Initial 4D Trajectory Management Concept Evaluation

Tenth USA/Europe ATM R&D Seminar
Dr. Laurence Mutuel
The 3 SESAR Concept Steps

**Step 1: Time-Based Operations → 2025**
- Time prioritisation for arrivals at airport is initiated
- Datalink is widely used
- Initial trajectory-based operations are deployed through the use of airborne trajectories (by ground systems), and a Controlled Time of Arrival (CTA) to sequence traffic and manage queue

**Step 2: Trajectory-Based Operations → 2030**
- 4D-based business/mission trajectory management using System Wide Information Management (SWIM)
- Air/Ground trajectory exchange to enable tactical planning and conflict-free route segments

**Step 3: Performance-Based Operations → 2030+**
- Achievement of SWIM
- Collaboratively planned network operations with User Driven Prioritisation Processes (UDPP)

**Step 3 achieves the European High-Performance, integrated, network-centric, collaborative and seamless air/ground ATM system**

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**Step focused on flight efficiency, predictability and the environment**

**Adds capacity to step 1**
Initial 4D Concept Overview

13:12:55

En Route

Extended TMA

TMA

AMAN HORIZON

MP

13:42:46

13:50:03

13:59:38

IF

FAF

14:00:21

MP : Metering point

Airline Ops

En route ATC Center

Descent Wind

TRU WIND/ALT  ALTN WIND
060 /060/FL320  010 /065 FL330
055 /058/FL300
WIND
040 /055/FL270  REQUEST*
PREV
020 /050/FL250  PHASE>
015 /045/FL200

<RETURN

Descent Temp

SAT /ALT
-40 /FL320
-35 /FL270 WIND/TEMP
-33 /FL230  REQUEST*
-35 /FL200
-25 /FL150

<RETURN

Meteo (wind/temp)
Initial 4D Concept Overview

- **En Route**: 13:12:55
- **Extended TMA**: T/D
- **TMA**: AMAN HORIZON
  - MP
  - IF
  - FAF
  - 13:42:46
  - 13:50:03
  - 13:59:38
  - 14:00:21

- **Meteo (wind/temps)**
- **4D predicted Traj.**
- **ADS-C**
- **Airline Ops**
- **En route ATC Center**

- **MP**: Metering point

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*Source: Tenth USA/Europe Air Traffic Management Research & Development Seminar – Chicago, June 2013*
Initial 4D Concept Overview

En Route

13:12:55

Airline Ops

4D predicted Traj.
ADS-C

Meteo
(wind/temperature)

En route ATC Center

Extended TMA

Route Clearance (CPDLC or voice)

ETA_{min-max}
ADS-C

ETA_{min-max} Request

TMA

AMAN HORIZON

MP: Metering point

13:12:55

13:42:46

13:50:03

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T/D

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Airline Ops
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13:12:55

4D predicted Traj.
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Meteo (wind/temp)

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En route ATC Center

Route Clearance (CPDLC or voice)

RTA Clearance

ETA<sub>min-max</sub>

ETA<sub>min-max Request</sub>

AMAN HORIZON

13:42:46

13:50:03

13:59:38

14:00:21

MP : Metering point

MP

FAF

T/D

TMA

Extended TMA

Tenth USA/Europe Air Traffic Management Research & Development Seminar – Chicago June 2013

1324Z FROM ESMM

OPEN

CROSS CH446 AT 13:50:03

+-10S

*UNABLE

STBY*

<OTHER

WILCO*
Tenth USA/Europe Air Traffic Management Research & Development Seminar – Chicago, June 2013

Initial 4D Concept Overview

En Route

Extended TMA

TMA

AMAN HORIZON

MP: Metering point

RTA Clearance

ETA_{min-max} Request

ETA_{min-max}

ADS-C

4D predicted Trajectory

Meteo (wind/temp)

Airline Ops

En route ATC Center

RTA

AT WPT DIST RTA

CH446  42  13:50:03

MANAGED ETA

270  13:55:04

ACT MODE

MANAGED

VMAX UTC

290/0.79  13:24:35

£$ ACCUR +/-10

<RETURN
Airborne Segment

- Cockpit Display Systems
  - Engagement of I4D operations
  - Monitoring of I4D operations
- Flight Management System
  - I4D Predictions
  - I4D navigation performance
  - I4D guidance
- Data Communication System
  - ADS-C application
  - CPDLC application

Ground Segment

- Arrival Manager (AMAN)
  - Arrival sequence with I4D CTA
  - Ground/Ground coordination
- Other ATC systems
  - Distribution of AMAN CTA
- Data Communication System
  - Dispatch of aircraft trajectory info
  - Emission of I4D messages
- Datalink Service Providers

Prototype equipments installed onboard Airbus 320 test aircraft; FMS prototypes from Thales/GE and Honeywell.

Thales automation system in shadow mode, dedicated controller position, flight tests over French, Maastricht and Danish/Swedish airspaces.
Initial 4D Flight Tests

◆ Objectives
  - Confront the onboard design with real conditions and environment
  - Demonstrate technical feasibility of I4D in nominal operations
  - Assessment of avionics interoperability (FMS)

◆ Performance
  - I4D flight trial was successfully executed on 10 February 2012
  - Round-trip flight from Toulouse to Stockholm with loop about Stockholm
  - Flight controlled by voice by operational controllers to ensure separation
  - Datalink used between aircraft and dedicated controller position for all I4D

◆ Scenario
  - 6 individual demonstration tests
  - 6 flight legs with each a single time constraint (Controlled Time of Arrival (CTA))
    - 2 en route CTAs, 4 descent CTAs
Feasibility of Onboard Nominal Operations
- Task sharing aligned with existing philosophy and well balanced
- No missing or out-of-sequence task
- Automation level satisfactory
- Manual entry of temperature in descent

I4D Onboard Functions Definition and Navigation Performance
- Level of definition satisfactory, including HMI and A320 cockpit integration

<table>
<thead>
<tr>
<th>CTA</th>
<th>Overfly time and error</th>
<th>Comment</th>
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<tbody>
<tr>
<td></td>
<td>FMS log</td>
<td>Crew log</td>
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<tr>
<td>1</td>
<td>08:27:04 +4s</td>
<td>08:27:06+6s</td>
</tr>
<tr>
<td>2</td>
<td>08:59:59 -1s</td>
<td>09:00:02 +2s</td>
</tr>
<tr>
<td>3</td>
<td>09:56:15 +0s</td>
<td>09:56:16 +1s</td>
</tr>
<tr>
<td>4</td>
<td>13:03:38 +2s</td>
<td>13:03:39 +3s</td>
</tr>
<tr>
<td>5</td>
<td>13:50:04 +1s</td>
<td>13:50:04 +1s</td>
</tr>
<tr>
<td>6</td>
<td>14:39:01 +1s</td>
<td>14:39:02 +2s</td>
</tr>
</tbody>
</table>

Navigation Performance: all CTAs met within prescribed tolerance
I4D Onboard Functions Time Performance

- Deceleration when RTA set in the middle of ETAmín/max window
  - Recommendation 1: AMAN favoring CTA values close to the aircraft initial ETA
  - Recommendation 2: simple algorithm on the ground to estimate initial speed adjustment at CTA insertion

- Initial ETA possibly outside the ETAmín/max window
  - Limited to cases of high initial aircraft speed or high cost index
◆ I4D Datalink aspects
  - VDL2 coverage limitations to be taken into account in I4D planning
  - Process time to downlink ADS-C EPP dataset after receipt of route clearance expected to be significantly improved for next flight test
  - CPDLC message set complete and understandable
  - Recommendation to directly load CTA clearance into active flight plan
  - Uplink of CLEARED [route clearance enhanced] erased all winds/temps; issue when this message is used for route amendment

◆ Technical Feasibility of ground and air segments integration
  - Demonstration of air/ground trajectory synchronization and CTA assignment
  - Demonstration of usability of CPDLC and ADS-C
Wide scale evaluation and without added supporting tools

- Commercial flights into Stockholm-Arlanda:
  - Scandinavian Airlines, Novair and Lufthansa; B737-600, -700 and -800; A320 and 321
- FMS with RTA function, CTA set at waypoint in descent about FL100
- Low to medium traffic densities

Main findings

- 92% of all flights achieved their assigned CTA within 30 seconds (tolerance)
- CTA operations are positive method to absorb delays and sequence arrival flow
- Airborne ETA function performs well for CTAs between FL70 and FL202
- ATC cross-coordination possible but increases workload and requires time
- Large difference between FMS ETA and ground ETA at metering fix and runway
- More mature tools on the ground needed for CTA operation in medium/high traffic
- Long time interval between assignment of inbound clearance and FMS ETA receipt
- Ground systems require more trajectory information from aircraft to reduce uncertainty in CTA operations
Next Steps

- Further air/ground coupled simulation validation exercises ➔ 2013/2014
  - Maastricht and Noracon control centers
  - Complete the coverage of I4D validation scope
    - Acceptability of I4D nominal operations (incl. workload)
    - Use-case development for abnormal operations
  - Address some of the recommendations from previous validation exercises
    - ETA outside ETAmn/max window
    - Monitoring of erroneous implementation of clearance message
    - Consolidation of the maturity assessment of I4D Trajectory Management
  - Issue validation reports and recommendations from various points of view
    - Aircraft/onboard systems
    - ATC/control center/ATM automation systems
Safety and Performance Requirements (SPR) of ATS datalink services (RTCA SC-214 / Eurocae WG-78)
- [no impact] 4DTRAD service supports I4D on ATN as part of new standard ATN Baseline 2 / FANS C

- [convergence required] Navigation performance requirements for I4D RTA to be re-including before closure of the standard

ICAO
- Revision of ICAO PANS-ATM for data communications
- Revision of ICAO Performance-Based Navigation manual

AEEC standards
- A702A AOC portion revised to support FMS loading of temperatures in descent
Flight trial of the I4D concept successfully demonstrated the operational and technical feasibility from both airborne and integrated air/ground perspectives

All key concept elements exercised

Avionics interoperability shown

Trajectory synchronization realized through data communications

Integration of airborne trajectory in ATM automation shown to improve trajectory prediction and computation of achievable CTA

Stakeholders favorably assessed concept in terms of procedures, expected tasks, Human-Machine Interface design, and workload

Sufficient feedback received to plan next validation exercises (flight tests and integrated air/ground simulations)
Thank you for your attention

Questions?

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