On the Feasibility of Traffic Synchronization in Central European Upper Airspace

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Future vision of Synchronized ATM system

- Proposed organizational changes
  - Multi Sector Planner
  - Super Sector
  - Shift

- The potential of flow synchronization
  - Future ATFM measures
  - En-route Miles-In-Trail Spacing

- Comparison of US and European Airspace

Difference: en-route techniques Miles-In-Trails

US controllers more productive than European!
tactical establishment and maintenance of a safe flow of traffic with higher throughput

Assumptions:

- In synchronized structure the control system applies the same procedures to each aircraft flying in a flow.

Each synchronized flow has its own speed and flight level; the flow speed fixes the speed of the flight (only vertical movements applied).
Improvements of safety through removing potential conflict situations and increasing the airspace throughput as a result of traffic flow synchronization is:

**Desired and needed!**

by 2020 100% increase

annual 3-4% traffic increase
Feasibility
- Is it possible to synchronize the traffic with current system?

Operational feasibility
- Is the solution solving the problem?
- Technological & economical issues to be investigated later

But for whom?
- Airspace users-airlines, providers
- Controllers, pilots
- Better utilization of existing route network
S = R; T; C

**R - REGULARITY**
- Variance of speed distribution over 1FL
- Coefficient of variance
- Standard deviation of speed over 1FL
- Moment of spread of traffic distribution over 1FL

**T - TASK-LOAD**
- Number of horizontal conflicts
- Number of vertical conflicts
- Number of conflicts within a flow

**C - COSTS**
- Over-flown time

**Level 1**
- Goal

**Level 2**
- Criteria

**Level 3**
- Indicators
Flow structure – transition time/distance?

C – capacity of the flow
  \( C_c \) – capacity of the flow under current conditions
  \( C_s \) – capacity of the synchronized flow
L – length of the flow
  \( L_s \) – synchronized length
  \( L_t \) – transit length
\( D_{\text{space}} \) – min. separation between aircraft

\[ C_s = \frac{L}{D_{\text{space}}} \]

Example: current conditions: 60 aircraft
The whole flow length synchronized: 100 aircraft

\[ C_s > C_c \]

Than: \( L_{\text{min}} = D_{\text{space}} \times \text{min. nb. of aircraft (61)} \)
And: \( L = L_s + L_t \)

Means that: \( L_t = L - L_s \)
The Target Flow is defined by:
- $A_T$ – the Assigned Flight Level
- $V_T$ – the Target Speed (desired speed of the flow)

Each aircraft $i$ is defined by:
- $V_i(t)$ – Actual Speed
- $A_i(t)$ – Actual Flight Level

The goal:
- $V_i(t) \rightarrow V_T$
- $A_i(t) \rightarrow A_T$

Does the transit phase encompass ONE sector (?)
CEATS—Central European Air Traffic Services

- High traffic growth
- Large area of operation
- Better inter-sector coordination

Czech, Slovakia, Austria, Hungary, Slovenia, Croatia, Bosnia & Herzegovina, Italy (ACC Padua)

There are some notable increases in delay in Paris, France West and “CEATS” =124%.
2 Selected routes (cruising traffic):

1. CHI EM - OBEDI - ZAG - JULIE
2. TONDO - BEGLA - GISPO - %LO11 - PASAU
There is more than an equation of speed and over-flown time

Limiting factors
- Aircraft performance envelop
- Number of conflict situations
- Task-load
- Costs
- …

1st step towards well-organized traffic flows and hence safety improvements is to have a sound knowledge of traffic distribution taking into account limiting factors
CEATS is not under the operation yet, the last model simulation is taken as a basis

“FTS 4” - basis

⇒ Already existing:
  ⇒ # of conflicts ✓
  ⇒ Capacity ✓
  ⇒ Task-load ✓

⇒ Additional measurements:
  ⇒ Over flown time (mean value per sector & per FAB) ✓
  ⇒ Average speed versus % of traffic ✓
  ⇒ Aircraft types versus speed ✓
  ⇒ Speed versus FL’s ✓
### Speed distribution by Flight Level (FL285 and above)

#### Analysis

- **96 different speeds** with only slight deviations
- **31 aircraft groups**
- **10 most preferred** represent 89.9%

**On the Flight Level Basis**

- Get overview over traffic (sample – 5241 aircraft) situation:
  - Created graphs showing relation between:
    - a/c - FL
    - a/c - M
    - a/c – wake cat.

- 17.78% → FL 370
- 54.42% → 0.8 M
- 83.53% → cat. M
Traffic flow synchronization can be used to smoothen the traffic operations in high density areas with mainly long-hauls flights.

Increasing the airspace throughput and remove potential conflict situations are the main elements of synchronized ATM concept.

The positive results depends on appropriate synchronization model with respect to aircraft performance envelopes.
Finalize the Synchronization model
  ➔ Mathematical and experimental set up

Finalize the Rule-based Algorithm
  ➔ To minimize the aircraft movements

Want to achieve
  ➔ Objective results of traffic flow synchronization through traffic flow capacity increase (?) and potential conflict situations decrease (?) and hence improvements of safety to support the operational feasibility applied in case of Central European Upper Airspace
THANK YOU FOR ATTENTION!
Formulas:

- **Variance of speed distribution over 1FL:**
  \[ S_x^2 := \frac{S_{xx}}{n} \]

- **Coefficient of variance:**
  \[ V_x := \frac{S_x}{x_m} \]

- **Standard deviation of speed over 1FL:**
  \[ S_x := \sqrt{S_x^2} \]

- **Moment of spread of traffic distribution over 1FL:**
  \[ S_{xx} := \sum_{i=1}^{n} x_i^2 - n.x_m^2 \]

- **Bunching index:**
  \[ b := \frac{1}{n} \sum_{j=1}^{n} (c_j - l_j)^2 \]

References:
- Karl Nachtigall, 2001, *Verkehrssystemtheorie*, Manuskript zur Vorlesung im WS und SS 2001/02, Technische Universität Dresden, Dresden, Germany
Horizontal & vertical conflicts

I. Average number of potential conflicts per hour

II. Index of conflict density
   - Describes the crossing without influence of the traffic flow

III. Capacity of crossing
   - Capacity of given average number of potential conflicts per hour
Conflicts within a flow

I. Average number of potential conflicts per hour

\[ E = \frac{M_h \cdot M_v \cdot (v_1 - v_2) \cdot N}{v_2 \cdot w \cdot h} \]

- w ... Minimum Horizontal Separation of the aircraft
- h ... Minimum Vertical Separation of the aircraft
- a ... Aircraft a
- b ... Aircraft b
- \( v_1 \) ... Speed of the aircraft a
- \( v_2 \) ... Speed of the flow
- \( v_R \) ... Speed difference between the aircraft a and aircraft b
- T ... Examined time interval
- N ... Number of aircraft in the flow
Costs arising due to over-flown time:

Due to the fact, that after the synchronization only one speed per flight one flight level will be used, the over-flown time can be defined precisely. It can be accurately calculated by using the formula:

\[ t = \frac{S}{V} \]

This can be appreciated by the airlines since they will be eventually able to optimize (modify) strategically integrated times in the flight planes when crossing given airspace.

References:
• Eurocontrol, April 2004, *Performance Review Report*
• Eurocontrol, *Evaluating the true Cost to Airlines of one minute of Airborne or ground delay*