Initial Evaluation of NextGen Air/Ground Operations with Ground-Based Automated Separation Assurance

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8th US/Europe ATM R&D Seminar
June, 2009
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Summary

• Objective of the study
  – To Investigate how controllers and pilots handle nominal and off-nominal situations when separation assurance is automated

Main Points
• Ground-based automated separation assurance is a generally sound concept
• Trajectory-based conflict detection and resolution automation integrated with data link is the key enabler
• Flight crew preferences can be accommodated, but air and ground systems need to be compatible
• Future research is required to address human/automation interaction issues particular with regard to near-term conflict prevention
• Aircraft should always be on predictable trajectories
Problem

NextGen envisions up to three times today’s en route capacity and greater routing flexibility for airspace users

but …

• cognitive resources of air traffic controllers are limited
• conventional clearance-based separation assurance is impossible for unstructured high density airspace
Approach

Ground-Based Automated Separation Assurance

- the *automation* manages the separation
- the *operators* manage the automation, provide additional services and make decisions

*Experimental display at three times today’s density (3x)*
Emerging Cockpit Technologies

Traffic Alert & Collision Avoidance System (TCAS)

Controller

Data Link

Voice Link

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Trajectory Automation
(3-20 min time horizon)

Safety Assurance Automation
(0-3 min time horizon)

Galileo

Trajectories

Ground-based automated separation assurance
Based on the “Advanced Airspace Concept “ (Erzberger, McNally)
Human-in-the Loop Evaluation of Ground-Based Automated Separation Assurance

- Levels of Automation for Trajectory-based Separation Assurance
  *Prevot, Homola and Mercer, ATIO 2008*

- Pilot perspective of automated conflict resolutions
  *Johnson et al., ATIO 2008*

- Feasibility of Mixed Equipage
  *Kopardekar et al., ATM 2009*

- **Air/Ground Operations with Off-Nominal Events**
Objective and Method

**Objective:**
Investigate how controllers and pilots handle off-nominal situations when separation assurance is automated

**Method:**
Part-task study with integrated air/ground operations
- 6 controllers (3 current, 3 retired), 20 pilots
- 24 runs per controller, each 30 minutes
- 3 scripted events every 10 minutes
- Independent variables:
  - Traffic density (2x, 3x)
  - Near-term conflict avoidance mode (TSAFE/No TSAFE)
  - Flight Deck Equipage (CD&R, No CD&R)

Example: High climb rate of BTA779 causes 3 near-term conflicts (TSAFE issues left turn)
Experimental Design

Flight Deck Capabilities

CD&R
No CD&R

TSAFE No TSAFE
Traffic density

Ground-based safety assurance automation

Three scripted “off-nominal” events every 10 minutes

- Loss of data link communication
- Medical Emergency
- Loss of cabin pressure
- Early descent
- Late descent
- Unexpected turn
- Expected turn, but aircraft straight
- Climb rate too low
- Climb rate too high
- Pilot rejects trajectory uplink
- Pilot modifies trajectory uplink
- Pilot requests trajectory change
Roles and Responsibilities

Trajectory-based operations (3 to 15 minute to Loss of Separation)

1. The ground automation detects and resolves conflicts automatically and sends new trajectories to the aircraft without controller involvement
2. The flight crews execute ATC trajectories if acceptable
3. Flight crews can downlink new trajectories. If conflict free the ground automation will uplink approval. If not, it will present the request to the controller for review.
4. The controller monitors and makes decision on flight crew requests

Tactical safety assurance (<3 minutes to Loss of Separation)

1. The automation is responsible for conflict detection.
2. Short-term conflict resolution is a primary independent variable:
   - No TSAFE: the controller issues a verbal clearance without the automation
   - TSAFE: the automation proposes and issues a maneuver resolution automatically
3. Flight crews will receive a verbal instruction or a data link message with the resolution maneuver and are expected to comply with it quickly.
The automation manages the trajectories for all aircraft. One flight declares an emergency and the controller handles it.
High climb rate of BTA779 causes 3 near-term conflicts
TSAFE automation recommends left turn
TSAFE issues left turn
Controller issues stop altitude verbally
Aircraft is off-trajectory
Controller plans trajectory that will get aircraft back to its original route
Results: Operational Errors (Nominal Operations)

Operational Errors resulting from Nominal Ops during each 30 minute scenario (n=4*12)

Average Number of OEs

Traffic Density

2x 3x

No TSAFE TSAFE

Average number of conflicts:

2x: 32/30 min
3x: 67/30 min

Significant effect of traffic density for total number of operational errors and conflict resolution rate
Results: Operational Errors (Off-Nominal Operations)

Average number of conflicts:
- 2x: 2.25/30 min
- 3x: 2.25/30 min

No effect of traffic density on total number of operational errors and conflict resolution rate.
Results: Operational Error Analysis

Operational Errors were almost always associated with a late conflict detection.
1873 trajectory changes were sent by the ground-side
31 scripted rejections , 43 unscripted rejections (2.3%)
Results: Flight Crew Initiated Downlinked Trajectory Requests

**2x (n=49)**
- Rejected by Controller: 24%
- Approved by Controller: 12%
- Approved by automation: 64%

**3x (n=40)**
- Rejected by Controller: 38%
- Approved by Controller: 10%
- Approved by automation: 52%

ADS-B range limitations and differences in trajectory data and look ahead times resulted in trajectory rejections.
Controllers reported workload via a button press every 5 minutes during the run on a scale of 1 (very low) to 7 (very high)

Controller workload was generally low, but short peaks are not captured very well by this metric
Results: Controller Acceptance

How acceptable/feasible was the overall concept?
1 = completely unacceptable, 7 = completely acceptable

3 active controllers
experience: 15, 27, 28 years
Conclusions

- Ground-based automated separation assurance is a generally sound concept for trajectory-based operations in high density en route airspace.
- Trajectory-based conflict detection and resolution automation integrated with data link is the key enabling technology.
- Automating nominal operations causes generally low controller workload and opens up resources for controllers and pilots.
- Pilot preferences can be accommodated through data link, but air and ground systems need to be compatible.
- Future research is required to address human/automation interaction issues particular with regard to near-term conflict prevention.
- Aircraft should always be on predictable trajectories.