Report on

Electronic Navigation Research Institute (ENRI)

Research and Development Long-term Vision

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National Research and Development Agency
Electronic Navigation Research Institute
Research and Development Long-Term Vision
Study Committee

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1. Introduction

Electronic Navigation Research Institute (ENRI), a National Research and Development Agency in Japan, has been contributing through research and development in order to improve safety, advance sophistication, enhance efficiency and reduce the environmental impact of the air traffic system in Japan as the only national organization in Japan conducting research related to electronic navigation since it was founded in 1967. While ENRI was keeping track of the trends and issues of the air traffic service in the world, ENRI was convinced that the sophistication of air traffic management (ATM) would become the important research and development project to meet the social needs providing the high quality and the low cost of air transport service with improved safety. In order to accomplish those objectives, ENRI considered that its important missions are to achieve "the ATM core research organization" to promote the research and development of ATM and yield the high quality results related to ATM. It means that, it is to fulfill the responsibilities of ENRI, as the National Research and Development Agency, to understand the issues for the realization of ATM suitable for Japan, to conduct research to precisely meet the social demands, to develop new technology and give proposals to solve those issues, and to contribute to the improvement of people's lives and the development of science and technology. In order to achieve these objectives, it is important for ENRI to establish the basic policies and a long-term direction of its research, and share it by all its researchers, and make it understood by off-site officials, and acquire their cooperation for its implementation.

Therefore, ENRI published its long-term vision of research and development in July 2008[1], and revised it to meet the changes in the internal and external situations in March 2011[2]. Through these activities, the ENRI Research and Development (R&D) Long-term Vision has been reflected in the Collaborative Actions for Renovation of Air Traffic Systems (CARATS)[3] program by the Japan Civil Aviation Bureau (JCAB), an agency under the Ministry of Land, Infrastructure, Transport and Tourism(MLIT). Therefore, the Vision has influenced the future plans on Japan’s aviation technology being studied by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Japan Society for Aeronautical and Space Sciences (JSASS), the Japan Aerospace Exploration Agency (JAXA), and so[4,5,6]. Furthermore, ENRI prepared a research plan with its R&D Long-term Vision in mind, which unified the overall direction of researches of the institute.

However, after the last revision of the R&D Long-term Vision in 2011, it has been going through major changes in the field related to air traffic in Japan and the International Civil Aviation Organization (ICAO). Corresponding to the increase of the air traffic in the future in Japan, JCAB compiled "CARATS roadmap" in September 2010 to achieve the targets in 2025. They are to increase by five times the aviation safety, to double the air traffic control processing capacity, to improve by 10 % the flight service levels and to reduce by 10 % the fuel consumption and CO_2 emissions such as punctuality of flight schedules compared with the level of 2010. The activities of CARATS have contributed to the steady improvement of ATM performance in Japan[7], and the activities of ENRI have also greatly contributed to the CARATS activities.

In the activities of the aircraft manufacturing industry of Japan, Mitsubishi Aircraft Corporation is developing Mitsubishi Regional Jet (MRJ) that rolled-out in October 2014, is planning for its first flight to be in the second half of 2015 and will be type-certified in 2017. That movement by that Japanese aircraft manufacturing company is for them to become an aviation integrator of the aviation system industry including Customer Support, through its complete airplane manufacturing business in Japan for the first time in about 50 years of absence, following the Boeing Company in the United States and the Airbus Company in Europe[8]. The essential requirement of an aviation integrator is not only to manufacture aircraft but also to propose new flight technology and so on taking into account the desires of the customer airlines. Therefore the full understanding of the air traffic system including the necessary ATM system and the operation of aircraft is essential. In the future, if that Japanese aircraft manufacturing company becomes an aviation integrator, they may develop the Flight Management System (FMS), which is said to be the brain of an aircraft, and it is considered to be possible for the Japanese industry to develop the advanced ATM system integrating the airborne system and the ground system compatible with the new ATM concept.

The ICAO, aiming towards the common goal to realize the harmonized global air traffic system for international civil aviation, discussed the draft of the fourth edition of the Global Air Navigation Plan (GANP), which is the implementation and technology development plan by agreement among all stakeholders such as states, regions, airlines and the aviation industry, at the 12th Air Navigation Conference (ANC-12) in November 2012, approved it at the ICAO General Assembly in September 2013 and issued it in December 2013[9]. The GANP fourth edition contains the Aviation System Block Upgrades (ASBU)[11] which describes the necessary step-by-step specific guidelines of implementation to realize the Global Air Traffic Management Operational Concept (GATMOC)[10], which aims at safety and efficient global ATM systems with harmonization and interoperability among the respective states and regions.

Reducing the environmental impact, a big issue among modern humans, is also one of the important goals of the ICAO. So the ICAO General Assembly in 2010 determined Global CO2 reduction goals, which are "to improve fuel efficiency by 2 percent every year in the future" and "not to increase CO2 emissions after 2020"[12]. Therefore, each stakeholder is required to take technical steps, such as the introduction of new technologies to aircraft, improvement of operational procedures, and use of alternative fuels to achieve the goal. The activities by the

GANP and the CARATS will perform a major role in reducing the environmental impact by improving operational procedures.

Thus in such a large change in the environment surrounding the air traffic including ATM, ENRI started to review the ENRI R&D Long-term Vision revised in March 2011 and decided to establish the new Vision to be suitable with the new era.

2 Expected New Environment of Air Transportation in 2040

When reviewing the R&D long-term vision, we have described hereunder all possible changes in the air traffic environment that may have only small possibility to occur in about 25 years by 2040, to cover and extract all the technologies that must be taken into account to make the R&D plan for the next 15 years.

2.1 Changes in Air Traffic Demand

ICAO estimates that the world passenger air traffic demand measured in terms of Revenue Passenger Kilometers (RPKs) is expected to increase by about 2.5 times over the next 20 years[13]. In particular, the expected average annual growth rate over the next 20 years in Asia is expected to be 6.2 %, much higher than that of the entire world at 4.6%.

On the other hand, the domestic passenger air traffic in Japan is estimated to level off, because of the decrease of population social associated with aging and less babies, the concentration of population in the metropolitan cities, and the expansion of the network of high-speed railways such as the starting of the service of the maglev bullet train service between Tokyo and Nagoya in 2027[14]. However, we expect it to be almost status quo or slightly increase the number of domestic flights, because of the trend for flight frequency using small aircraft rather than conventional large aircraft to meet passenger demand and the expansion of the Low Cost Carrier (LCC) flight network. In addition, it is forecasted that the number of international flights and those flying-over flights will steadily grow, in accordance with the international air traffic demand due to the economic growth of Asian countries. The number of aircraft handled by the Japanese Air Traffic Control agency in 2033 is expected to increase by about 1.4 to 1.6 times that of in 2013, as shown in Figure-1[15], because of the expected new international flights between the regional cities in Japan and the cities in other Asian countries, and the increase of the inter-regional city flights and island-connecting flights, and the increase of the business jet flights because of the increase of wealthy people in Asia and the world. Judging from this material, the traffic volume in domestic airspace will exceed the capacity of air traffic control using the current air traffic control rules in the 2020s.

2.2 Changes in Aircraft Technology

The aircraft technology is also considered to progress steadily. Currently two pilots are required to operate passenger aircraft, but only one pilot may be able to operate passenger aircraft by the development of technology for system automation and labor-saving and the improvement of reliability of the aircraft system. Furthermore, an aircraft with no onboard pilots, or Remotely Piloted Aircraft (RPA) named so by ICAO, may be widely used mainly in the cargo transportation field in general airspace. As a result, the amount and frequencies of air–to-ground communication is considered to significantly increase for the purpose of detecting surrounding situations necessary in flights and monitoring of airframe and engines to detect their failures and malfunctions.

The use of aircraft with high maneuver abilities, such as vertical take-off and vertical landing aircraft, high-speed supersonic aircraft and electric airplanes with low speed capability may be promoted. It means that aircraft with very wide speed range may coexist in regular airspace. The variation of aircraft size from large to small also increases, and various aircraft will fly in the same airspace to meet the variety of demands on airplane operators. In addition, the advent of the further lower-noise planes will abate the noise problems when they fly above urban areas, and the advent of the green fuel airplanes will mitigate the environmental impact caused by aircraft operation.

On the operating side, following the dissemination of the aircraft capable of flying by the RNP

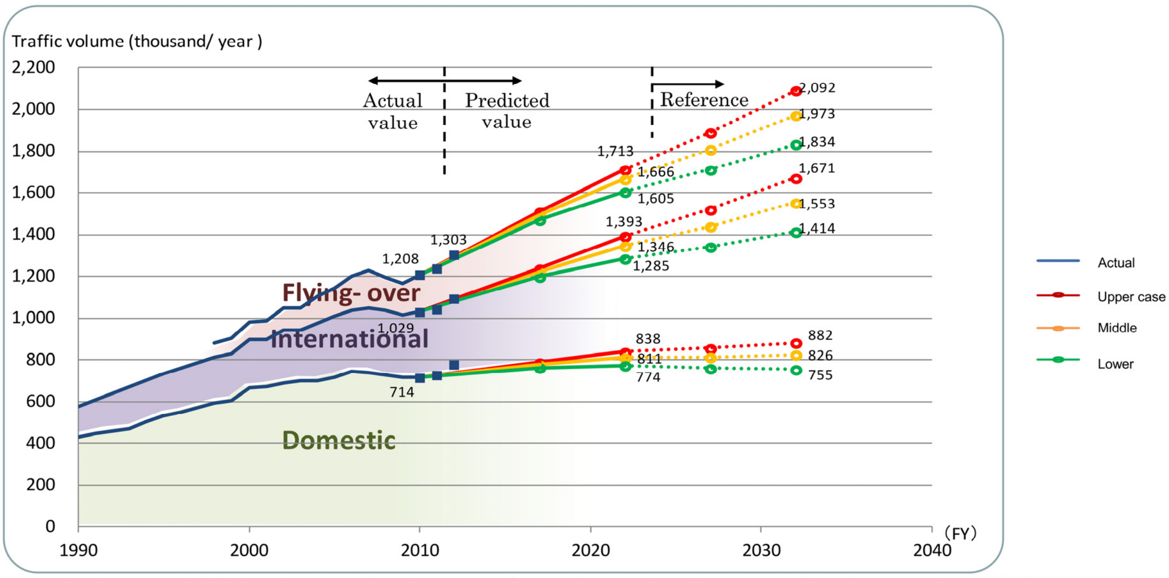

Figure-1: Demand Forecast of Air Traffic in Fukuoka (Japanese) Flight Information Region (FIR) from 1990 to 2035

(Refer to Material of 15th Basic Aviation Policy Committee, Transportation Policy Council)

(Required Navigation Performance) procedures equipped with Global Navigation Satellite System (GNSS) receivers and FMS, the aircraft will be able to fly by In-Trail Procedure (ITP) or FIM (Flight-deck Interval Management) procedure with the equipped with the Aircraft Surveillance Applications System (ASAS). In addition, aircraft will be able to fly more efficiently by the improvement of reliability and functionality of FMS. Furthermore, it may be possible to conduct automatic landing by FLS (FMS Landing System).

The progress of the intelligence of aircraft in accordance with the further evolution of aircraft avionics will enable aircraft to fly safe and optimum four-dimensional flight paths, including time schedule in high-density airspace by Trajectory Based Operation (TBO) procedure, and also will make operating the autonomously free-flights in low-density airspace with optimum trajectories. In addition, the flow corridor flights or formation flights may be adopted in high-density airspace in order to fly with high fuel efficiency for aircraft flying the same trajectory. Furthermore, fly-by-wireless, or Wireless Avionics Intra-Communications (WAIC), may be adopted in airborne equipment to make aircraft lighter.

2.3 Changes in Airport Facilities

Airport facilities will evolve to meet changing aircraft and high-density operations. For example, it is considered that the detection system of wake turbulence and wind shear in the approach path, and the fully automatic towing system that enables the taxiway running of the aircraft on the entire airport surface even in zero visibility will be developed and operated. Advanced surveillance techniques to monitor aircraft and vehicles and to detect foreign objects on airport surfaces will be developed, and airport management's automation and information system will improve. On the other hand, the management of regional airports will become more efficient by the improvement of monitoring, communication and control technology, in airport control in remote locations.

2.4 Changes in Air Traffic Management (ATM)

All aircraft except very small aircraft will come to be operated by the TBO in all phases including take-off and landing, which will make flights safer and more efficient, and the aircraft can fly planned trajectories very precisely. In TBO, aircraft can fly at almost best individual trajectories to optimize the flight time or fuel efficiency, although it may be different for each airline or aircraft model, without conflicts by adjusting, for example, the departure time in the flight planning stage. Furthermore, in order to operate by the flow corridors or formation flights using an autonomous separation utilizing the ASAS and air-to-air communication for fly-over-traffic and so on, it is conceivable that the ATM will change.

The ATM system has to meet the requirements to assign individual trajectories in order to increase the optimum and flexible operations of many types of aircraft, to reduce fuel consumption, and to avoid the wake turbulence and the decentralization of the flight noise and so on. As a result, the increase in airport and airspace capacity is expected through the introduction of the sophisticated ATM system corresponding to flexible flights, although complexity works of Air Traffic Controllers will increase. And the introduction of the sophisticated ATM system and the low-noise aircraft together will make it possible to fly above urban areas during approach and departure.

The trajectory planned before the flight will need not to be altered by reason of weather except in the case of extreme weather because of the improvement of weather forecasts. The improved monitoring technology of aircraft will decrease the changes of the trajectory due to the trouble or malfunction of the aircraft or engines. However, it is considered that the incidents such as change of the departure time caused by the delay of passengers or the like will still remain.

Ultimately the promotion of automation of the ATM system is expected to resolve many tasks of air traffic controllers, such as to avoid the near collision of aircraft by the automatic system. As a result, even if a lot of aircraft are flying at different flight trajectories, direct control of air traffic by the air traffic controllers will decrease. Moreover, even if one automatic system fails, the ATM system including humans will keep its robustness and resilience by using the backup system and so on.

2.5 Changes in Enabler Technology Supporting ATM (CNS-IM)

The technology called Enabler to support the aircraft operations, which are consisted of Communications, Navigation and Surveillance (CNS) and Information Management (IM), will also be expected to advance. In the area of navigation technology, Global Navigation Satellite System (GNSS) will be used as time and position reference in the operations in all phases of all aircraft, and the conventional navigation aid systems are moving to degenerate. Furthermore the combination system of the ground-based augmentation system (GBAS: Ground-Based Augmentation System) for GNSS and RNP-AR (Required Navigation Performance-Authorization Required), and GBAS TAP (Terminal Area Path) system allows aircraft to carry out curved precision approaches with a high degree of freedom. Regarding vertical navigation of aircraft operation, conventionally the barometric altitude is commonly used, but GNSS is expected to come to be used mostly at low altitude.

In the area of surveillance technology, Automatic Dependence Surveillance (ADS) functioning with the automatic transmission function of the location information detected by aircraft using navigation equipment will be commonly used. Especially the broadcasting type called

ADS-Broadcast (ADS-B) will become mainstream, and the current radar systems will be used as backup. In addition, the ASAS operated by the ADS-B-In function and trajectory prediction, which is calculated by using the intent information of aircraft included in the messages of the ADS-B and in the Downlink Aircraft Parameters (DAPs) of the SSR mode-S system, will make progress in more efficient and safe operations. Furthermore, it is considered that flexible and highly reliable avoidance by horizontal maneuvers will be realized by the improvement of Airborne Collision Avoidance System (ACAS).

In the area of communication technology, a large-capacity and high-speed communication technology will be evolved, and the aircraft pilots will be able to access necessary information for safe and efficient operations such as flight information and weather information through the System Wide Information Management (SWIM). Furthermore, the air-to-air communication system will also be equipped to directly exchange information between aircraft. As a result, the use of voice communications will be reduced, with the exception of emergencies, and the digital communications, such as Controller-Pilot Data Link Communications (CPDLC), will be mainly used in all flight phases. Along with the increasing importance of digital communication in ATM, the security technology will also be introduced in aviation radio communication, and will be strengthened and sophisticated. By the spread of SWIM, sophisticated security technology necessary to perform the information sharing among the stakeholders such as users, airlines, ATC service providers and the Meteorological Organization will be required, and a new industry that supplies good information of high usability and added value-based on the needs of passengers and so on will come to advance.

3. Outline of New ICAO Global Air Navigation Plan (GANP)

We have been watching the trends of ICAO GANP to understand the changes in the international ATM. The new ATM concept, GANP, was discussed in order to develop and implement the global harmonized seamless ATM system in the 21st century based on Future Air Navigation System (FANS) concept at ICAO's 11th Air Navigation Conference (ANC-11) in 2003. As a result, the Global ATM Operational Concept (GATMOC), aiming to realize the safe, economic, efficient, dynamic and integrated air traffic service for all parties and all flight phases by providing the necessary information and seamless service, was discussed and published as the document (ICAO DOC 9854) in 2005, that is based on the TBO and the adjustment of the air traffic demand quantity by Cooperative Decision Making (CDM). DOC9854 introduces that ATM consist of seven elements, which are Airspace Organization and Management (AOM), Conflict Management (CM), Demand/Capacity Balancing (DCB) of traffic, Airspace User Operations (AUO), Aerodrome Operations (AO), ATM Service Delivery (SD) management and traffic Synchronization (TS). And it also proposes six research and development areas, which are Data link communications, Satellite navigation and augmentation, Enhanced surveillance using aircraft-provided information, Controller decision-support tools, Cockpit and controller shared situational awareness and Human factors evaluations of new concepts of use for CNS/ATM technologies.

In response to the publication of DOC 9854, ENRI developed the first edition of the research and development long-term vision to realize TBO concept; which is the core concept of the GATMOC. The first edition of the R&D long-term vision describes that the management and operation of the aircraft in TBO concept is aiming at the realization of the "actual trajectory" of aircraft to be as close as possible to the "trajectory at which they should fly". This "trajectory at which they should fly" is desirable to match the "optimized trajectory which users expected" of the stakeholders, and it is also needed to have management and administration flexibility corresponding with dynamic trajectory depending on changing operational conditions such as weather.

ICAO published the third edition of the GANP which describes the necessary subjects in 2007, in order to achieve the proposed GATMOC. Its technical subjects were described, but the methods to realize it were not described in this GANP. Therefore, ICAO held the Global Air Navigation Industry Symposium (GANIS) in 2011 in order to promote the realization of GATMOC. At this meeting, the Aviation System Block Upgrades (ASBU) global framework was discussed and developed to aim at a harmonic and efficient ATM system, including a technology road map of CNS, IM and avionics technology fields devised as a 20 years plan of four blocks of five years. The ASBU global framework is intended to aim at the development and implementation of the new improved ATM in accordance with the needs of each country and each region and by harmonizing their technical levels, through a feasible timeline of implementation provided by ICAO. ASBU incorporates a long-term perspective matching with ICAO GANP documents. The core of the concept is linked to four specific and interrelated aviation Performance Improvement Areas (PIA), which are Airport operations, Globally interoperable systems and data, Optimum capacity and flexible flights, and Efficient flight paths, shown in Figure 2. ASBU, related to the four PIAs, describes the four operational concepts, which are Full Arrival Management/Departure Management/Surface Management (Full AMAN/DMAN/SMAN), Full Flight and Flow-Information for a Collaborative Environment (Full FF-ICE), Complexity Management and Full Trajectory Based Operation (Full TBO), and introduces 21 modules containing technologies and capabilities to realize the four operational concepts. It consists of four blocks and aims at efficiency improvement, regional aviation harmony, and capacity expansion. New GANP including ASBU was proposed at ANC-12 in

2012, and it was approved at the ICAO General Assembly in 2013 and published as the fourth edition of GANP. The aim of the fourth edition of GANP is to achieve improvement of all the world aviation safety together with the Global Aviation Safety Plan (GASP) [16] of ICAO, which is the same as the first priority goal of ICAO.

4. Direction of Technology Development

4.1 Technology Subject to Realize Development

The technology subjects which should be researched and developed in the field of ATM/CNS and IM are selected along with the expected changes in air traffic environment discussed in Chapter 2 and the changes described in the ICAO GANP in Chapter 3. However, the technology subjects related to weather are excluded, because they are outside the scope of ENRI. The technology subjects are divided into areas: Communications, Navigation, Surveillance, Information Management, Airports Facilities or ATM, and they are also classified according to the

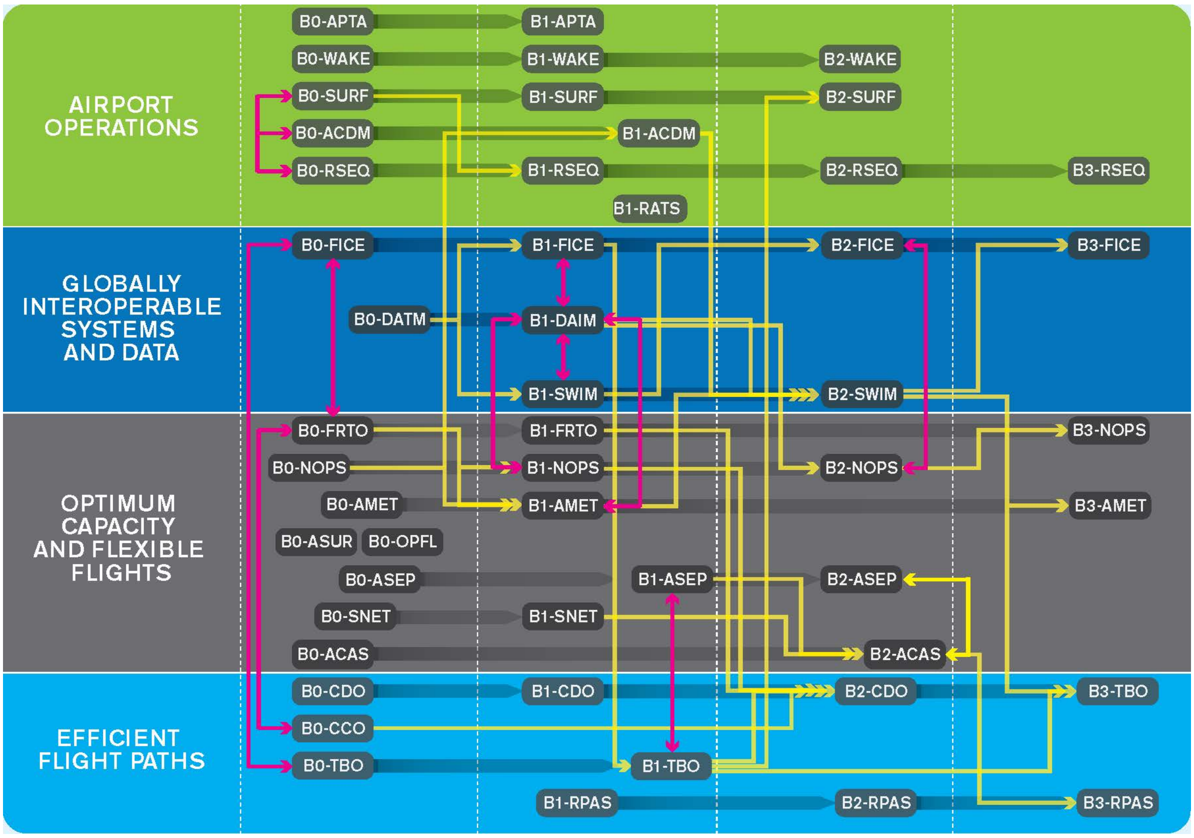

Figure-2: Module Dependencies in Performance Improvement Areas and Blocks

This figure depicts the various dependencies which exist between 21 Modules in Performance Improvement Areas (PIA) and Blocks. (Gray Arrows show Links from a Module in Block ‘n’ to a Module in Block ‘n+1’; Red Arrows show Dependencies across Threads/Performance Areas; Yellow Arrows show Links to other Threads/Performance Areas where a Module is dependent on an earlier Module or Modules.)

required period for research and development, as a short term being within 5 years, or a medium term being from 5 to 10 years, or a long term being more than 10 years. The results are shown in Table 1.

If considering the necessary time to realize a new system, not only the time for researching the element technology and developing the system, but also the time for implementing the ground facility and the airborne equipment must be considered. And what also must be considered is the time for developing the international standards and the related documents, and the time for developing necessary laws and institutions. Furthermore, the time of operation under the actual ATM environment to gain the required know-how in practical operation is also necessary. That is to say, when the necessary time to operate the new ATM system is estimated, the total time of the development and evaluation in the same environment as the actual operations at various stages must be considered.

4.2 R&D Roadmap

Considering the R&D roadmap of ENRI, the GANP includes not only the ASBU roadmap, but also 11 roadmaps of each technology area. However, its roadmap shows the timing and necessary types, but it isn't the R&D roadmap including the necessary time of the research and development. Therefore, the necessary roadmap of the R&D long-term vision of ENRI was revised based on the roadmap in the R&D long-term vision in 2011. ENRI is to achieve "Safety Improvement and Capacity Expansion of Air Transport" and "Flight Efficiency Enhancement to Reduce the Environmental Impact" by the research and development of ENRI for 15 years from 2016 to 2030 corresponding to the movement of ICAO and CARATS, and the expansion of Air traffic demand, and it includes four projects consisting of 14 research subjects and three fundamental research areas as shown in Figure 3.

Table 1: List of the Technology Subjects which should be Researched and Developed, and Corresponding Research and Development Items in the Long-Term Roadmap

Area	Term	Technology Subject	Corresponding Research and Development Items in the Long-Term Roadmap
Communication	Short	Expansion of the handled number of planes for CPDLC	Development of High Speed Communication System for Aviation
		Communication system to a plane, the vehicle on the airport surface	Development of High Speed Communication System for Aviation
	Medium	large-capacity communication system for airplane operation and weather information	Development of High Speed Communication System for Aviation, and Development of System Wide Information Management (SWIM) System
		Expansion of the communication capacity for airplane monitoring	Development of High Speed Communication System for Aviation
		Air-to-air communication system	Safety improvement and optimized separation with on-board information
		Security technology for ATC communication	Development of High Speed Communication System for Aviation, and Development of System Wide Information Management (SWIM) System
		Communication system for Remotely Piloted Aircraft Systems	Research on CNS/ATM of Remotely Piloted Aircraft Systems (RPAS)
	Long	Communication navigation integration system	Development of Advanced Integrated CNS system
		Wireless Avionics. Intra-Communications. (WAIC).	Spectrum Managements and Radio Interference Analysis
Navigation	Short	High angle approach using GBAS, Displaced Threshold, Curve precision approach from RNP-AR	Development of Curved Approach Procedures and Dynamic Optimal Trajectories in Terminal Airspace with GNSS
		Multi-core multi-frequency GNSS system	Development of Risk-Robust Resilient CNS/ATM System
		GNSS altimeter	Development of Curved Approach Procedures and Dynamic Optimal Trajectories in Terminal Airspace with GNSS
		Development of new standards and evaluation techniques for new navigation system	Evaluation on Safety and Performance of Air Traffic Management (ATM)
	Medium	GBAS-TAP approach	Development of Curved Approach Procedures and Dynamic Optimal Trajectories in Terminal Airspace with GNSS
		Alternate navigation system for robustness	Development of Risk-Robust Resilient CNS/ATM System
	Long	Communication navigation integration system	Development of Advanced Integrated CNS system, and Spectrum Management and Radio Interference Analysis
Surveillance	Short	Monitoring integrity of information of on-board surveillance	Improvement Surveillance Performance with Downlinked On-board Information
		ADS-B via Satellite	Improvement Surveillance Performance with Downlinked On-board Information
		Surveillance system for debris on airport surface	Enhancement of Surveillance Technologies on Airport Surface and in Surrounding Airspace
	Medium	Automatic separation control with ASAS	Improvement of Safety and Optimized Aircraft Separation with On-board Information
		Alternate surveillance system for robustness	Development of Risk-Robust Resilient CNS/ATM System

	Long	Next generation ACAS	Research on CNS/ATM of Remotely Piloted Aircraft Systems (RPAS), and Research on Ultra-high Density Air Traffic Operations
Information Management	Short	Information standardization for SWIM	Development of System Wide Information Management (SWIM) System
	Medium	Aircraft Access to SWIM (AAtS)	Development of System Wide Information Management (SWIM) System
		Assurance technology for SWIM	Development of System Wide Information Management (SWIM) System
Airport Facility	Short	Remote airport tower	Enhancement of Surveillance Technologies on Airport Surface and in Surrounding Airspace
	Medium	Automation of unmanned towing system of the Airport Surface	Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN))
ATM	Short	airborne-ground collaboration for Air traffic control system	Improvement of Safety and Optimized Aircraft Separation with On-board Information, and Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN))
		AMAN/DMAN collaboration	Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN)
		Improvement of point passing time prediction accuracy	Development of Trajectory Based Operation (TBO)
		Establishment of safety index of ATM	Evaluation of Safety and Performance of Air Traffic Management (ATM)
		Development of optimal induction ATM system, optimal route allocation system and aircraft guidance system	Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN)
		Efficient Airspace Control and Dynamic Trajectory Management	Research on Efficient Airspace Control and Dynamic Trajectory Management
	Medium	Collaboration of AMAN/DMAN/SMAN	Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN)
		Development of TBO in air-route	Development of Trajectory Based Operation (TBO)
	Long	Flow corridor operation control	Research on Ultra-high Density Air Traffic Operations
		Cooperation of TBO and DMAN/AMAN/SMAN	Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN)
		Development of Risk-Robust Resilient CNS/ATM System	Development of Risk-Robust Resilient CNS/ATM System
Avionics	Short	GBAS-TAP or curve approach by FLS can be realized in navigation control technology	Development of Curved Approach Procedures and Dynamic Optimal Trajectories in Terminal Airspace with GNSS
	Medium	Flight control technology for flow corridor operation	Research on Ultra-high Density Air Traffic Operation

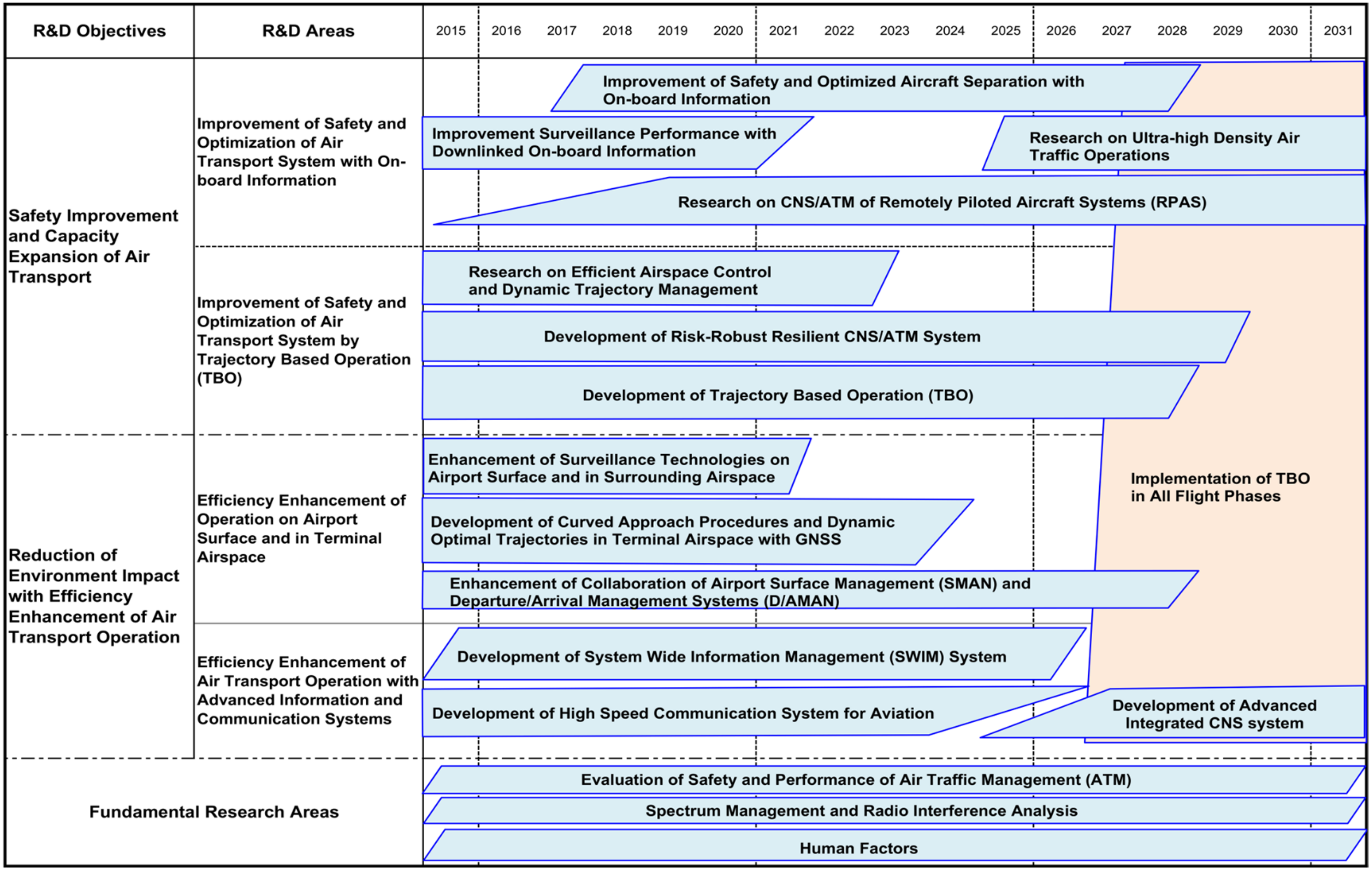

Figure-3 Research and Development Roadmap of ENRI R&D Long-term Vision

4.2.1 Technology for "Safety Improvement and Capacity Expansion of Air Transport"

(1) Improvement of Safety and Optimization of Air Transport System with On-board Information

(1.1) Improvement Surveillance Performance with Downlinked On-board Information (~ 2021)

The objective of this project is the improvement of the surveillance performance, such as the expansion of the surveillance area of SSR mode-S, and the enhancement of the monitoring techniques for the quality downlinked information from on-board equipment, in order to utilize the on-board information by the ATM ground facility and other aircraft.

(1.2) Improvement of Safety and Optimized Aircraft Separation with On-board Information (2017 ~ 2028)

The objective of this project is the improvement of the air traffic safety and the optimization of the aircraft separations by the collaboration of ground ATM system and Aircraft Surveillance Applications System (ASAS), and to develop Flight-deck Interval Management (FIM) that automatically keeps optimum aircraft separations.

(1.3) Research on CNS/ATM of Remotely Piloted Aircraft Systems (RPAS) (2015 ~)

The objective of this project is the development of the communication systems and the next-generation Airborne Collision Avoidance System (ACAS) corresponding to unmanned aircraft system defined as Remotely Piloted Aircraft Systems (RPAS) by ICAO, and the improvement of the ATM system corresponding to the airspace mixed with conventional aircraft and unmanned aircraft.

(1.4) Research on Ultra-high Density Air Traffic Operations (2025 ~)

The objective of this project is the development of CNS and IM systems possible to operate with the ultra-high density air traffic, such as the flow corridors operation and the formation flight, and the studying of the ATM system corresponding to such situations.

(2) Improvement of Safety and Optimization of Air Transport System by Trajectory Based Operation (TBO)

(2.1) Research on Efficiency Airspace Control and Dynamic Trajectory Management (~ 2022)

The objectives of this project are the development of the air traffic and space management techniques that realize the flight path desired by airline operators in order to increase enough capacity of air traffic, to improve the safety and to enhance the efficiency of air transportation.

(2.2) Development of Risk-Robust Resilient CNS/ATM System (~ 2029)

The objective of this project is the development of the CNS/IM/ATM system having enhanced robustness, high stability and high affinity ability to adapt to human judgment and behavior corresponding to the complex system operating in various conditions with changing weather and flight status.

(2.3) Development of Trajectory Based Operation (TBO) (~ 2028)

The objective of this project is the development of the techniques that realize TBO in various airspaces of the kind offshore airspace, also high-density airspace and complex airspace.

(2.4) Implementation of TBO in All Flight Phases (2027 ~)

The objective of this project is the implementation of TBO in all flight phases, integrated with the airport surface management systems and the departure and arrival management system, in order to realize the optimized air traffic system with gate-to-gate guidance and to improve air traffic safety.

4.2.2 Technology for "Flight Efficiency Enhancement to Reduce Environment Impact"

(1) Efficiency Enhancement of Operation on Airport Surface and in Terminal Airspace

(1.1) Enhancement of Surveillance Technologies on Airport Surface and in Surrounding Airspace (~ 2021)

The objectives of this project are the development of the surveillance system combining millimeter radar and image sensor to detect the debris on airport surfaces, and the sophistication of the surveillance system utilized with the fiber-optic technology for airport surrounding airspace, and the development of support technology for remote tower operations.

(1.2) Development of Curved Approach Procedures and Dynamic Optimal Trajectories in Terminal Airspace with GNSS (~ 2024)

The objectives of this project are the development of advanced flight procedures for the curved precision approach and landing system using GNSS, the enhancement of the operating efficiency by the expansion of the continuous descent operation time at large-scale airports, and the development of the necessary technologies to reduce environment impact and increase airport capacity.

(1.3) Enhancement of Collaboration of Airport Surface Management (SMAN) and Departure/Arrival Management Systems (D/AMAN) (~ 2028)

The objectives of this project are the development of the techniques to eliminate the congestion of the traffic flow of arrivals and departures on the airport surface by conducting the arrival and departure management (AMAN/DMAN) based on the prediction of taxiing time and arrival time at the runway, and the development of the technologies of the ATM system including the surface management system (SMAN) with high efficiency, harmony and punctuality by the cooperation of the departure and arrival flights.

(2) Efficiency Enhancement of Air Transport Operation with Advanced Information and Communication Systems

(2.1) Development of System Wide Information Management (SWIM) System (2015~ 2026)

The objective of this project is the research and development of the System Wide Information Management (SWIM) System, including the standardization of flight information, weather information and aeronautical information, and the development of the assurance technology for SWIM system, in order to provide the necessary information for the efficient operation of the air transportation system to users.

(2.2) Development of High Speed Communication System for Aviation (~ 2026)

The objective of this project is the development of high speed communication system for aviation to connect air-to-ground, in order to share information about the flights, weather and so on.

(2.3) Development of Advanced Integrated CNS system (2023 ~)

The objective of this project is the development of advanced integrated communication, navigation and surveillance system with high speed communication, accurate navigation and high reliability capability to effectively utilize radio wave resources.

4.2.3 Fundamental Research Areas

(1) Evaluation on Safety and Performance of Air Traffic Management (ATM)

The objective in this research area is the progression of research on the indicators and the calculation methods of safety assessment methods and ATM performance for the new systems.

(2) Spectrum Managements and Radio Interference Analysis

The objective in this research area is the progression of research on the radio wave interference measurement technology, radio wave propagation analysis technology and signal design technology for the effective utilization of the radio resources required for air traffic system.

(3) Human Factors

The objective in this research area is the progression of research on the safety assessment based on human factors and the management and training techniques to reduce the human errors related to air transportation system.

4.3 Research Policy of ENRI

There are many necessary technological items, even only in the field of ATM/CNS/IM, to research and develop by ENRI in order to respond to the increase of the air traffic in the future and to implement the air traffic system with the safety, and efficient and environmental friendliness. In the case of ENRI, it is necessary to also consider the implementation of short-term additional research items to support the administrative authorities and the air service provider.

It is difficult to carry out all the research in all areas by ENRI alone. In such a situation, Japan Civil Aviation Bureau (JCAB) starts the presentation of some traffic data to research organizations for ATM/CNS [17], and ENRI has carried out the open competition research concerning ATM/CNS technology [18]. Therefore, many universities began to have an interest in the research area of ATM/CNS. As a result, since it is carried out as the mainly basic field of research at universities, in many cases, there is commonality of long-term research projects of ENRI, so the possibility of joint research between universities and ENRI in the future is increasing. Furthermore, the researchers in ENRI are making it possible to share the values for research purposes with the many researchers working at research institutes domestically and abroad, through international conferences and academic meetings and through public relations activities of the ENRI R&D long-term vision and CARATS. Therefore, under such circumstances, ENRI needs to decide what focused research and development projects are truly necessary, to distribute research resources to them, and to optimize the research and development system including implementing joint research between universities and other research institutions, in order for ENRI to conduct the research and development to maximize obtained results.

ENRI will determine the research projects to be focused on in the future to vigorously promote the research and development that breeds vitality to national life, through ENRI discussing with many stakeholders such as universities, other research institutions, aircraft operating companies as well as administration authorities, and also through building the efficiently research system including the strengthening and expansion of the research collaboration and arranging necessary research facilities.

5. Conclusion

Due to recent changes in social conditions, a review of the current ENRI R&D long-term vision was carried out in order to reveal new findings and to reflect the technology, etc. This review was conducted by referring to the progress state of CARATS, the contents of the ICAO GANP issued in December 2013, and the discussion results of EIWAC2013 (ENRI International Workshop on ATM/CNS)[19], which is the largest workshop in Asia related to ATM/CNS in February 2013. It started in June 2013, and aims at the clarification of the research goals with the consideration of projects to be developed that solve issues facing in our country.

As a result, ENRI decided to address two objectives, four R&D project areas and three fundamental research areas. The addressed two objectives are "Safety Improvement and Capacity Expansion of Air Transport" and "Flight Efficiency Enhancement to Reduce the Environment Impact", and the selected four R&D project areas are "Improvement of Safety and Optimization of Air Transport System with On-board Information", "Improvement of Safety and Optimization of Air Transport System by Trajectory Based Operation", "Efficiency Enhancement of Operation on Airport Surface and in Terminal Airspace" and "Efficiency Enhancement of Air Transport Operation with Advanced Information and Communication Systems". ENRI is willing to make efforts to contribute to society, the government, the relationship between academic society and people's lives, and to make efforts to establish the position of research institutions representing Asia, by promoting research on ATM, based on this R&D long-term vision which has been revised.

On the other hand, ENRI wants to strive to meet the social needs through the collaboration research with other research institutions and universities domestically and abroad, which have the knowledge for ATM modernization, because the number of the research projects and the field of expertise, which can be carried out by ENRI, is limited. In addition, although in this study the long-term vision has not been described, the training plan from a long-term perspective for the improvement of the researchers' "research capabilities" is also necessary. The review of the R&D long-term vision will be carried out in the future when the review became necessary, becauses the research projects to be carried out in ENRI will change largely by social conditions.

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Appendix-I Member List of Electronic Navigation Research Institute, Research and Development Long-Term Vision Study Committee

Chairman

Naoki FUJII   Director Research Management and Planning

External Members

Akinari IIZUKA   Project Associate Professor of Center for Aviation Innovation Research, The University of Tokyo

Toshiaki TSUJII   Institute of Aeronautical Technology, Japan Aerospace Exploration Agency

Miwa KOBAYASHI   Director of Government and Corporate Affairs, Boeing Japan

Shinichi YAMADA   Special Assistant to the Director, Air Navigation Planning Division, Civil Aviation Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Internal Members

Satoru INOUE   Air Traffic Management Department

Ryouta MORI   Air Traffic Management Department

Takeyasu SAKAI   Navigation Systems Department

Takuya OTSUYAMA   Surveillance and Communication Department

Akiko KOHMURA   Surveillance and Communication Department（ – 2014.3.31）

Xiaodong LU   Surveillance and Communication Department（2014.4.1 – ）

External Observers

Keichi YAMADA   Chief Researcher, ANA Strategic Research Institute

Tetsushi YAMAMOTO   Chief Researcher, ANA Strategic Research Institute

Fumio UENO   Researcher, ANA Strategic Research Institute

Internal Observers

Kazuo YAMAMOTO   President

Kazunari DAIKI   Executive Director（– 2014.7.31）

Ikuo TAKAGI   Executive Director（2014.8.1 – ）

Masahiro ITO   Director, Planning Division（2014.9.1 – ）

Presenter of Research and Development Subjects

Sachiko FUKUSHIMA Air Traffic Management Department

Marc BROWN Air Traffic Management Department

Izumi YAMADA Air Traffic Management Department

Secretary

Masato FUJITA Special Assistant to Director Research Management and Planning（ – 2014.3.31）

Akiko KOHMURA Special Assistant to Director Research Management and Planning （2014.4.1 – ）

Appendix-II History of ENRI R&D Long-Term Vision Study Committee Meetings

No.1	August 28, 2013
No.2	October 28, 2013
No.3	December 16, 2013
No.4	January 22, 2014
No.5	February 25, 2014
No.6	April 22, 2014
No.7	June 16, 2014
No.9 (Expanded MeetingNo.1)	June 26, 2014
No.9	August 4, 2014
No.10	August 29, 2014
No.11 (Expanded MeetingNo.2)	September 5, 2014
No.12 (Expanded MeetingNo.3)	November 11, 2014
No.13 (Expanded MeetingNo.4)	March 27, 2015