Collaborative research activities on time-variable approach procedures for wake vortex encounter avoidance

Takayuki Yoshihara
Electronic Navigation Research Institute

Meiko Steen and Thomas Feuerle
Institute of Flight Guidance (IFF), TU Brauncshweig

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Introduction of ENRI

- The only institute in Japan conducting research relating to air traffic systems related to ATM and CNS technologies
  - Established in 1967
  - Supported by Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
  - Budget: 1.5 billion yen in FY2013, including personnel costs
  - Personnel: 65 (47 researchers)
- Supports a long term vision of CARATS (Collaborative Actions for Renovation of Air Traffic Systems) which was developed by Japan Civil Aviation Bureau (JCAB)

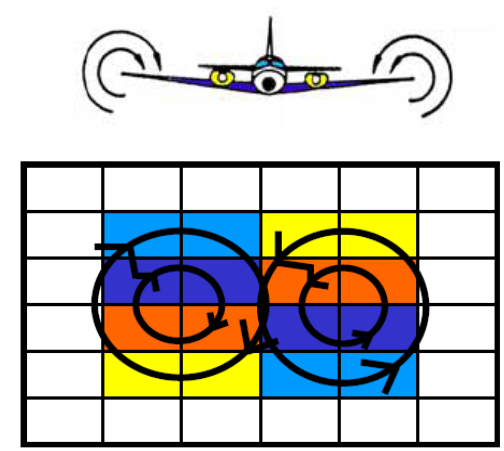
Past activities associated with wake vortex research at ENRI (1)

- A Lidar system was installed on a roof of a building in ENRI's Iwanuma branch, which bordered on Sendai Airport
  - To detect and observe wake vortex including its temporal changes
  - Manufactured by Mitsubishi Electric Corp.
- The first observation was performed in 2004

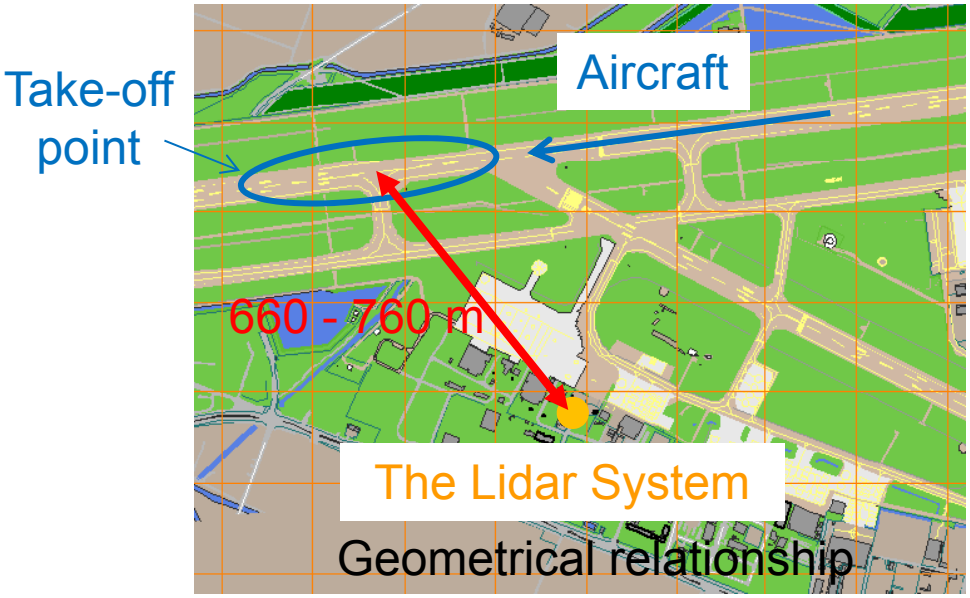
Wave length	1.54μm
Power (Ave.)	2.0W
Pulse repeat freq.	4000Hz
Pulse width	0.2μs
Beam diameter	100mm
Range resolution	30m
Scan rate	20 deg./s
Angle resolution	0.05 deg.
Horizontal scan range	0~360deg.
Vertical scan range	-5~185deg.

Past activities associated with wake vortex research at ENRI (2)

- Initial purpose: feasibility study reducing separation for departure
  - A geometrical condition: observation of wake vortices produced by take-off aircraft
- To detect and identify wake vortices
  - A template matching method, which examines two-dimensional wind field in vertical cross-section of wind over the runway to find a pattern of wake vortices



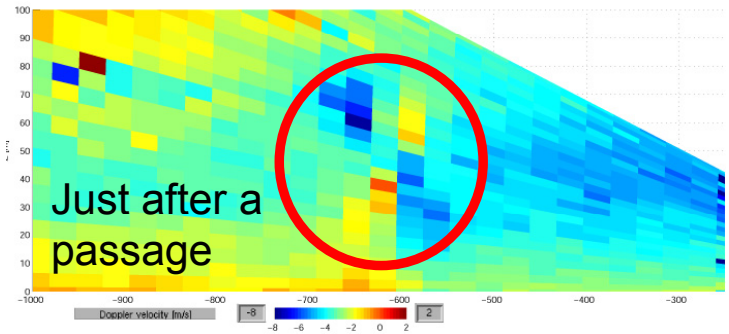
A pattern of wake vortices

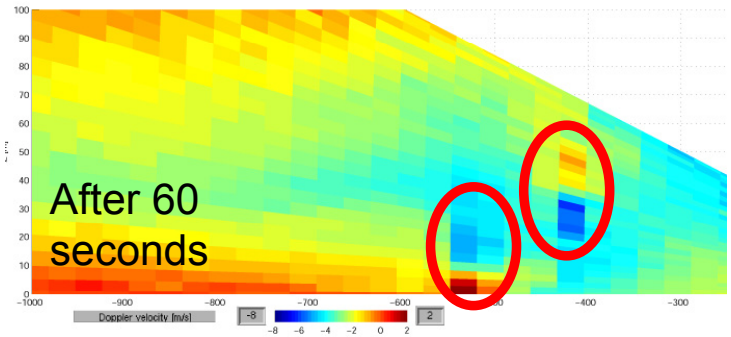


Geometrical relationship

Past activities associated with wake vortex research at ENRI (3)

- A sample event of wake vortices caused by a departure of B747
  - Blue and red colors indicate Doppler velocities in approaching and receding directions, respectively.



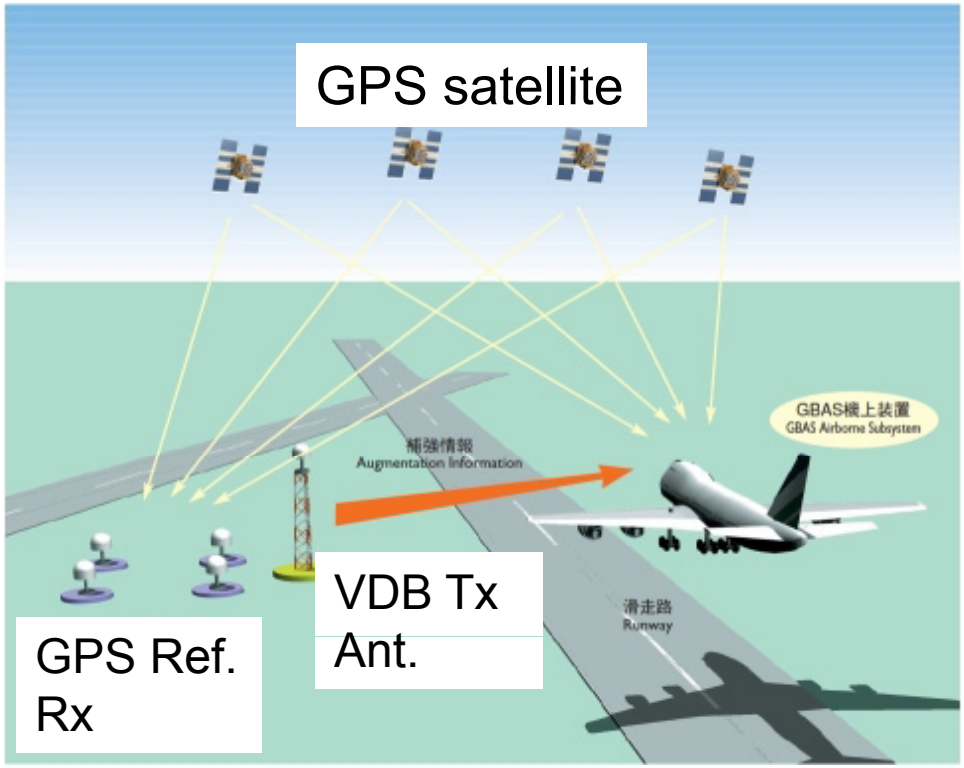


T. Komatsubara, et al., 2005

- A collaborative research to evaluate wake vortex effects on aircraft
  - Institute of Fluid Science (IFS) of Tohoku University
  - Japan Aerospace Exploration Agency (JAXA)
- Total of 620 cases for departures during April 2006 and May 2009
  - B767-300, B737-400/500/700/800, Airbus 320 and MD-81/90
  - Examined relationship among residence time of wake vortices, advection and meteorological conditions such as cross wind velocity (Kato et al., 2009)

Advanced procedures for avoidance to encounter wake vortex using GBAS

- GPS reference stations
  - 4 sets of GPS Ant/Rx
- Data processing system
  - GPS range corrections
  - Integrity messages
- VHF Data Broadcast system (VDB; 108–118MHz)
  - Broadcasts augmentation information together with approach path information
  - Coverage for approach service: 23NM
- CAT-I operation
  - First implementation in 2012
  - Germany and U.S.



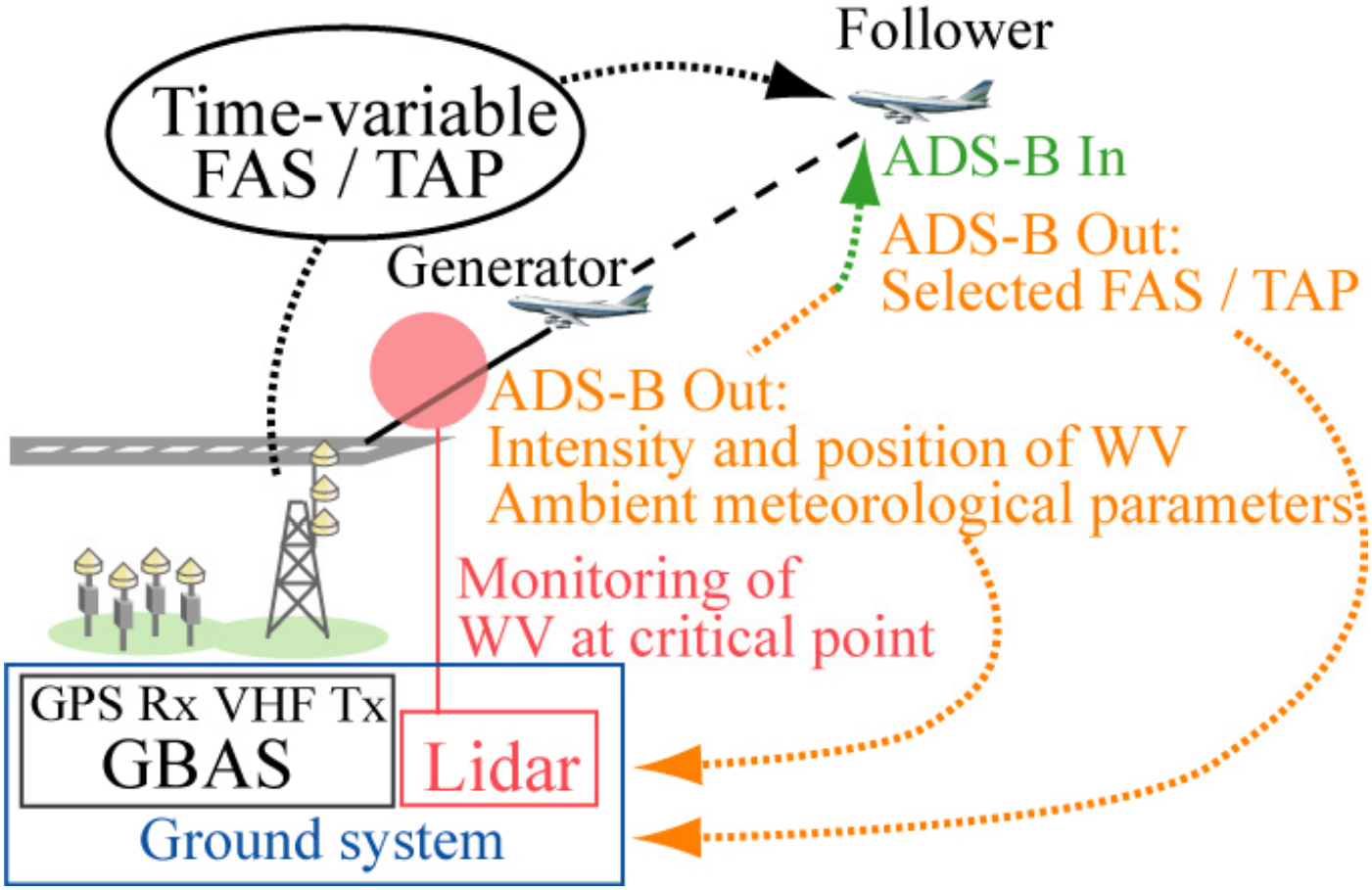
Advanced procedures for avoidance to encounter wake vortex using GBAS (2)

- ENRI had developed a CAT-I prototype system
  - Safety design and analysis including integrity monitors under environment of Japan
  - Currently, ENRI is also developing a research prototype of CAT-III GBAS
- Capability of flexible procedure design
  - Final Approach Segment (FAS): broadcasted as digital data
  - Future function: TAP (Terminal Area Path) can provide curved segments
- Investigation and development of operational concept to enhance GBAS benefits
  - We regard wake vortex application as one of important items using GBAS
  - Displaced threshold, Variable angle
  - Time-variable approach path
- IFF/TUBS and ENRI started discussion on a possible future operational concept for wake vortex avoidance in 2011

IFF/TUBS and ENRI discussed and tested a possible future operational concept for wake vortex avoidance

- GBAS
  - broadcasts simultaneously multiple approach paths to support aircraft with different categorized types which are approved in advance
  - Such path configurations may be switched with meteorological condition changes like runway changes
- A following aircraft
  - Obtains wake vortex information produced by a preceding aircraft via ADS-B
    - Aircraft type, position, speed (and weight) for calculation initial intensity of wake vortex or wake vortex intensity itself
    - Surrounding meteorological condition of a preceding aircraft such as cross-wind condition along approach path
  - Required to select the most suitable path judging from wake vortex condition produced by a preceding aircraft and report the selected path
- A preceding aircraft
  - Transmit the above required information via ADS-B, which enable both the following aircraft and the ground systems

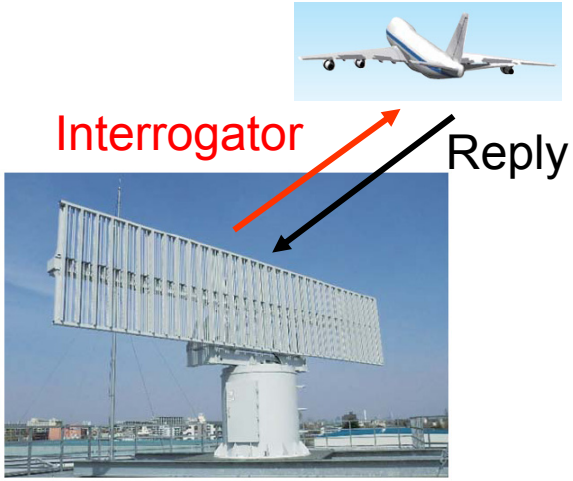
IFF/TUBS and ENRI discussed and tested a possible future operational concept for wake vortex avoidance



Ongoing activities on feasibility study of the concept

- Flight experiments
  - Conducted to extract subjects to proof the concept under different meteorological conditions with a research aircraft of the IFF/TUBS in spring 2011
  - On-board meteorological data: simultaneously collected to calculate the wake vortex strength, decay and transport parameters for predictions by the Air Data Reference (ADR) to identify required parameters to broadcast via ADS-B
  - The flight experiments includes demonstration for a high Glide Path Angle (GPA) of 5 degrees and curved approach assuming TAP by manually control
- Investigation and validation of capability to apply on-board meteorological information to wake vortex prediction
  - Collect and investigate meteorological data on operational on-board systems using DAPs data
  - Compare with independent observational data such as Lidar and meteorological weather forecast model

Collection of DAPs data as on-board meteorological information

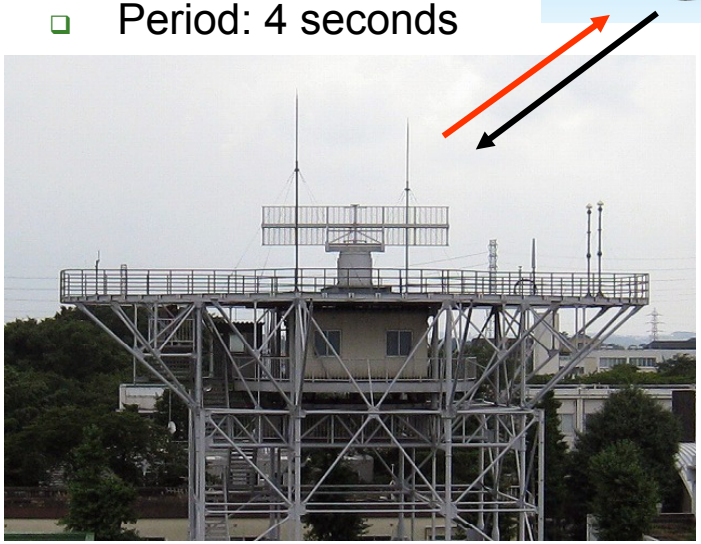


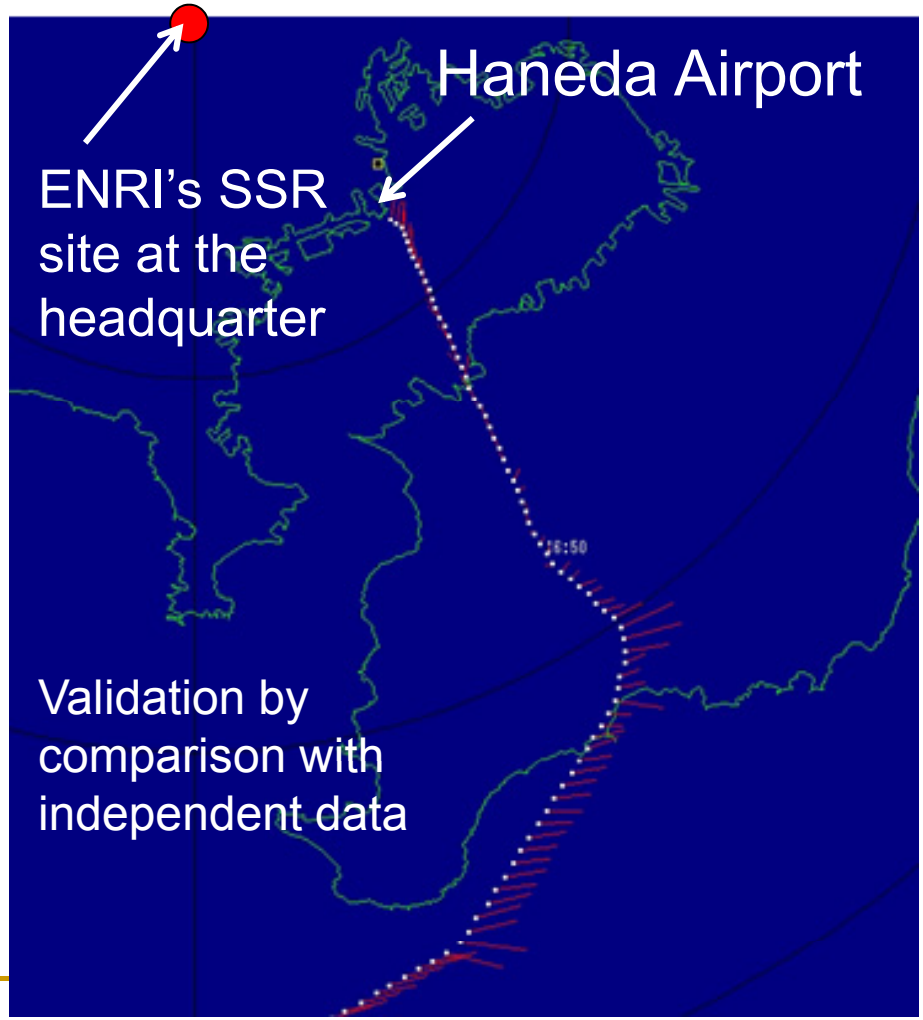
- DAPs (Downlink Aircraft Parameters) data
  - Meteorological data (BDS code 4,4 and 4,5)
  - Aircraft intent and state data (BDS code 5,0 and 6,0)
- Secondary Surveillance Radar (SSR) mode S
  - Advantage: control downlink rate by interrogator
- Meteorological data
  - BDS code 4,4: Meteorological routine air report
    - Wind speed/direction, static temperature/pressure
  - BDS code 4,5: Meteorological hazard report
    - Turbulence, wind shear, mircroburst, icing and wake vortex

  -> Number of capable aircraft is few
- Aircraft intent data
  - Provides aircraft type, position and speeds
  - Estimation of wind conditions is capable (S. Haan, 2010, B.J. Puntin, 2012)
    - BDS code 5,0: Track and turn report
    - BDS code 6,0: Heading and Speed report

DAPs data collection with ENRI's two research systems of SSR mode S (2)

- Headquarter site
  - Operated from 2008
  - Coverage: 250NM,
  - Period: 10 seconds
- Iwanuma blanch site (boarders on Sendai Airport)
  - Operated from 2010
  - Coverage: 200NM
  - Period: 4 seconds





The current status of Lidar observation at Sendai Airport

- Lidar
  - Expected to be a monitoring tool for critical points to avoidance of aircraft to encounter wake vortex
  - Provides independent measurement data to validate on-board meteorological data in the concept
- Data accumulation activities
  - Restarted in May 2012 in cooperation with Mitsubishi Electric Corp. after a blank of a few years
  - The system was also upgraded in December 2012 with the cooperation activities
- RHI
  - Investigation of characteristics of wake vortex
- PPI
  - Focused on viewpoint of providing information enough to broadcast suitable flight paths with GBAS so as to avoid the effect of wake vortex caused by preceding aircraft
  - Comparison with DAPs data collected by SSR mode S data to validate on-board meteorological data in the concept

Summary

- ENRI started study on wake vortex avoidance application for departure using a Lidar, which was installed at ENRI's Iwanuma blanch in 2004
  - Total of 620 cases were investigated in collaboration with IFS/Tohoku Univ. and JAXA
- The current focus is directed to investigate and develop an operational concept to enhance GBAS benefits
  - IFF/TUBS and ENRI discussed and tested a future operational concept of avoidance to encounter wake vortex
  - Flight experiments under different meteorological condition
  - Investigation and collection of DAPs data using SSR mode S from a viewpoint from meteorological information on aircraft
- The current status of the Lidar observation at Iwanuma blanch
  - The Lidar observation was restarted in May and upgraded in December 2012 in cooperation with Mitsubishi Electric Corp
- A GBAS research system is also going to be installed at Sendai airport in Spring 2014

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