, and electronic warfare devices for electronic jamming to advance device standardization and multi-functionality, simplify connections between equipment from different companies, and shorten the development cycle. Japan must also closely observe the trends in electronic device standardization in foreign countries and consider ways to resolve the conflict between the requirement to rapidly add equipment functions and improve capabilities with the requirement to restrain equipment acquisition costs.

Class 1 (Ground-based warning control sensors)

- Short wave band ocean surface clutter suppression technologies and other technologies required to establish radar systems are being researched within the "short wave band surface wave radar research" underway since FY 2014.

- A "next-generation warning control radar component research prototype" was implemented between FY 2011 to FY 2015. The fundamental principles of MIMO radar were verified, and based on the results, development of next-generation warning control radar equipment began in FY 2018.

Next warning control radar equipment

Class 2 (Equipped sensors)

- The Ground, Sea, and Air SDF branches operate various types of aerial (ground monitoring, ocean, and antisubmarine search), maritime (air and ocean), and vehicle-based (air, battlefield monitoring, counter-battery) search radars which apply the results of various research and development.

Hyuga escort vessel equipped with the FCS-3

Class 3 (Satellite-equipped sensors/SSA)

- The distributed radar technologies established in the "next-generation warning control radar component research prototype" (reprint) have also been applied to the JASDF SSA sensor system.

✓ Research prototypes are being implemented for Class 1
✓ Class 2 initiatives have been developed or equipped
✓ Research prototypes have been completed and development is starting for Class 3

Class 1 (Ground-based warning control sensors)

- In the civilian sector, such sensors have been applied as a radar-based tsunami monitoring support technology, but to a large extent the goal is to acquire surface wave radar technologies for aircraft and ship targets in five years.
- The U.S. is already operating OTH radar (Over The Horizon) as well as promoting further high resolution advancements. However, because it requires a large-scale area to install compared to typical ground radar, it is limited to partial operation.

Class 2 (Equipped sensors)

- In addition to researching the integration of weapons, etc. with countermeasure technologies for stealth aircraft and ballistic missiles, further miniaturization and cost reductions across the entire system are being devised through integration with anti-air/maritime/electronic warfare radars on the ocean.
- Within Japan, it is expected that the technological issues required for Element DBF technologies, which are expected to improve perimeter combat and electronic warfare capabilities, will largely be resolved in 20 years.

Class 3 (Satellite-equipped sensors/SSA)

- The resolution of images acquired from satellites is improving within Japan and foreign countries. In addition, with the adoption of miniature satellites, detector elements are being developed which provide miniature, lightweight, and low power consumption features.
- Ground-based space ISR aims to obtain high resolution images targeting up to geostationary orbits, the research into the next-generation elements needed to research the required high-power and high-efficiency modules is advancing, and the technological issues are expected to be largely resolved in 10 years.

Previous Research Results at the Ministry of Defense (Light Waves)

Class 1 (Ground-based warning control sensors)

Class 2 (Equipped sensors)

- Regarding passive sensors, short-range/medium-range/shooting and other low light night vision and infrared equipment has been developed and equipped.

- In addition, research and development has continued into multi-pixels, high sensitivity, and high temperature operation sensor devices as a long-distance infrared imaging apparatus, and the fighter aircraft-mounted IRST system* is being developed.

*IRST: Infrared Search and Track

- Portable range finders, the Type 90 tank range finder, and other laser distance measuring equipment have been equipped to active sensors. In addition, "eye-safe laser radar research" was jointly carried out by Japan and the U.S. from FY 1996 to FY 2001, which obtained technical data regarding multifunctional (distance measurement, target shaping, distance imaging, obstacle warning and avoidance, etc.) laser radar.

Eye-safe laser radar research

Class 3 (Satellite-equipped sensors/SSA)

- From FY 2000 to FY 2010, a research prototype and interior testing was carried out for future light wave sensor system component technologies, and technical knowledge was gained with respect to high resolution sensor technologies, miniaturization and weight reduction technologies, image signal processing technologies, and high-precision orientation technologies required for light wave sensor systems which perform long-distance missile searching and automatic detection and tracking.

- Research into "satellite-mounted dual wavelength infrared sensors" started in FY 2015 to accumulate technical knowledge concerning the usability of infrared sensors in space

AIRBOSS: Advanced Infrared Ballistic-missile Observation Sensor System

✓ Class 1 and 3 initiatives have been developed or partially equipped

Class 1 (Ground-based warning control sensors)

Class 2 (Equipped sensors)

- Regarding short-range passive sensors, the U.S. is already fielding night vision equipment using third-generation night vision tubes while Japan, which finished the third-generation research in FY 2014, is dependent on imports from the U.S. for equipment and other components. In addition, the U.S. is continuing nighttime piloting goggle research to overcome image blurring due to the incidence of intense, spot-shaped light and is also advancing research into next-generation low light night vision technologies which will enable the wearer to directly see outside with the naked eye even if night vision is not possible due to a sudden burst of light. Within Japan, it is expected that the necessary technological issues will largely be resolved in 15 years.

- Regarding active sensors using low power laser light, they have been put to practical use within civilian technologies in Japan as equipment for measuring electrical wire separation while in Europe, obstacle warning systems using eye-safe lasers to warn helicopter pilots have already been developed and introduced. In addition to advancing high sensitivity, low cost, miniaturization, and weight reduction, research and development into using such sensors to detect obstacles from 3D image information obtained by spatially scanning high speed repetitive laser light and narrow-field/high angular resolution receiving optical systems to prevent collisions and crashes is expected to largely resolve the necessary technological issues in 20 years.

- Regarding active sensors which use high-power lasers, Doppler LIDAR technologies for measuring the wind velocity at airports, etc. are advancing, and the development of laser radar for analyzing aerosol components is underway. Because they require high-power light sources, the development of semi-conductor laser excitation solid lasers in particular as laser light sources is expected to largely resolve the necessary technological issues in 10 years from the perspectives of miniaturization, high efficiency, and high reliability.

Class 3 (Satellite-equipped sensors/SSA)

- With the adoption of miniature satellites, detector elements are being developed which provide miniature, lightweight, and low power consumption features.

- Satellite-mounted high resolution and high sensitivity detector elements are being developed, and it is expected that the necessary technological issues will largely be resolved in 15 years.

- Space ISR from the ground aims to acquire high resolution images up to geostationary orbits.