Research on Flight Operational Efficiency for Fuel and Noise

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Aeronautical Technology Directorate
Technology Demonstration Research Unit
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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.

Number of departure & arrival (domestic + international)

Current capacity (710 thousands times/year)

In 2020’s, demands will exceed airport capacity

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.

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

source: NAA
CARATS
(Long term vision of future ATM)
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

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
CARATS Policies (OIs, ENs)

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

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

source: JCAB (partly updated by JAXA)
ATM R&D Organizations in Japan

Government Research Organizations
- MLIT (Ministry of Land, Infrastructure, Transport and Tourism)
  - JCAB (Japan Civil Aviation Bureau)
- MEXT (Ministry of Education, Culture, Sports, Science and Technology)
  - ENRI (Electronic Navigation Research Institute)
  - JAXA (Japan Aerospace Exploration Agency)

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

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

source: ENRI
About JAXA: Organization

Strategic Headquarters for Space Policy (Secretariat: Cabinet Secretariat)

Cabinet Office

Council for Science and Technology Policy (CSTP)

Space Activities Commission

Council for Science and Technology / Committee on Science and Technology for Aeronautics

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

Ministry of Internal Affairs and Communications

Ministry of Economy, Trade and Industry (METI)

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) / Civil Aviation Bureau

Ministry of Defense

Ministry of Environment

Space Technology Directorate I

Human Spaceflight Technology Directorate

Institute of Space and Astronautical Science (ISAS)

Space Exploration Innovation Hub Center

Aeronautical Technology Directorate

Research and Development Directorate

Space Technology Directorate II

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**

- **Environment-Conscious Aircraft Technology Program (ECAT)**
- **Safety Technology for Aviation and Disaster-Relief Program (STAR)**
- **Sky Frontier**

### High-efficiency airframe

- **“Eco-Wing”**
  - Aircraft resistance reduction based on aerodynamics/structure, Composites structure design technology
- **Next-Gen ATM**
  - “DREAMS Project”

### Disaster Response Aircraft Technology

- **“D-NET 2”**

### Radiation Monitoring UAS

- **“UARMS”**

### Turbulence Accident Prevention

- **“SafeAvio Project”**

### Airframe noise reduction

- **“FQUROH Project”**

### Sonic boom reduction

- **“D-SEND Project”**

### Electric Aircraft

- **“Feather Project”**

### HALE UAS

- **“aFJR Project”**
  - Technology demonstration

### Next-gen Fan/Turbine System

- **“D-SEND Project”**

- **Electric Aircraft**

- **HALE UAS**
DREAMS Project
(JAXA’s ATM Research)

DREAMS: Distributed and Revolutionary Efficient
Air-traffic Management System
**ICAO**
**Global ATM Operational Concept (2003)**
An integrated, harmonized and globally interoperable ATM system in 2025 and beyond.

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

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**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

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**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.

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

**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.

诘 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.

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

Approach Path Optimization
- Minimize additional noise exposure area.

<table>
<thead>
<tr>
<th>Traffic</th>
<th>Optimize</th>
<th>Area of noise exposure [km^2]</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Lden = 48 dB</td>
</tr>
<tr>
<td>Current</td>
<td>No</td>
<td>74.1</td>
</tr>
<tr>
<td>x1.5</td>
<td>No</td>
<td>115.8</td>
</tr>
<tr>
<td>x1.5</td>
<td>Yes</td>
<td>44.1</td>
</tr>
</tbody>
</table>

Measurement points at Narita Int’l Airport
**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)
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.
- 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.

![JAXA's Exp. Jet Plane: Cessna Citation Sovereign](image)

![Probability of Loss of Lock](graph)
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.

- 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.

**3 types of curved approach**

- **Visual Flight Rule** (visibility is crucial)
  - flight path are defined by FMS
  - RNP-AR
  - Special skill is needed
  - flight path are defined by ILS or GLS
  - RNP to xLS
  - suitable for automatic landing
  - TAP

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

Guidance display shows the flight path as the same as the straight path.
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
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.