Issues for Near-Term Implementation of Trajectory Based Operations

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Technical Challenge

Develop procedures and surface issues for near term implementation of Trajectory Based Operations (TBO) during en route weather operations.
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No vectors allowed. All aircraft are always on a “publicly” known 4D trajectory.
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We are assuming that ground stations can be upgraded, but that equipage in the air is close to today’s.
Technical Challenge

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Weather poses a special problem for TBO because pilots make requests for weather deviations that are not precise (e.g., “request 20 left for weather”).
Technical Challenge

Develop procedures and surface issues for near term implementation of Trajectory Based Operations (TBO) during en route weather operations.

We will be “stress testing” TBO.
Types of Flight Deck-ATC Communication

- **Voice**
  - No Datacom
  - < 20% of aircraft

- **ACARS**
  - Aircraft Communications Addressing and Reporting System
  - Datacom, not integrated with FMS (text only)
  - Available on most transport category aircraft
  - Currently used only for communication with AOC

- **FANS**
  - Future Aircraft Navigation System
  - Datacom integrated with FMS
  - < 20% of aircraft
  - Currently used only in oceanic environments (VDL Mode 2 in Europe)
Current Day Procedures
Do Not Work for TBO

• Current day, HOST doesn’t know about flight changes

• What the controller knows (could put in HOST) is vague
  - Plane turns left 20 degrees at some point
  - Plane turns back at some point
  - The HOST doesn’t know where the plane is going

• To remove vagueness you need the point at which the maneuver will start and return
Creating Flight Plans with Initial Maneuver Points

Flight deck created FPs are off-the-nose

Prototype tools allow controller created FPs with maneuver points
Technical Approach

Human-in-the-Loop Simulation
Design

• 3 Aircraft Equipage Levels:
  - FANS-1A
  - ACARS
  - Voice Only

• Three Airspace Mixtures:

```
+----------------+---------+
| FANS           | Voice   |
| FANS           | ACARS   |
| FANS           | Voice   |
```

ACARS:
• Currently not available for ATC use but could be
• Similar to other possible solutions in that it provides non-integrated datacom
Scenario Participants

- Ghost Controller
- Experimental Controller
- Experimental Flight Deck
- Experimental Flight Deck
- Pseudo Aircraft
Controller Stations

• Single R-Side Station
• Prototype DSR interface
  - Conflict Detection
  - Manual Trial Planner
  - Auto Resolver
  - Dynamic Weather
• Display distinguished between the three classes of equipage
• Added ability to translate TBO flight plan to text for ACARS aircraft
Pilot Stations

• Two Pilot Crew

• Generic Boeing transport category flight deck
  - Mode control panel
  - Primary flight display
  - Navigation display with weather radar and TCAS traffic

• Three types of Datacom (Voice, ACARS, FANS-1A)
General Procedures

• Clearances
  - Controller creates a flight plan using tools and delivers to flight deck using available communications
  - Pilot enters into CDU, approves and executes

• Requests
  - Flight Deck requests (direct to waypoint if possible) and delivers to ATC using available communications
  - Proceed as Clearance (above)

• Controller monitors status and adjusts flight plans in host if planes drift off trajectory
Procedures

• Voice
  - Clearances
    - Controller creates off-the-nose flight plan (without initial maneuver point) using tools and radios it up
    - Flight deck turns to heading and then enters waypoint
    - Controller adjusts plan in host if plane cannot turn immediately
  - Requests
    - Flight Deck radios in like today (but may ask for specific waypoint)
    - Proceed as Clearance (above)

• FANS
  - Clearances
    - Controller creates flight plan with initial maneuver point and data-links it up
    - Pilots load, approve and execute flight plan
  - Requests
    - Pilots create off-the-nose flight plan using CDU and datalink it down
    - If controller approves, pilot executes flight plan
Procedures

• ACARS
  - Clearances
    - Controller creates flight plan with initial maneuver point and data-links it up
    - Clearance is translated into human readable plan (text) and transmits to flight deck
    - Pilots type clearance into CDU and approve
    - Execute flight plan at contingency time
  - Requests
    - Pilots free-text request to controller using ACARS
    - Proceed as Clearance (above)

AT: N3907W08710 PROCEED DIRECT BEGWI PRINC REST OF ROUTE UNCHANGED
FMS CONTINGENCY:
AT TIME 02:05:15Z FLY 055 TRACK.
WHEN ABLE DIRECT BEGWI PRINC REST OF ROUTE UNCHANGED
Dependent Measures

• Trajectory conformance
• Path stretch (efficiency)
• Closest Approach to Weather
• Errors (input errors, LOS, Wx Penetration)
• Negotiation duration/iterations
• Workload (ATWIT-like, Real time subjective)
• Post-trial questionnaire (Workload, Acceptability)
• Usability and acceptability ratings for procedures
• Rated quality of resolution (Real time)
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Trajectory
Conformance
Cumulative Distribution of Cross Track Error

World Predominantly:
- FANS
- ACARS
- Voice

Fraction Less Than or Equal

Cross Track Error

AC Type
- FANS
- ACARS
- Voice
Why Did Planes Go Off Track?

• Most flight path amendments were the result of off-the-nose requests from the flight deck

• With off-the-nose maneuvers it is difficult to synchronize the trajectory
  - Delays between requesting and approving
  - Delays between approving and executing
Workload
Mean of 4 Post-Trial Ratings

**Pilots**
- FANS: 2
- ACARS: 3
- Voice: 4

**Controllers**
- FANS: 4
- ACARS: 3
- Voice: 3
Concept Ratings

• Asked to rate agreement with 45 statements after the simulation (15 for each equipage level or mix)

• Examples:
  - (Controller) I was able to handle the # of aircraft in my sector when predominately FANS/ACARS/Voice
  - (Controller) Interactions with FANS/ACARS/Voice aircraft was acceptable
  - (Pilot) My ability to conform to FANS/ACARS/Voice delivered trajectories was acceptable
Controller Ratings
Number of Responses Implying Preference

FANS vs ACARS

Datacom (mean) vs Voice

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Pilot Ratings
Number of Responses Implying Preference

FANS vs ACARS

FANS vs Voice

Participant ID

Prefer FANS

Prefer FANS

Prefer ACARS

Prefer Voice

P1.1 P1.2 P2.1 P2.2 P3.1 P3.2 P4.1 P4.2 P5.1 P5.2 P6.1 P6.2 P7.1 P7.2 P8.1 P8.2

P1.1 P1.2 P2.1 P2.2 P3.1 P3.2 P4.1 P4.2 P5.1 P5.2 P6.1 P6.2 P7.1 P7.2 P8.1 P8.2
Main Issues with Datacom

Pilot Questionnaire Responses

“The typing was more time consuming than voice request and too much wait for a response.”

“ Took ATC too long to respond. Had to use voice often.”
Data Summary

• Surprising number of planes off trajectory
  - Flight trajectories were executed at different times so trajectories were not coincident
  - Planes appear to “miss” initial maneuver points

• Controllers did not differentiate between ACARS and FANS

• Pilots dislike Datacom
  - Longer response times
  - More head down time
Conclusions
Near-Term Implementation of TBO Possible

• Possible to make ACARS look like FANS to controllers
  - Conformance as good as FANS or Voice
  - Controller workload as good as FANS or Voice
  - Controller ratings as good as FANS or Voice

• Data suggest ways to improve procedures
  - Better conformance
    - Automating updates of trajectory in HOST after a maneuver
    - Unified procedures with controller always uplinking trajectory
  - Better pilot acceptance
    - Use voice for initial request then uplink trajectory