Research on Flight Operational Efficiency for Fuel and Noise

Japan Aerospace Exploration Agency

Aeronautical Technology Directorate

Technology Demonstration Research Unit

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DREAMS

Distributed and Revolutionary Efficient Air Safety Management System

Outline

1. Background
   - Air Traffic Situation in Japan
   - CARATS (ATM Long Term Vision)

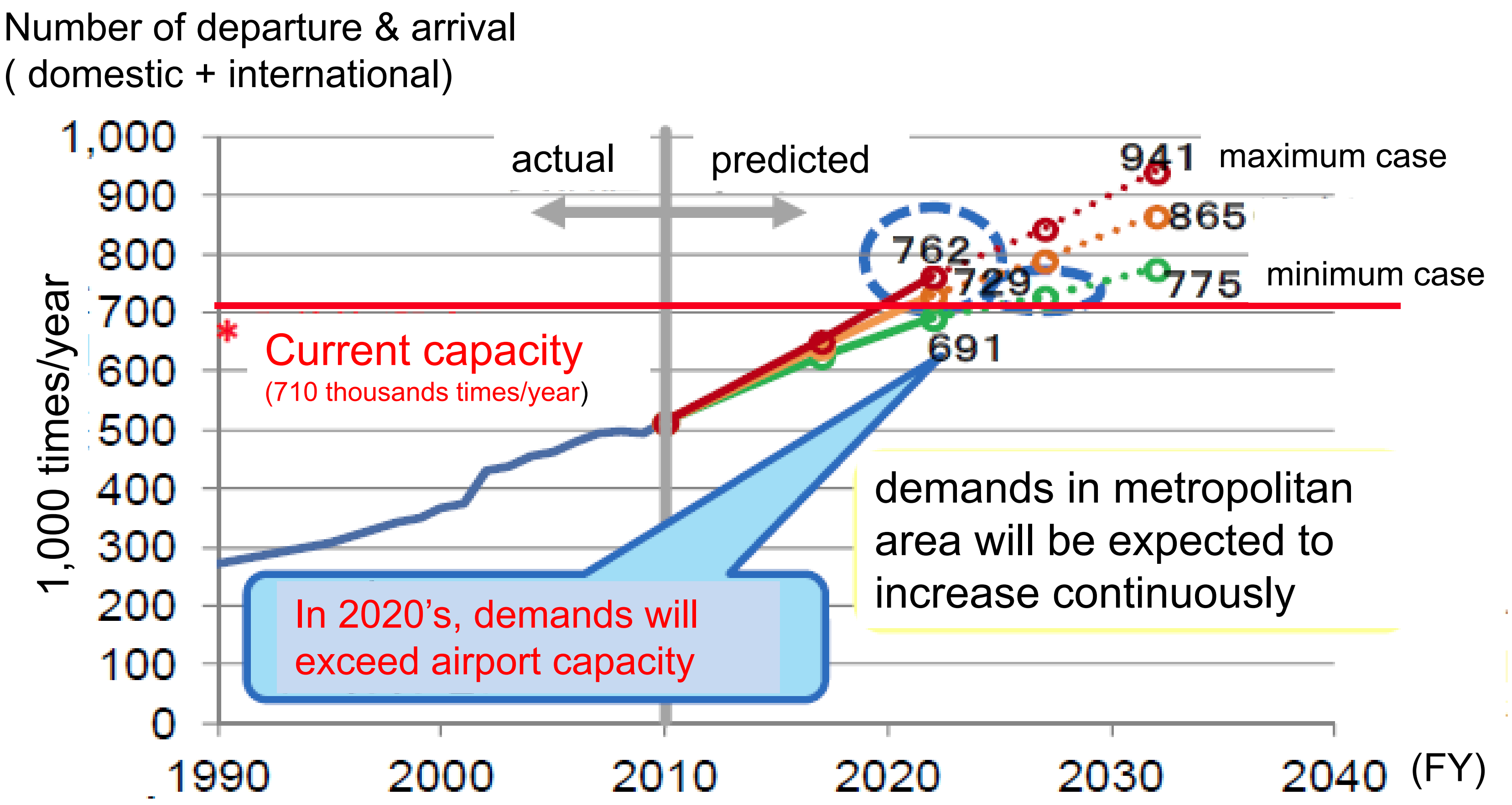
2. JAXA's DREAMS Project Outline

3. DREAMS Technologies
   - Noise Abatement Operation
   - High Accuracy Satellite Navigation
   - GBAS-TAP based Curved Approach

4. Summary

Increasing Demand

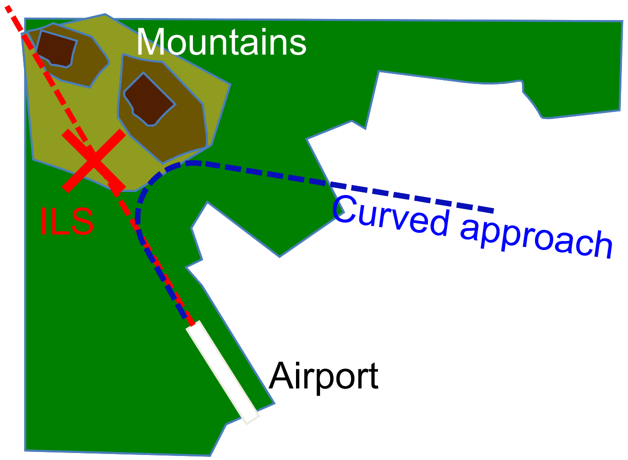
In 2020's, air traffic demands will exceed current airport capacity at Tokyo Metropolitan airports.



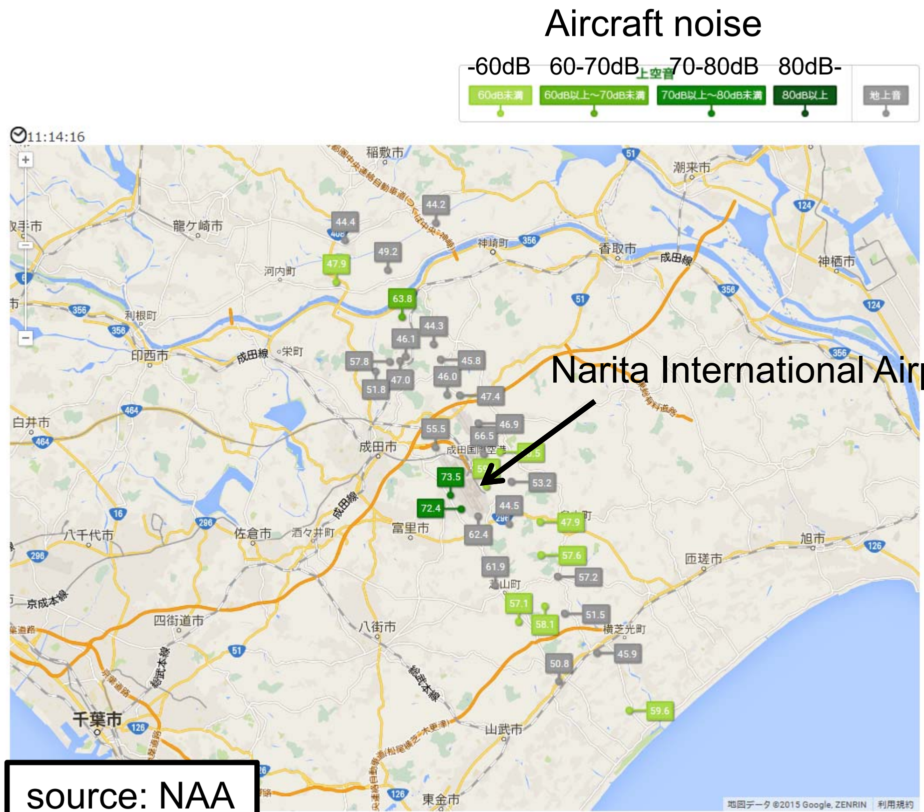
Ref. JCAB

Constraints on Departure/Arrival Paths

- Terrain constraints (e.g. mountains) prevent ILS approach.
- Aircraft noise impact limits airport operation time.
  (e.g. Narita International Airport operates from 6AM to 11PM only.)



Over 10% of airports in Japan (10 out of 95) can NOT use ILS approach mainly due to terrain constraints.



source: NAA

Narita International Airport shows aircraft noise impact in real-time via internet.

CARATS
(Long term vision of future ATM)

Outline of CARATS

Goals setting toward 2025

1. Enhance safety
   5 times Safety
2. Increase ATC capacity
   Double Capacity
3. Improve user convenience
   +10% Service level
4. Efficient Operation
   -10% Fuel Consumption
5. Enhance ATM service efficiency
   +50% Productivity
6. Respond to Environmental issue
   -10% CO2 emission
7. Strengthen International Cooperation

Eight Pillar of Renovations

- Trajectory based Operation
- Enhance Predictability
- Performance base Operation
- Satellite based Navigation
- Improve Situational Awareness
- Automation System and Human
- Information Sharing & CDM
- High Density Operation

Realizing the renovation

Lay out a roadmap, representing step-by-step implementation of the measures required to build the future air traffic systems

Clarify the roles of the industry, academy and government partners.

Consider and set index for achievement analysis of numerical goals .

source: JCAB

CARATS Policies (OIs, ENs)

33 operational improvements (OIs) and 15 enablers (ENs)
to implement CARATS

		Category	Number of measurements	2015 · 2020 · 2025
OI	Airspace organization	Flexible use of airspace	8	Variable sector boundaries Flex use of mil airspace Dynamic variable use of terminal airspace Free routing for high altitude airspace Dynamic variable airspace organization Flow corridor
OI	Airspace organization	Performance based operations	4	RNP AR app and dept RNP operations with high accuracy including the "time" element
OI	Pre-flight	Collaborative trajectory generations	5	CDO and CCO Collaborative coordination of trajectories prior to the flight operations Conflict-free trajectories from gate to gate
OI	In-flight	Trajectory-Based Operation	5	Initial CFDT (single point) CFDT (multiple points) TBO
OI	In-flight	High density operations	8	Optimize off-block time Air-to-Air surveillance (ASAS) Improved capacity of ATC using datalink and decision support tools
OI	In-flight	Improved information services	2	Enhanced information in the cockpit
OI	Post-flight	Sharing and utilizing safety related information	1	Sharing and utilizing safety related information Real time risk management
EN		Information management	3	FODB FF-ICE
EN		Weather information	3	Improved weather capabilities
EN		Navigation	2	CAT-I GBAS CAT-III GBAS
EN		Surveillance	5	WAM (gnd) & ADS-B (UAT) WAM (enroute/airport) ADS-B
EN		Communications	2	FANS-1/A+(POA/Mode2) ATN-Baseline2, AeroMACS, L-DACS

source: JCAB (partly updated by JAXA)

ATM R&D Organizations in Japan

MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

- JCAB (Japan Civil Aviation Bureau)

MEXT (Ministry of Education, Culture, Sports, Science and Technology)

Industry

- NEC
- NTT Data
- Mitsubishi Electric
- Toshiba
- Oki Electric Industry
- Japan Radio Co.
- Etc.

Government Research Organizations

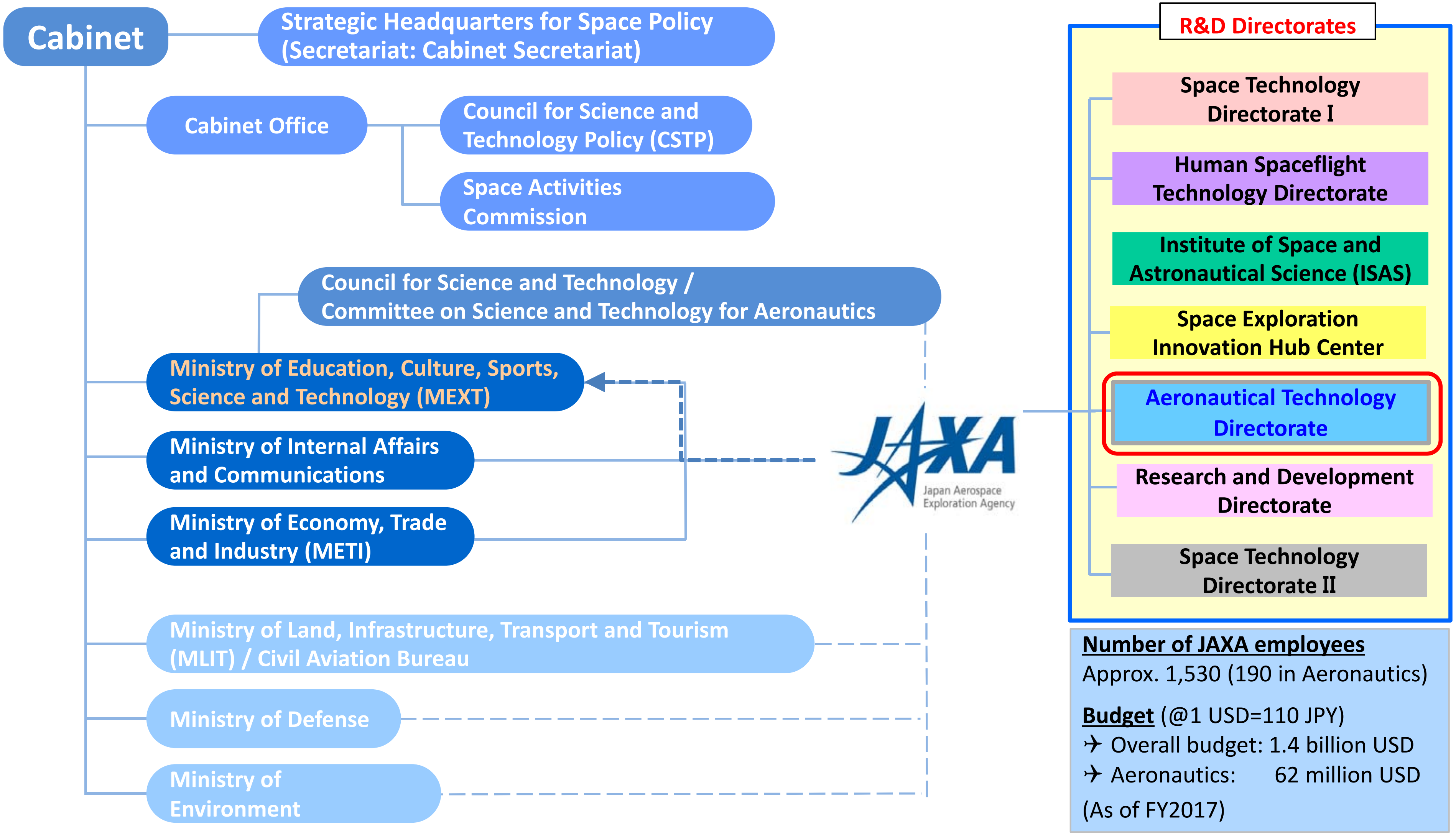
- ENRI (Electronic Navigation Research Institute)
- JAXA (Japan Aerospace Exploration Agency)

Universities

- Univ. of Tokyo
- Nagoya University
- Tokyo Inst. Tech.
- Etc.

source: ENRI

About JAXA: Organization



Number of JAXA employees
Approx. 1,530 (190 in Aeronautics)

Budget (@1 USD=110 JPY)
✈ Overall budget: 1.4 billion USD
✈ Aeronautics: 62 million USD
(As of FY2017)

About JAXA: Aeronautical Research Activities

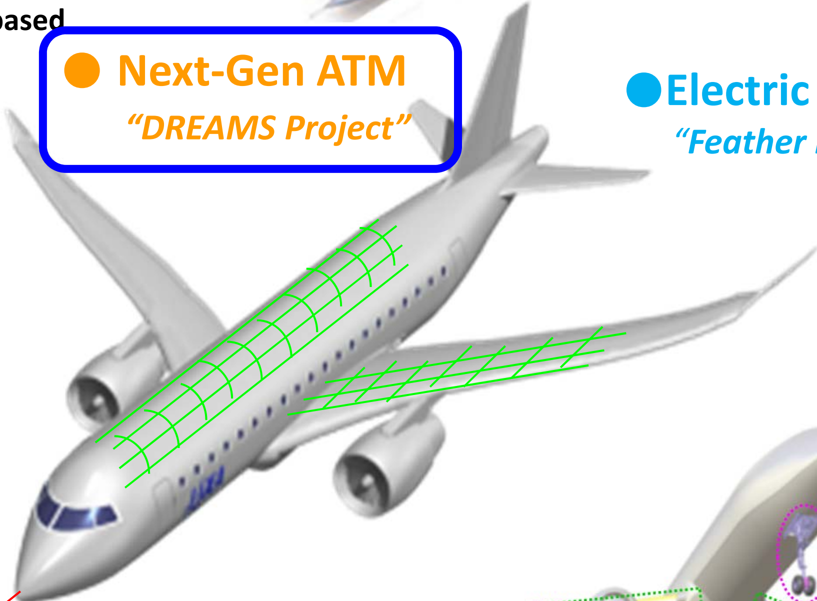
Major research themes

● Sonic boom reduction
"D-SEND Project"

● HALE UAS

● High-efficiency airframe
"Eco-Wing"
Aircraft resistance reduction based on aerodynamics/ structure, Composites structure design technology

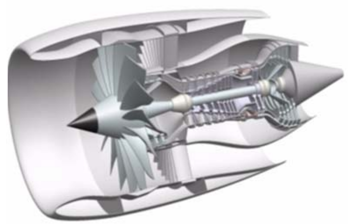
● Next-Gen ATM
"DREAMS Project"



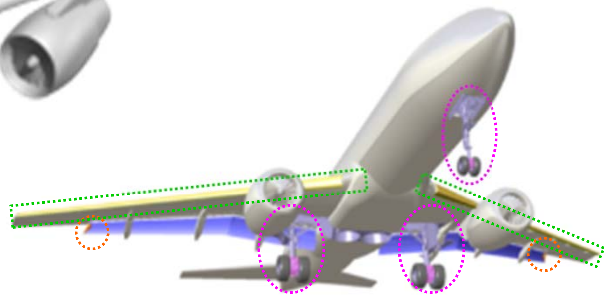
● Electric Aircraft
"Feather Project"

● Disaster Response Aircraft Technology
"D-NET 2"

● Next-gen Fan/ Turbine System
"aFJR Project"
Technology demonstration



● Radiation Monitoring UAS
"UARMS"



● Turbulence Accident Prevention
"SafeAvio Project"

● Airframe noise reduction
"FQUROH Project"

DREAMS Project
(JAXA’s ATM Research)

DREAMS: Distributed and Revolutionary Efficient Air-traffic Management System

DREAMS Project: Objectives

ICAO
Global ATM Operational Concept (2003)
An integrated, harmonized and globally interoperable ATM system in 2025 and beyond.

ATM related Institutions
Improve rescue helicopter operation and operational availability in severe weather

long-term vision for R&D for each region

reflects to ATM policy

USA
Europe

Seamless ATM system

Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
CARATS (Sep. 2010) JCAB's long term vision
Enhance safety, Increase ATC capacity, Improve user convenience, efficient operation, Enhance ATM service efficiency, Respond to environmental issue

NextGen Implementation Plan

SESAR Master Plan

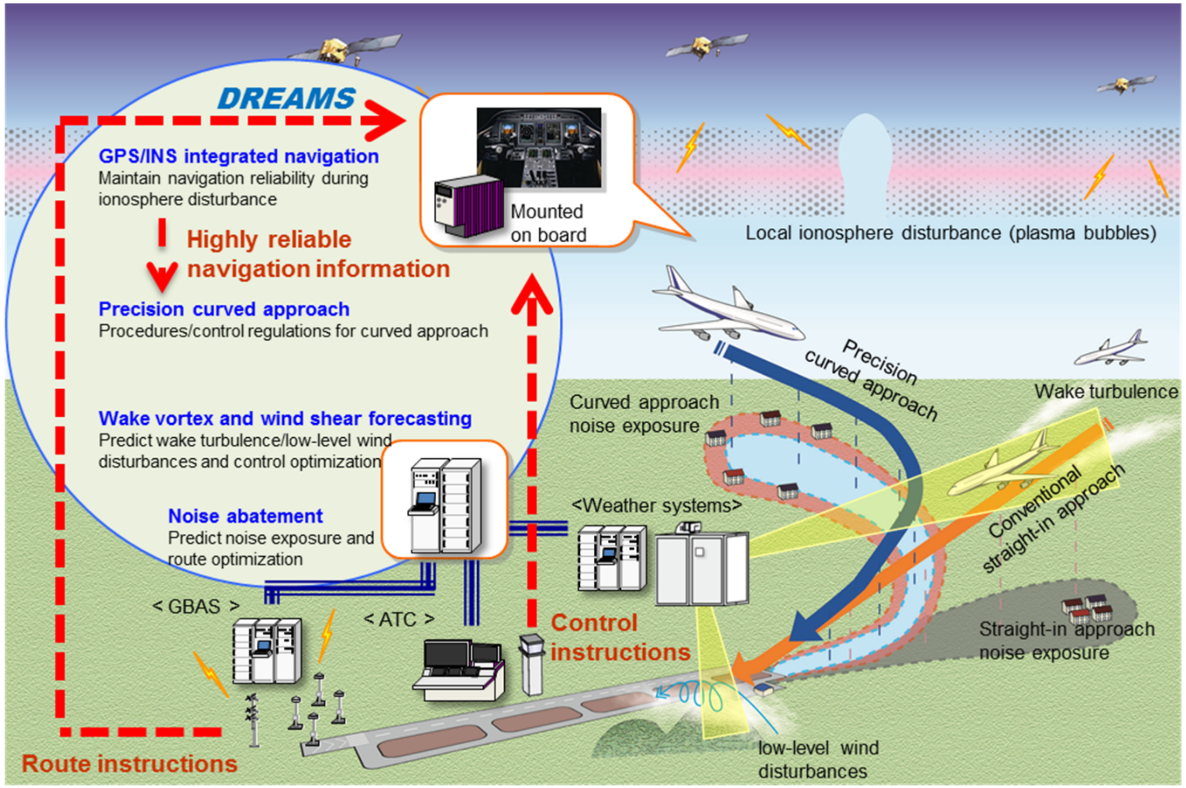
MLIT / CARATS Board
CARATS Road Map（March. 2011）
46 policies to realize 5 times safety, double air-traffic capacity,
10% improvement in user convenience and air-traffic efficiency, etc.

JAXA
Objectives of DREAMS project (2009-2014)
To propose key technologies to realize CARATS policies and transfer them to related institutions.

DREAMS Project: Developed Technologies

JAXA developed key technologies to improve air-traffic operation in terminal area.

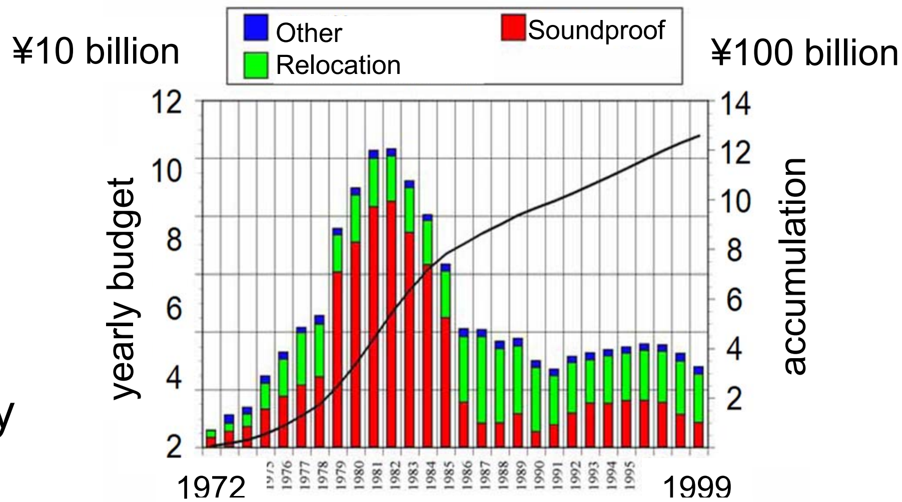
- **Weather Information Technology;** **Wake vortex forecasting** technology to reduce aircraft separation for airport capacity increase.
- **Noise Abatement Operation Technology;** **Forecasting ground noise impact** to the ground and **optimizing the approach path** to reduce ground noise impact & fuel consumption.
- **High-Accuracy Satellite Navigation Technology;** **GPS/INS integrated navigation** technology to improve the availability of satellite-based precision approach.
- **Trajectory Control Technology;** **Precision curved approach utilizing GBAS** to increase the number of flight service even under poor visibility.



Noise Abatement Operation (1/2)

Background

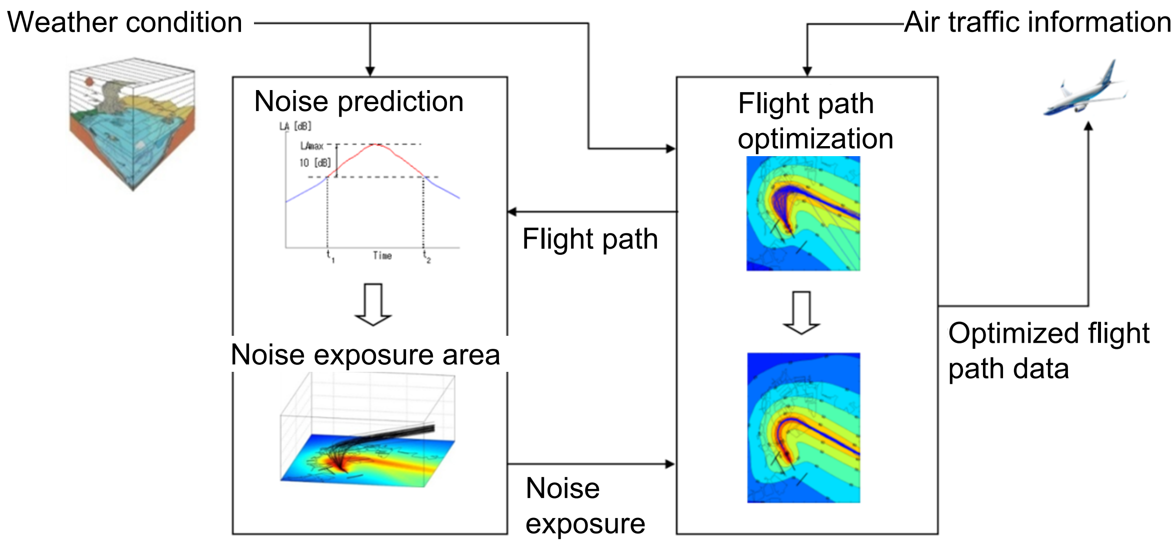
- As air traffic volume increase, additional environmental expenditures are needed.
- Because aircraft noise propagation is affected by the weather condition, the noise exposure area are broadened by weather condition.



Environmental expenditures around airport

Solution

- By predicting noise propagation and exposure area, we can optimize the flight path that minimizes the noise exposure area.



Noise Abatement Operation (2/2)

Noise prediction model

- Predict time-series of noise levels.
- Consider the effect of meteorological conditions on noise propagation.

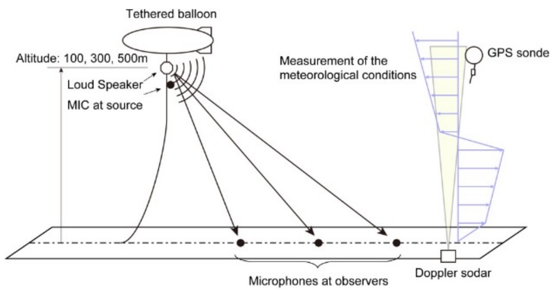
➔ Verification

- MET effects; AtoG Propagation test using balloon
- Sound Exposure Level; Over 30,000 data in four seasons were obtained at Narita Int'l Airport.

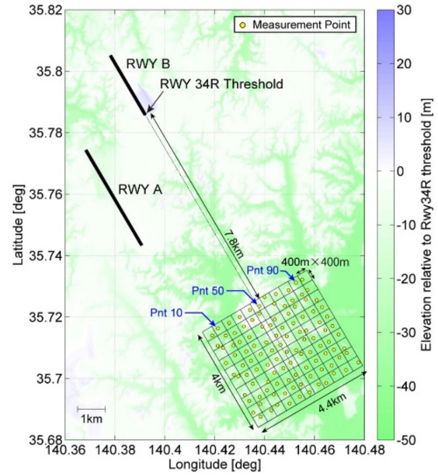
➔ The overall prediction error was less than 3dB for most conditions (more than 90%).

Approach Path Optimization

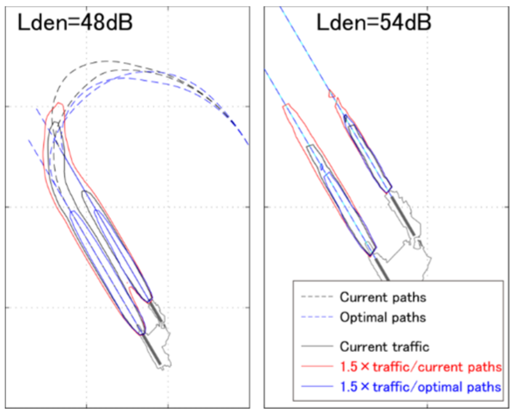
- Minimize additional noise exposure area.



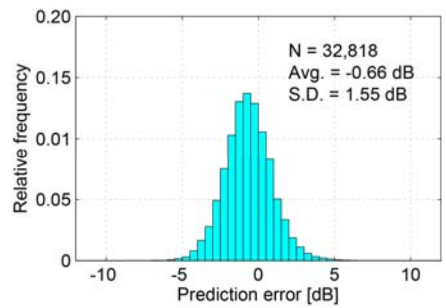
Air-to-Ground propagation test



Measurement points at Narita Int'l Airport



Traffic	Optimize	Area of noise exposure [km^2]	
		Lden = 48 dB	Lden = 54 dB
Current	No	74.1	8.4
x1.5	No	115.8	14.1
x1.5	Yes	44.1	8.2



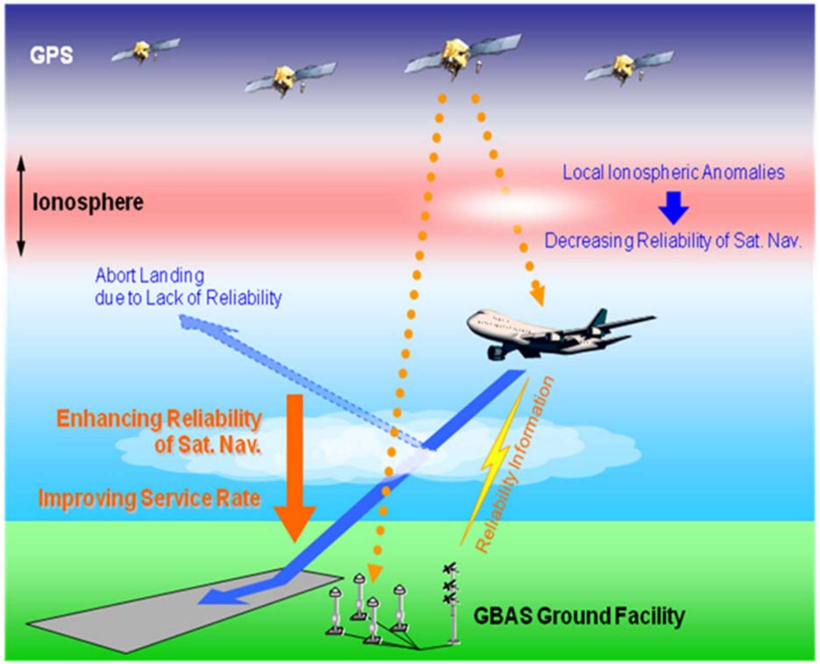
SEL prediction error

High Accuracy Satellite Navigation (1/3)

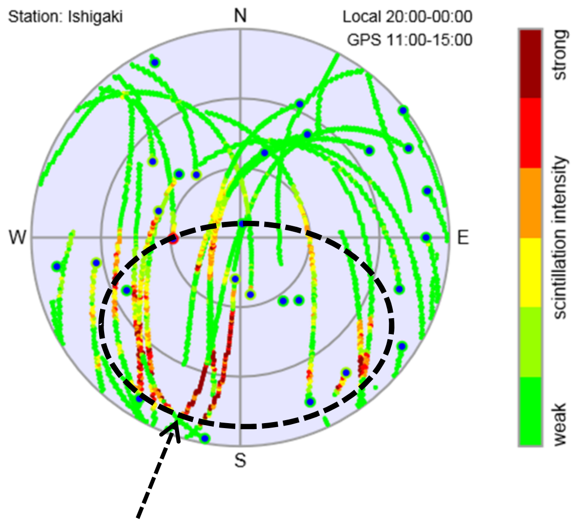
Background

GNSS (Global Navigation Satellite System) is widely used in positioning, navigation and timing, its accuracy and reliability may be inadequate under harsh conditions, such as in the presence of ionospheric anomalies.

For safety-of-life applications, such as aircraft operations, maintaining high reliability under all conditions is of great importance, so augmentation systems are necessary.



Degraded availability of precision approach due to ionospheric anomalies (conceptual image)

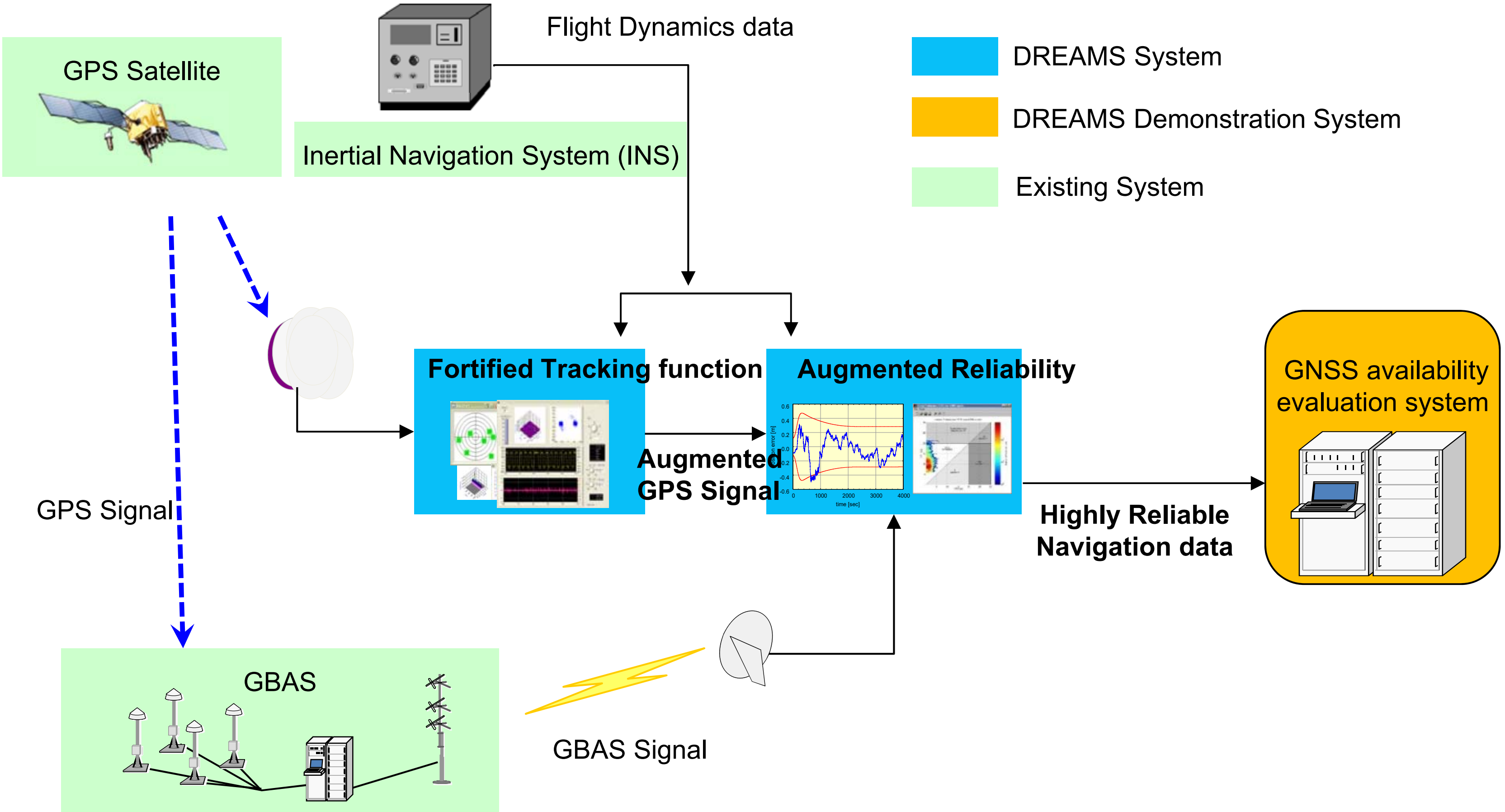


Satellite orbit and scintillation intensity (5 satellites in southern direction were unavailable at Ishigaki Island in Mach 24th 2013)

High Accuracy Satellite Navigation (2/3)

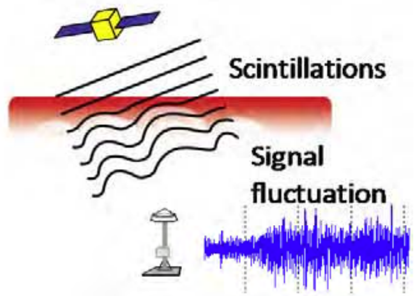
Solution

To achieve more than 99% GNSS availability, JAXA developed fortified satellite tracking using INS and augmented reliability (INS coasting).



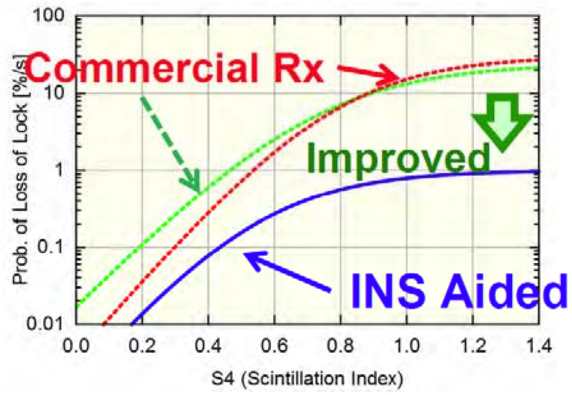
High Accuracy Satellite Navigation (3/3)

- ✓ Ionospheric Anomalies cause losses of GPS signals, and reduce the availability of GBAS precision approach



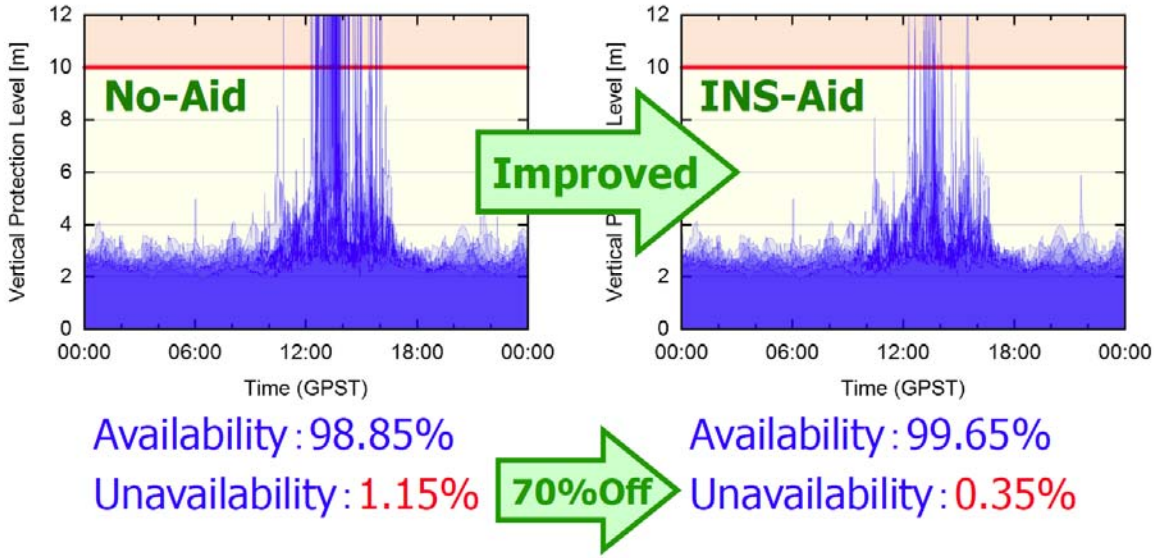
Probability of Loss of Lock

Commercial Rx. vs. INS-Aided Rx



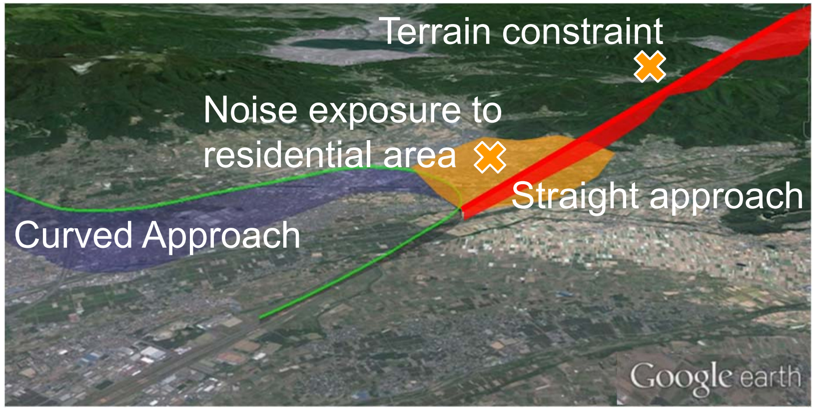
- ✓ Robust signal tracking by INS aiding was developed, and performance was demonstrated by flight tests.

- ✓ Monte-Carlo simulation showed improvement of GBAS availability by INS integration



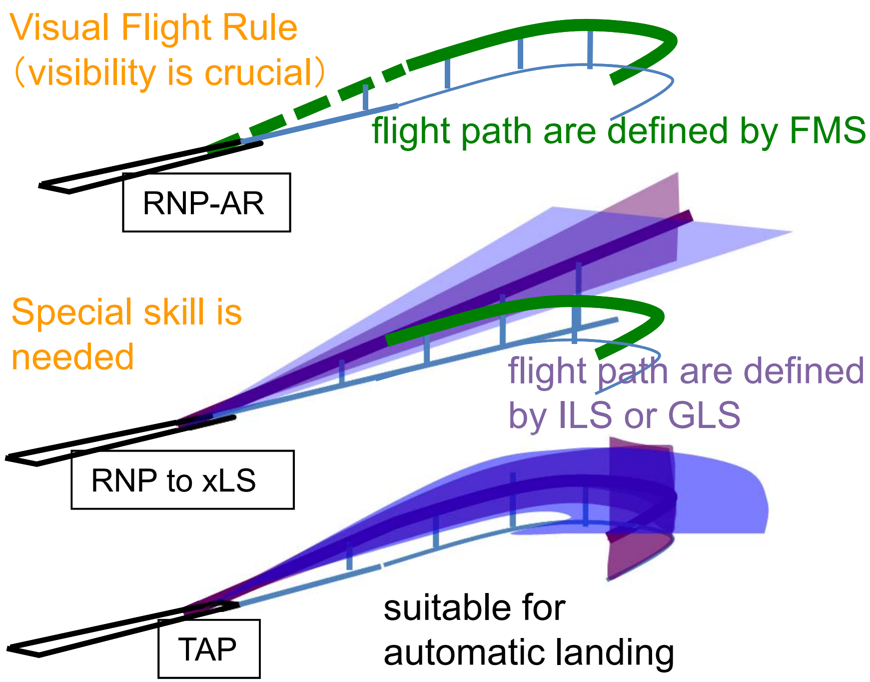
GBAS-TAP Curved Approach (1/3)

Background



- Using curved approach, it is easier than straight approach to handle the noise exposure problem or terrain constrain problem.

3 types of curved approach



- Among the 3 curved approach procedures, GBAS-TAP procedure is most promising one in the future. Therefore, automatic landing algorithm for this landing procedure were developed.

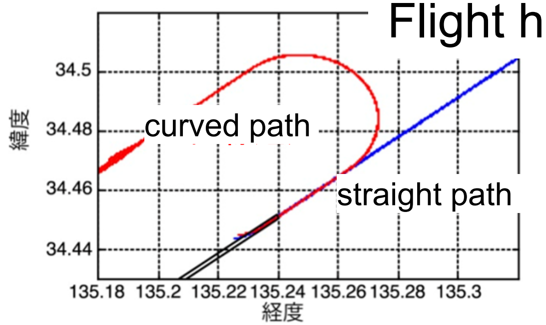
FMS: Flight management system
ILS: Instrumental landing system
GLS: GNSS landing system
TAP: Terminal area path

GBAS-TAP Curved Approach (2/3)

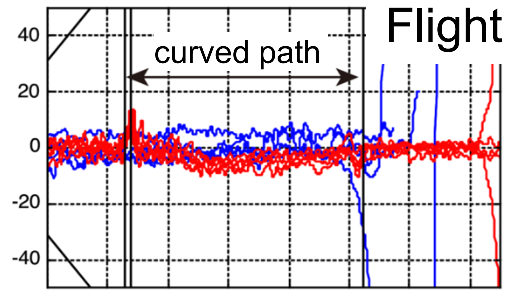
Flight Demonstration

- Development auto flight system for precision curved approach
- TAP path definition and data link protocol for high-density ATM operation
- Using GBAS station (ENRI), TAP-based curved approaches were successfully conducted by JAXA experimental airplane.

Flight history



Flight path error



same as the straight path

JAXA's experimental plane

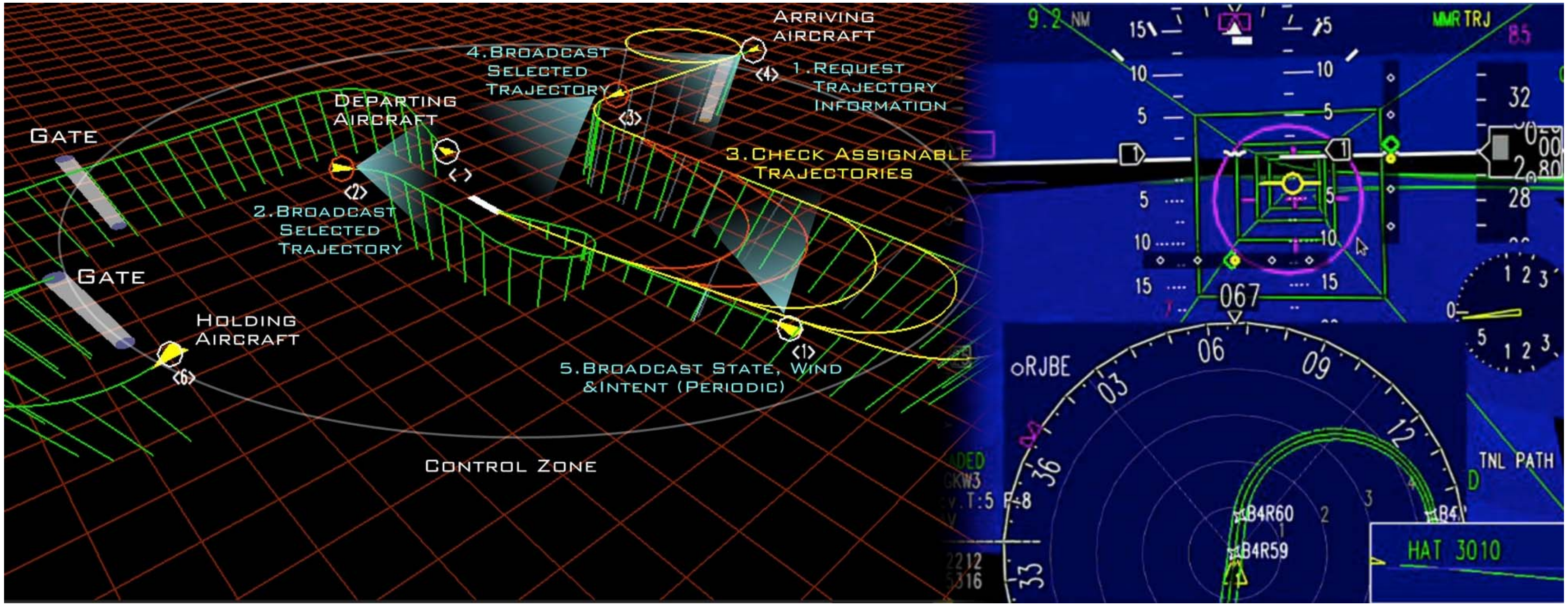
GBAS station (ENRI)

(Under collaboration with ENRI)

Guidance display shows the flight path

GBAS-TAP Curved Approach (3/3)

Dynamic Downwind



GBAS Dynamic Trajectory enables;

- Metering tool in high density operation
- Noise abatement procedures taking account of wind conditions
- Less pilot workload, data base update in comparison with FMS

Summary

1. Japanese Air Traffic Situation
   - Increasing demand and congestion in Tokyo area
   - Constraints on departure/arrival paths due to terrain, noise impact

2. CARATS (Long-term vision of ATM)
   - Outline (targets, renovation)
   - Operational improvements, enablers

3. JAXA DREAMS Project
   - Noise Abatement Operation
   - High Accuracy Satellite Navigation
   - GBAS-TAP Curved Approach

→ Research outputs are regularly reported to related institutions including JCAB, ICAO, RTCA and IGWG.