THE SESAR CONCEPT AND i4D

David Bowen
Head of ATM Operations & Systems
SESAR Joint Undertaking
SESAR Priority Strategic Business Needs

- Moving from airspace to 4D trajectory management
- Traffic synchronisation
- Network collaborative management and DCB
- Airport integration and throughput
- Conflict management and automation

System wide information management
Moving from Airspace to 4D Trajectory Management

- 3D Position & Time - all phases of flight, all stakeholders
- A set of trajectories delivering preferred routes and timings taking into account all constraints
- Predictable Civil Airline Operations & Military Mission Planning
- All phases of operation
- Depends on a predictable Airport Turnaround process
The Business/Mission Trajectory

- The trajectory requested by the Users is called “business/mission trajectory” (B/MT) and becomes the trajectory that the ANSP agrees to facilitate and the AU agrees to fly.
- A common view of the trajectory is shared between air and ground stakeholders.
- The trajectory supports better predictability and automation.
What is i4D?

A first step towards 4D Trajectory Datalink (4D-TRAD)

- Sharing and synchronising airborne and ground trajectory.
- Flying to a single time constraint

4D \( \rightarrow \) Latitude, Longitude, Altitude + Time
i4D Demonstration

• A 7-minute film
  – Selected portions of a simulated flight cruising through Maastricht UAC then descending to CPH
  – Recorded during the preparation of the i4D flight trial earlier this year
  – Illustrates:
    • Exchange of 4D trajectory
    • Use of CTA to sequence arrival traffic
  – 3 different views of i4D operations:
WHERE ARE WE TODAY WITH i4D/CTA VALIDATION?

Marouan Chida
i4D project manager
AIRBUS
Agenda

1. Cockpit Integration and Validation Campaign
2. Airborne Findings
3. Conclusions
Agenda

1. Cockpit Integration and Validation Campaign
2. Airborne Findings
3. Conclusions
i4D Cockpit Integration

Electronic Information System (EIS) Displays

Air Traffic Service Unit (ATSU) Communication

Flight Management System (FMS) Navigation & Guidance

Avionics A429 link
i4D Airborne Features

- **Improved Time of Arrival Control**
  - Accuracy +/- 10 seconds with 95% reliability

- **Improved Weather Modeling**
  - 10 wind levels to the FMS wind model (5 levels today)
  - 10 temperature levels to the FMS temp model (1 level today)
  - Enhanced loading of Wind and Temperature uplinks into the FMS

- **Min/Max Estimated Time of Arrival (ETA) Function**
  - Available onboard for any waypoint (RTA FMS page)
  - Min/Max ETA reported through ADS-C

- **Datalink**
  - Enhanced FANS capability (Datalink B2) with integrated HMI
  - CPDLC: Enhanced Route Clearances & New RTA messages
    (1 Sec resolution + tolerance value)
  - ADS-C: Downlink of the 4D Trajectory (Demand/Event/Periodic)

Available in the SESAR airborne prototypes!
i4D Challenges

Demonstrate the Technology
(Air and Ground)

Assess Operational Acceptability
(Air and Ground)

Assess Benefits

Standardize
(Datalink and Navigation Performance)
i4D Validation Campaign

• SESAR Validation Campaign - Essential to Achieve Maturity
  • Closely-coordinated Air and Ground developments
  • Stepped and integrated Air and Ground validations
i4D Simulations

More than 400 hours of simulation and flight testing ...

Non-Coupled Sessions

Coupled Sessions

Technical Flight Tests

SESAR Flight Tests
Agenda

1. Cockpit Integration and Validation Campaign

2. Airborne Findings

3. Conclusions
Flight trial results

- All RTAs made: +4s, -3s, +2s, +7s, +3s and -2s
- Datalink exchanges ADS-C and CPDLC messages done correctly
- GND/GND coordination done
- Wind/temp & FPLN uplinks by AOC highly appreciated by the flight crew
- Gathered feedback on system behaviour

Note: All times in the document are UTC

March 2014
Airborne Findings

- **Demonstrate the Technology**
  - i4D Technology works:
    - A/G Datalink & Cockpit Technology tested and demonstrated
    - Avionics design is mature and performance was demonstrated
    - CTA accuracy +/- 10 seconds with 95% reliability was achieved

- **Assess Operational Acceptability**
  - i4D is well-integrated in the cockpit:
    - Operational Acceptability has been validated with test pilots, flight test engineers and airline pilots
    - i4D is compatible with current crew operations
    - Pilots & Controllers are able to see the concept working

- **Assess Benefits**
  - i4D will bring valuable benefits to the airspace users:
    - RTA is more efficient than holding and path stretching techniques
    - i4D has a great potential for improving flight efficiency.

- **Standardize (WG85, WG78)**
  - i4D offers fully-standardised solutions
    - All validation findings were fed back to EUROCAE & RTCA
    - Interoperability is guaranteed.
    - “Datalink B2” standards is available (released in May)
    - “4DNav “standards will be released in Oct 2014.
The Airborne industry supports Ground partners, in further developing this potential and in moving towards deployment.

The maturity of the Datacom Service (AF6) considered by the PCP is demonstrated.

Initial 4D is feasible, interoperable and demonstrates a great potential to improve ATM operations.
1. Cockpit Integration and Validation Campaign
2. Airborne Findings
3. Conclusions
i4D AS PART OF AN AIR TRAFFIC CONTROL SYSTEM
– EN-ROUTE

Ramon Tàrrech
ATM Strategy Development Director

Indra
The ATM system relies on all actors having the same view; it is therefore essential that the trajectory in the Flight Management System (FMS) is the same as that held on the ground in the Flight Data Processing Systems (FDPS) and the wider Network systems.
Initial 4D operation → ATM System

- i4D is the initial step of the 4 Dimension Trajectory Data-Link (4DTRAD) operational concept previous to full 4D.
- i4D Operations requirements → Ground ATM System
  - Sharing of On-Board 4D trajectory data with ground system → Synchronisation between air and ground of the Flight Plan or Reference Business Trajectory -RBT.
  - Provision of a single time constraint (CTO/CTA) at a specific point during the cruise/descent/approach phase including monitoring of its trajectory → Imposing a time constraint and allowing the aircraft to fly its profile in the most optimal way to meet that constraint
  - Conformance to the assigned constraints → Improving predictability
i4D/CTO operational concept → ATM System

- Controlled Time Over-fix (CTO), including the use of i4D aims at better pre-sequencing traffic in the last sector of En-Route
  - It allows the controller to sequence the inbound traffic aircraft well in advance on a selected Metering Fix located in the entry sector
  - It allows the sharing and synchronisation of airborne and ground trajectories

- The i4D/CTO concept allows the supervisor or other planning authorities to better predict the trajectory of an entry aircraft from its current position in cruise to a new sector En-route (CTA/CTO calculated with reference to the airborne ETAmín/max).

- It can be associated with Traffic Management System (TMS) for flow management

i4D is a first step towards trajectory-based operations
i4D ATM System - Technology

- Discrepancy indicator
  Airborne/Ground trajectory
- Flag an on-going RTA uplink
- Speed Change Assessment Tool (SCAT)
- Speed Change Monitoring & Alerting Tool (SCMAT)

Modified HMI to display new functions including improved ATCOs Awareness via EPP display

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Flight Data Processing

- Modified data link: ATN Baseline with additional messages
- Inter-centres coordination via OLDI slightly modified 1st phase) and SWIM

Communications

HMI-Controller Working Position
Discrepancy Indicator: identification

EPP & SDD Snapshot
Discrepancy Indicator: Resolution

EPP & SDD Snapshot
RT* process’g: Speed Change Assessment
RT* process’g: request to Airspace User

EPP & SDD Snapshot
RT* process’g: WILCO received

EPP & SDD Snapshot
i4D AS PART OF AN AIR TRAFFIC CONTROL SYSTEM

Michel Procoudine
SESAR Programme Technical Director
Thales
The Initial 4D/CTA concept

- Controlled Time of Arrival (CTA), including the use of i4D aims at better sequencing traffic in the Terminal Manoeuvring Area (TMA)
  - It allows the controller to sequence the arriving aircraft well in advance on a selected Metering Fix located in TMA
  - It allows the sharing and synchronisation of airborne and ground trajectories
- The i4D/CTA concept allows the controller to better predict the trajectory of an arriving aircraft from its current position in cruise down to the runway
- It can be associated with Arrival Management Extended to En Route

i4D is a first step towards trajectory-based operations
The Initial 4D concept

Weather forecast from AOC (Airline Operations Center)

ADS-C CPDLC initiation

EPP with 4DT

2D Route Clearance

EPP with 4DT

ETA min/max request on ETA min/max

CTA constraint

EPP with 4DT

13:55:20

ETA min = 13:47:36

CTA = 14:00:49 (Controlled Time of Arrival)

14:02:43

14:06:40

14:11:58

ETA max = 14:03:56

AMAN Arrival HORIZON

TOD

Metering Fix (MF)

IAF

FAF

FROM INNOVATION TO SOLUTION
The main technical enablers/functions

- Modified data link: ATN Baseline 2
  - Additional messages
- Enhanced AMAN (Arrival MANager)
  - To compute CTA based on ETA$_{\text{min,max}}$
- Modified HMI
  - To display CTA related windows, EPP trajectory
- Improved ground Trajectory Prediction
  - Optimising the use of EPP
- Inter centres coordination
  - via OLDI (On-Line Data Interchange) at first stage (slightly modified)
  - with SWIM
Ground Findings

- **Demonstrate the Technology**
  - i4D Technology works
    - Evolutions of ATC Ground Systems were developed, tested and demonstrated
    - Design is mature and performance was demonstrated

- **Assess Operational Acceptability**
  - i4D is well-integrated
    - Operational Acceptability has been validated with air traffic controllers
    - The information in the EPP is greatly appreciated and increases controller confidence for planning, monitoring and separation management
    - Operations benefits from CTA accuracy +/- 10 seconds with 95% reliability performance

- **Assess Benefits**
  - i4D will bring valuable benefits
    - The trajectory element of the i4D concept shows promise for future operations to enhance the trajectory prediction and controller tools (AMAN, MTCD, CWP, ...)

FROM INNOVATION TO SOLUTION
i4D and ATC efficiency

Niclas Gustavsson
Director Business development & International affairs

LFV
The ANSP challenge – automation is needed
Initial 4D Trajectory Management (i4D) is a concept ensuring:

- trajectory information exchange directly from aircraft FMS to ground ATC System (and other users via a digital network)
- time-constraint management between the air and ground using RTA (Required Time of Arrival) airborne FMS functionality

It is expected to provide

- improved efficiency
- predictability
- safety
- support to efficient traffic synchronisation
The key enablers

• Reliable aeronautical information by all stakeholders
• Access to safety critical air ground communications
• Digital aircraft and ground ATM environment
• Synchronised research and development – SESAR
• Next generation of air traffic controllers – the digital generation
• Increased traffic volumes providing incentives to change

Automation
The rationale for i4D

• Initial 4D Trajectory Management (i4D) enhances ATC efficiency
  – Through synchronisation of the precise trajectory onboard the aircraft with the trajectory in the ATC system, the controllers get high confidence in the expected behaviour of the aircraft, thereby, allowing for more efficient handling of the air traffic.

• i4D support precise resource allocation
  – Through high predictability of the airspace hotspots where high volume of traffic will interfere and likewise airspace where low traffic demand and complexity will occur. ATC will manage their resources in the most efficient way.
The rationale for i4D

• i4D brings reduces workload
  – The precise predictability allows improved Arrival Management Processes that reduces the workload in Terminal Area Approach Units. En Route controllers are more involved in synchronising the traffic merging towards high density/complexity TMAs.

• i4D brings less environmental impact reducing noise and pollution
  – The improved Arrival management process leads to shorter flight distance at lower altitude in the vicinity of the airport.
  – Will enable more continuous descent approaches or green arrivals (CO2 – noise)
Validation observations – work in progress

**Ground (ATC)**

- Concept globally accepted by controllers but with the need for further refinement and assessment
- Benefits observed but no conclusive - no negative impact identified
- Interaction between key stakeholders is an important factor for success.

**Focus for the coming developments and validations:**

- Further improve the HMI related to i4D procedures
- Concept and platform maturity to be improved to get conclusive feedback
- Refine the concept on topics such as:
  - the arrival management (AMAN) should comply integration of i4D/CTA aircraft with other traffic
  - i4D-equipped aircraft may be given tactical instructions by the ATCO, in which situations?
  - The working methods of the controllers when i4D/CTA aircraft are in the traffic flow mixed with other traffic
i4D set the scene for the ATS system upgrade(s)

En-Route

- FMS with RTA capability
- ETA min/max window
- Extended Projected Profile (EPP)
- Data link capability supporting CPDLC and ADS-C

- Ground-Ground coms
  - Current solution is limited
  - SWIM is a pre-requisite for full conceptual support

TMA

- Extended AMAN Horizon (i.e. 200 NM)
- ETA min/max support
- CTA negotiation

- Ground trajectory prediction tools supporting EPP
- i4D+CTA HMI

ATSU 1

ATSU 2

AMAN

FROM INNOVATION TO SOLUTION
To see is to believe......ATCO involvement
i4D IN ASIA: A REGIONAL PERSPECTIVE

Rosa Weber
Globalisation Manager
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China’s Projected Traffic Growth

• IATA reported on 6 February 2014
  – Between 2012-2017, 24% of new passengers worldwide will fly on Routes within or connected to China
  – Additional passengers: 195 million domestic, 32.4 million international
  – Domestic China traffic climbed 11.7% in 2013 compared to 2012, the strongest growth for any market
• China will likely need additional solutions to address this rapid traffic growth.
  – i4D is one possible solution.

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3 Hr i4D Flight From Tianjin to Guangzhou

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ADS-C EPP Report and Min-Max ETA Report

• FMS computes Optimum Flight Profile = User Preferred/Optimum Trajectory
  – Flight crew loads updated meteorological data for the flight route
  – FMS uses AC performance data, AC sensor data, forecasted and sensed weather data, flight trajectory data and ATC constraints.

• Aircraft downlinked 4D Trajectory (ADS-C EPP) includes:
  – Waypoints (lateral and vertical), TOD, TOC
    • Altitude, time, and speed predictions
    • Aircraft Gross weight
  – Constraints in the flight plan (altitude, speed, time)
  – Fuel-Optimum descent speed schedule
  – Performance data that enhances the predictions on the ground
  – Min-Max ETA not part of downlinked 4D Trajectory, separate report
    • ETA range at waypoints specified by ATC, computed by FMS using fastest/slowest speeds

• A/C in FMS managed mode (LNAV/VNAV) accurately flies the predicted 4DT
  – Reduced uncertainty on the aircraft position
  – Reduced fuel usage, emissions and noise via more efficient descent profiles

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i4D – Benefits

• Gain Accuracy and Predictability
  – ETA and RTA are tools to improve predictability of flights; AMAN is another tool.
  – Trajectory downlinks provide TOD, TOC knowledge to the ground
  – Constraint on time of arrival and predictability of flight enables
    • improved strategic control of traffic,
    • reduced tactical corrections (vectoring, path stretching) by ATC,
    • reduced need for holding patterns

• Improved Airspace Capacity
  – Coordinated trajectory enables better airspace throughput and optimization on most demanding and congested airspace.
  – i4D enables ATC to anticipate sequencing to the merge point, thus improving predictability and throughput in a very constrained environment

• Improve Safety
  – Reduced frequency congestion with the use of datalink communication
  – Enhanced conflict detection via shared knowledge of predicted flight trajectories

• Reduce Pollution
  – 4D Control enables Continuous Descent Arrival (CDA) / Optimal Profile Descent (OPD) during higher density operations.
  – Reduced fuel, reduced emissions and reduced noise through optimum flight trajectories, more efficient descent profiles.

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China’s i4D: Potential Next Steps to meet Traffic Growth

1. Extend regional ATFM system(s) into a national ATFM system to share traffic and trajectory data across China’s ATFM facilities
   – Arrival Management systems need 250 miles and ~40 mins time to be strategic.

2. Implement 4D management of flights (e.g., AMAN system)
   – Basic 4D management of flights is possible after step 2.

3. Expand the use of Datalink Communications (CPDLC, ADS-C EPP)
   – Enable ATC to send departure and route clearances, weather-avoiding reroutes, via text messages directly to the flight deck.

4. Deploy China’s ATN network for ground-ground and air-ground communication
   – Enable flight deck to downlink ADS-C EPP report (4DT) and Min-Max ETA report
   – FANS via ACARS limited to 2 waypoint downlinks instead of full trajectory
   – i4D with FANS and CPDLC (baseline 1) can only define minute-based spacing (to avoid conflict).

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中国空中交通增长的预期

- 国际航空运输协会（IATA）在2014年2月6日报道
  - 在2012-2017年间，有新增24% 的旅客将飞往或在中国转机
  - 新增加的乘客：国内1.95亿人次，国际3240万人次
  - 2013年，中国国内空中交通比2012年增长11.7%，是所有市场中增长最快的
- 中国或许需要额外的手段来应对快速的空中交通增长
  - i4D 可能是其中一种解决方案.

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3小时 i4D飞行从天津到广州
ADS-C的EPP 报告和最小/最大 ETA报告

- **FMS**计算最优飞行剖面 = 用户首选的/最优的航迹
  - 机组为飞行路线加载更新后的气象数据
  - **FMS**运用到飞行器性能数据、传感器数据、预报和测量的天气数据、飞行航迹数据和**ATC**的限制约束等数据

- 飞行器下行传送四维航迹（**ADS-C EPP**报告）包含:
  - 航路点（水平和垂直）、 最高下降点、爬升最高点
  - 高度、时间和速度预测
  - 飞行器总重
  - 飞行计划中的限制约束（高度、速度、时间）
  - 燃油最优的下降速度方案
  - 增强地面预测的飞机性能数据
  - 最小/最大**ETA**报告并不是下行传送的四维航迹的一部分，是一个单独的报告
  - **ATC**指定的一些航路点预计到达时间（**ETA**）的范围是**FMS**利用最快/最慢速度计算

- 飞行器在**FMS**管理模式（**LNAV/VNAV**）下可沿预测的四维航迹精确飞行
  - 减小飞行器位置的不确定性
  - 利用更有效的下滑剖面来减少燃油使用、排放和噪声

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i4D — 效益

• 增加精度和可预测性
  — ETA和RTA是提高飞行可预测性的工具，AMAN是另一种工具
  — 轨迹的下行传送为地面提供了最高下降点（TOD）和爬升最高点（TOC）信息
  — 对到达时间的约束和飞行可预测性能够
    • 提升空中交通的战备管制
    • 减少ATC的战备修正（航向改变、路线延伸等）
    • 减少对空中等待航线的需要

• 提高空域容量
  — 经协调的航迹可提高空域的吞吐量，并优化非常苛刻和拥挤的空域
  — i4D使ATC可预见飞机到合并点的排序，从而提高可预测性和在强约束环境下的
    飞机通过数

• 提高安全性
  — 用数据链通讯以减少频率拥堵
  — 用共享的预测飞行航迹以增强冲突探测

• 减少污染
  — 四维航迹控制可实现在高密度运维中的连续下降进近（CDA）/最优剖面下滑
    （OPD）技术
  — 通过最优航迹和更有效率的下滑剖面来减少燃油、减少排放和减少噪声

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中国的i4D：潜在的应对交通增长的下一步计划

1. 将区域性空中交通流量管理（ATFM）系统扩展为一个全国的ATFM系统，让中国所有流量管理单位共享交通和轨迹信息
   - 实现战略上的到场管理系统，其作用范围需要250海里距离和约40分钟时间
2. 实施四维飞行管理（例如：AMAN系统）
   - 基本的四维飞行管理在第2步后是可行的
3. 扩大数据链通信的应用（CPDLC、ADS-C EPP）
   - 使ATC可以通过文本信息直接向飞行机组发送离场放行和路线许可，以及因天气回避而产生的变更路线
4. 为地-地和空-地通讯部署中国的ATN网络
   - 让驾驶舱可以向下传送ADS-C EPP报告（四维航迹）和最小/最大ETA报告
   - 基于ACARS的FANS仅支持两个航路点的下传，而不是完整的四维航迹
   - 仅基于FANS和CPDLC（基线1）的i4D只能定义分钟级的间隔（用以避免冲突）

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SESAR i4D TRAJECTORY MANAGEMENT - TOWARDS DEPLOYMENT

Lionel Rouchouse
SESAR Project Manager

Thales
i4D impact

- **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
i4D requirements

- **Airborne Segment**
  - **Flight Management System**
    - Compliant against the WG 85 / SC 227 : DO-236C / ED 75B (available October 2014)
  - **Data Communication System (Communication Management Unit / Air Traffic System Unit)**
    - ATN protocol (ED-110 B)
    - VHF DataLink Mode 2 has to cover all areas where I4D will be used
    - Compliant against WG 78 / SC 214: DO-250/ED 228 and DO-351/ED-229 (published)
i4D - Towards deployment: Data collection phase

- A data collection phase has been proposed prior to deployment
  - In the scope of Large Scale Demonstration Activities – under evaluation
  - Objectives:
    - Data Collection for flight trajectory prediction (Extended Predicted Profile) performance assessment (Approximately 80 A320 production aircraft ferry flights)
    - Establish reference Business trajectory with CFMU
  - Timeframe: End 2014 till March 2016
  - Actors: Airbus, Thales, NATS, skyguide

Route 5

MEN UN871 MOLUS UN853 DIK LIRSU ARCKY
UZ907 ABAMI UM170 BASUM Z78 WSR T903
RISBO

FROM INNOVATION TO SOLUTION
i4D - Towards deployment

• Very Large Scale Demonstration (part of SESAR2020 scope)
  – Objectives:
    • demonstrate a global improvement in ATC tool performance based on an enhanced ground Trajectory Predictor (TP), using accurate aircraft 4D trajectory information
  – Maturity:
    • Functions and systems are fully developed, based on mature standards and certified on the basis of regulations similar or close to the ones that will support deployment
    • Air/Ground procedures are fully representative of the targeted mode of operations
i4D Wide Scale deployment phase

- « Initial Trajectory Information sharing (towards i4D) » is part of the first set of **ATM Functionalities (AF#6)** for a wide scale coordinated deployment
- European Commission has adopted June 27th 2014 a Regulation for the implementation of this first set of ATM Functionalities
- AF#6 deployment time frame is from 2018 to 2025
- With some i4D capable aircraft, we will already obtain some of the benefits of i4D
TOWARDS i4D DEPLOYMENT

Ramon Tàrrech
ATM Strategy Development
Director

Indra
ATM Ground Systems i4D Way Forward

i4D deployment

Very large demonstrations

Refine and industrialize ground tools

EPP data to improve ATM Sys.

Trajectory Prediction (TP)
- Actual Gross mass
- Dynamic speed schedule for each aircraft
- Modelling detailed 2D turning manoeuvres

Medium Term Conflict Detection (MTCDD)

Ground calculated Vertical Profile and Sector Sequences
Thank you for your attention!