US/Europe comparison of ATM-related operational performance

Joint study between FAA and PRU

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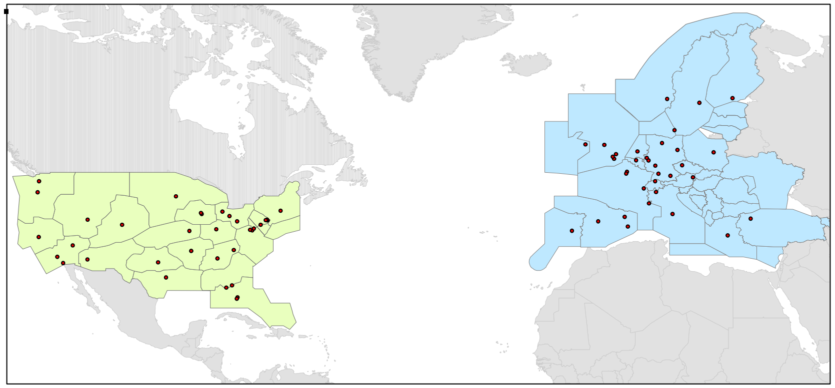
Objective & Scope

OBJECTIVES

- to provide a high-level comparison of operational performance between the US and Europe Air Navigation systems.
- Initial focus on the development of a set of comparable performance indicators for high level comparisons between countries and world regions.

SCOPE

- Predictability and Efficiency of operations
- Link to “Environment” when evaluating additional fuel burn.
- Continental US airspace (Oceanic and Alaska excluded)
- EUROCONTROL States (excluding oceanic areas and the Canary Islands)
- Focus on data subset (traffic from/to top 34 airports) due to better data quality (OEP airports) and comparability (general aviation).
- Commercial IFR flights



NOT in SCOPE

- Safety, Cost effectiveness, Capacity
- Trade-offs and other performance affecting factors (weather, etc.)

Key characteristics of the two systems

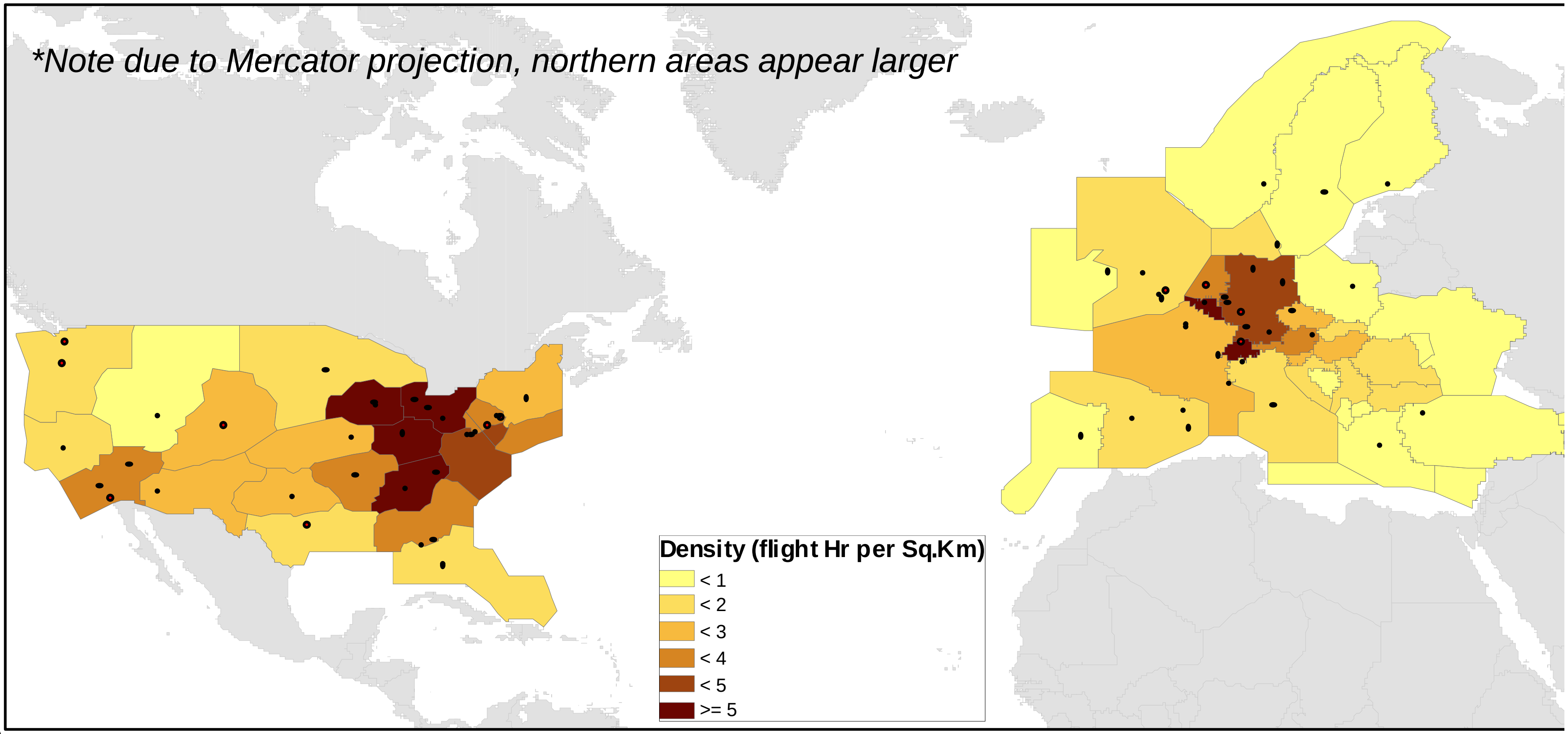
Calendar Year 2008	Europe[1]	USA[2]	Difference
Geographic Area (million km^2)	11.5	10.4	-10%
Number of en-route Air Navigation Service Providers	38	1	
Number of Air Traffic Controllers (ATCOs in OPS)	16 800	14 000	-17%
Total staff	56 000	35 000	-40%
Controlled flights (IFR) (million)	10	17	+70%
Share of General Air Traffic	4%	23%	x5.5
Flight hours controlled (million)	14	25	+80%
Average length of flight (within region)	541 NM	497 NM	-8%
Nr. of en-route centers	65	20	- 70%
En-route sectors at maximum configuration	679	955	+40%
Nr. of airports with ATC services	450	263 [3]	-38%
Of which are slot controlled	> 73	3	
Source	Eurocontrol	FAA/ATO	

[1] Eurocontrol States plus the Estonia and Latvia, but excluding oceanic areas and Canary Islands.

[2] Area, flight hours and center count refers to CONUS only. The term US CONUS refers to the 48 contiguous States located on the North American continent south of the border with Canada, plus the District of Columbia, excluding Alaska, Hawaii and oceanic areas.

[3] Total of 503 facilities of which 263 are FAA staffed and 240 contract towers.

Airspace Density Comparison (CONUS & European Centers)



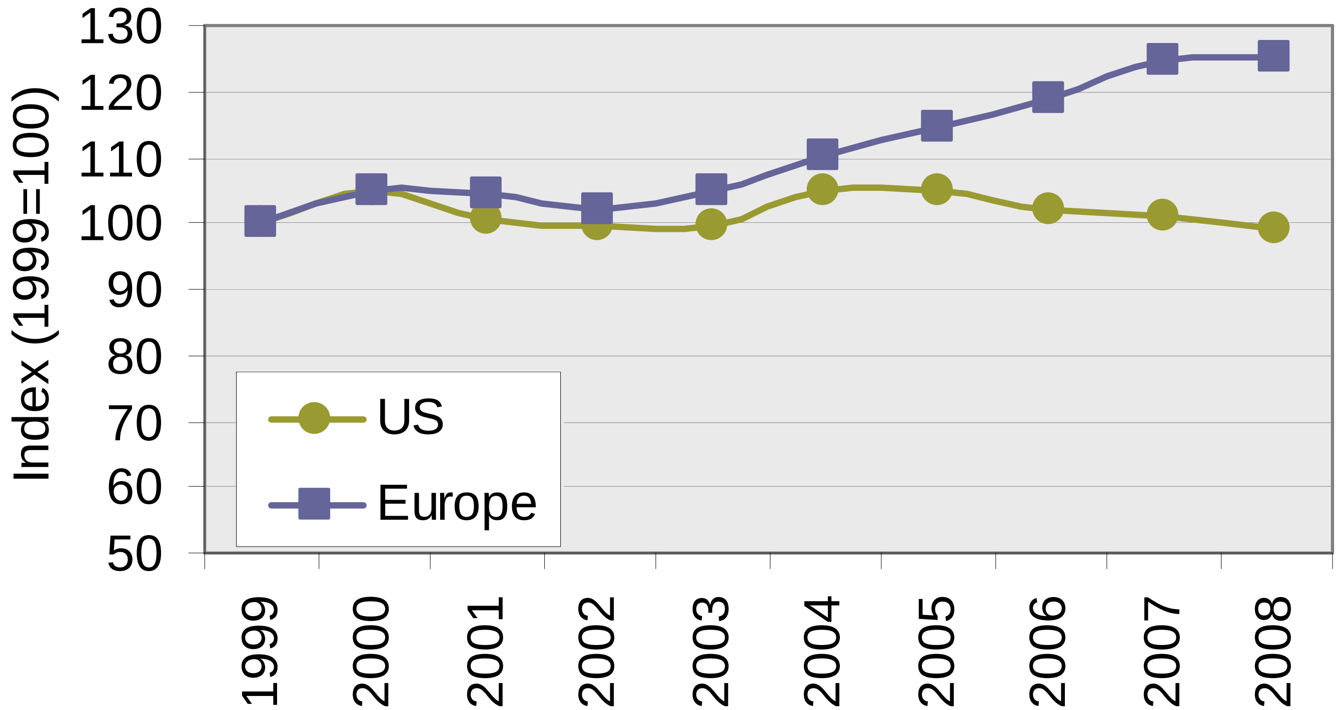
- Actual sizes are comparable (USA 10.4 vs Europe 11.5 M km^2)
- Relative density (flight hours per km^2) is 1.2 in Europe and 2.4 in US

Some facts about the main airports in the US and in Europe

Main 34 airports in 2008	Europe	US	Difference US vs. Europe
Average number of annual movements per airport ('000)	265	421	+59%
Average number of annual passengers per airport (million)	25	32	+29%
Passengers per movement	94	76	-19%
Average number of runways per airport	2.5	4.0	+61%
Annual movements per runway ('000)	106	107	+1%
Annual passengers per runway (million)	10.0	8.1	-19%

- Traffic to/from the main 34 airports represents some 68% of all IFR flights in Europe and 64% in the US.
- The share of general aviation to/from the main 34 airports is more comparable with 4% in the US and 1.6% in Europe.
- Average number of runways (+61%) and the number of movements (+59%) are significantly higher in the US;
- Number of passengers per movement in the US (-19%) are much lower than in Europe.

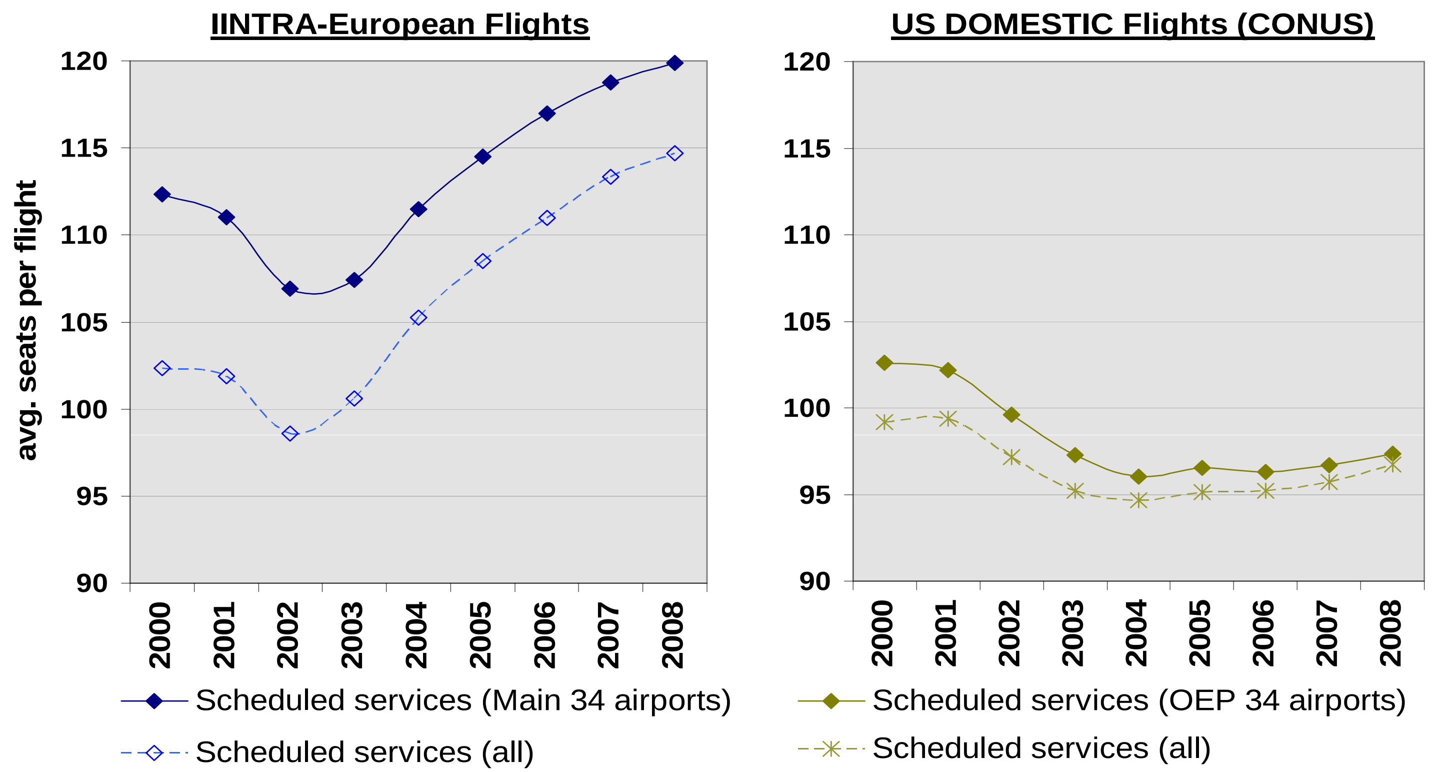
Air traffic growth in the US and in Europe (IFR flights)



Source: EUROCONTROL/ FAA

- After 2004, number of controlled flights did not increase in the US, and increased approximately +25% in Europe (~4% p.a.).
- Average values mask contrasted growth rates within the US and Europe

Average seats per scheduled flight in the US and in Europe

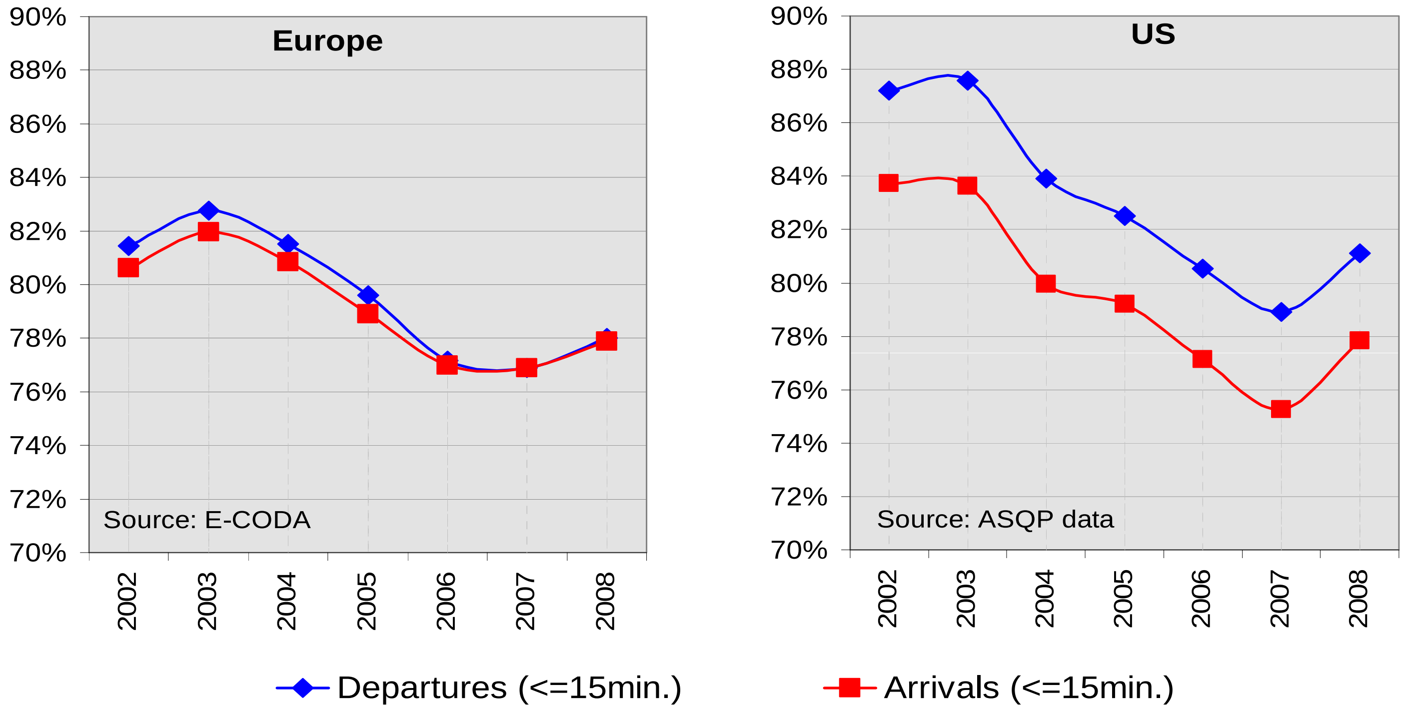


Source: FAA/ PRC analysis

- Average seat size per scheduled flight differs in the two systems with Europe having a higher percentage of flights using “Large” aircraft than the US.

On-time performance in the US and in Europe

On-time performance compared to schedule
(flights to/from the 34 main airports)



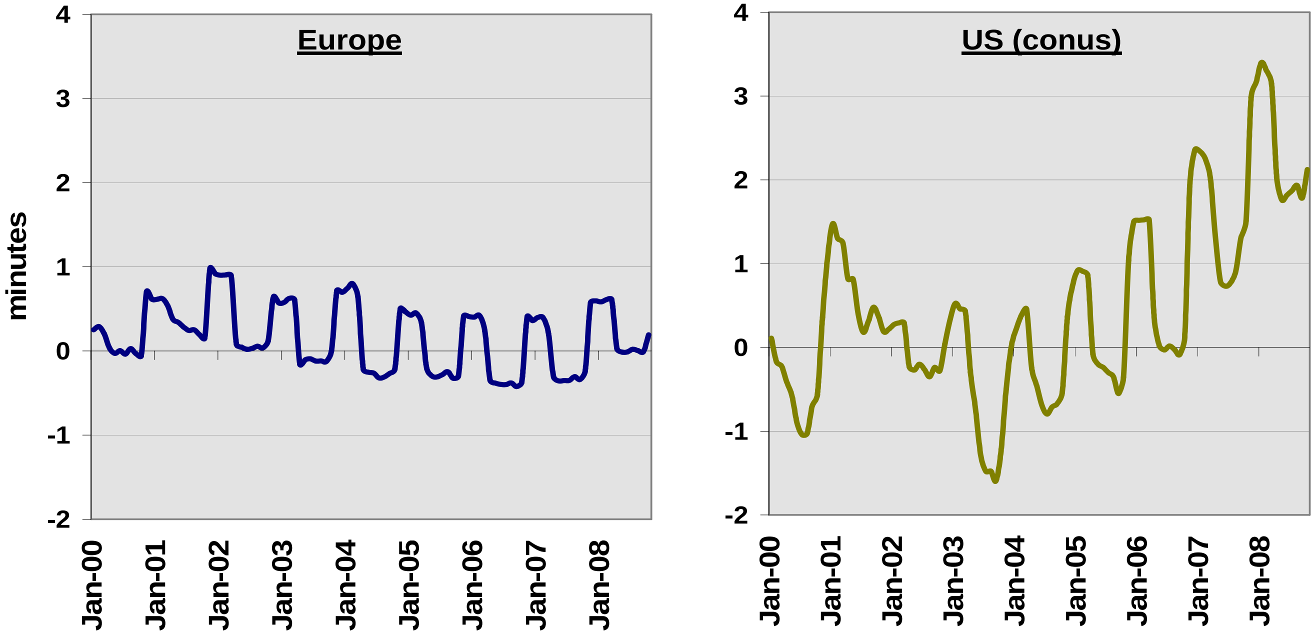
Punctuality –

Arrivals/ departures delayed by less than 15 minutes versus schedule

- ➔ Similar pattern in US and Europe with a comparable level of arrival on time performance;
- ➔ The gap between departure and arrival punctuality is significant in the US and quasi nil in Europe suggesting differences in flow management strategies

Airline Scheduling: Evolution of block times

Evolution of Scheduled Block Times
(flights to/from 34 main airports)

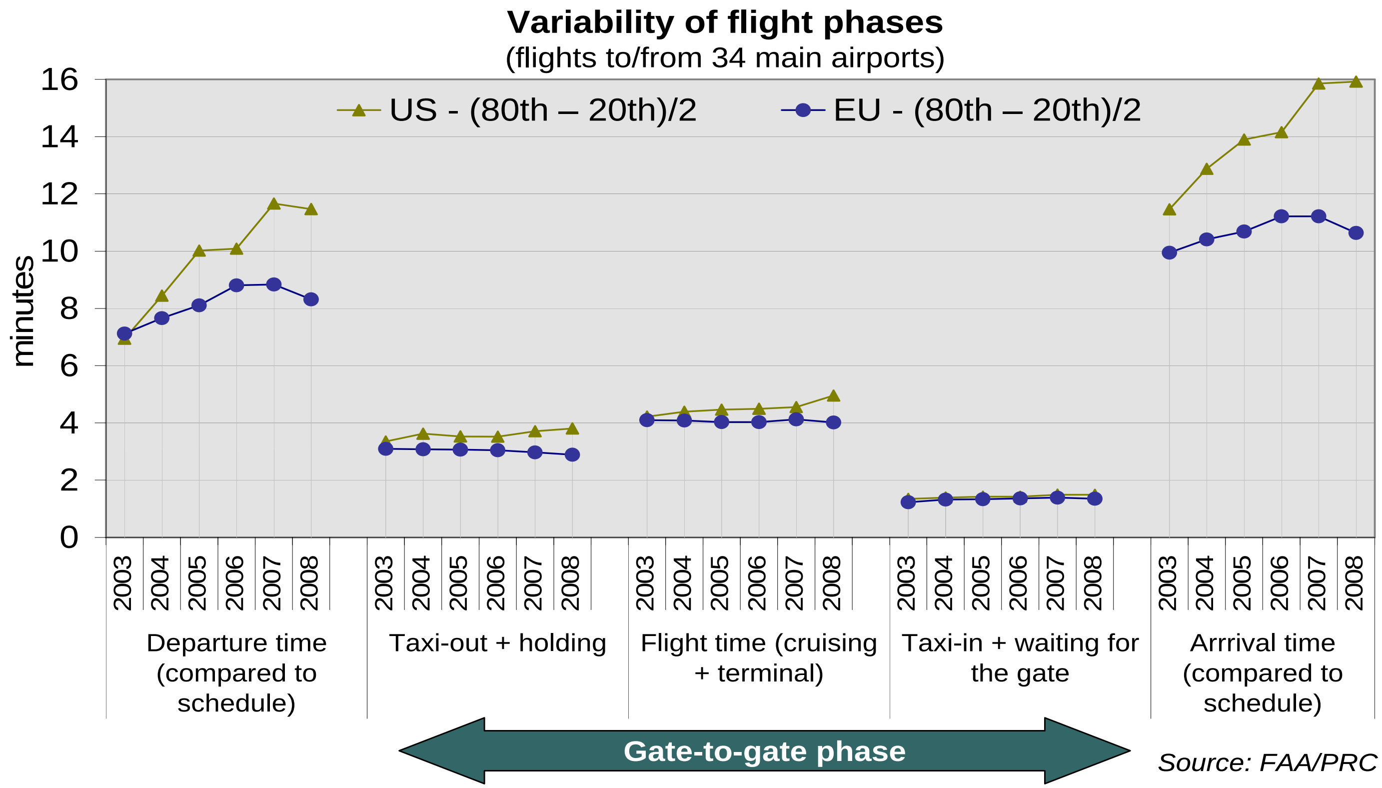


Scheduled block times compared to the long term average at city pair level.

Source: FAA/PRU

- **Europe:** Block times remain relatively stable (left side)
- **US:** In addition to decreasing on time performance (previous slide), there is a clear increase in scheduled block times (right side)
- Seasonal effects are visible in the US and in Europe (due to wind)

Predictability: Variability of flight phases

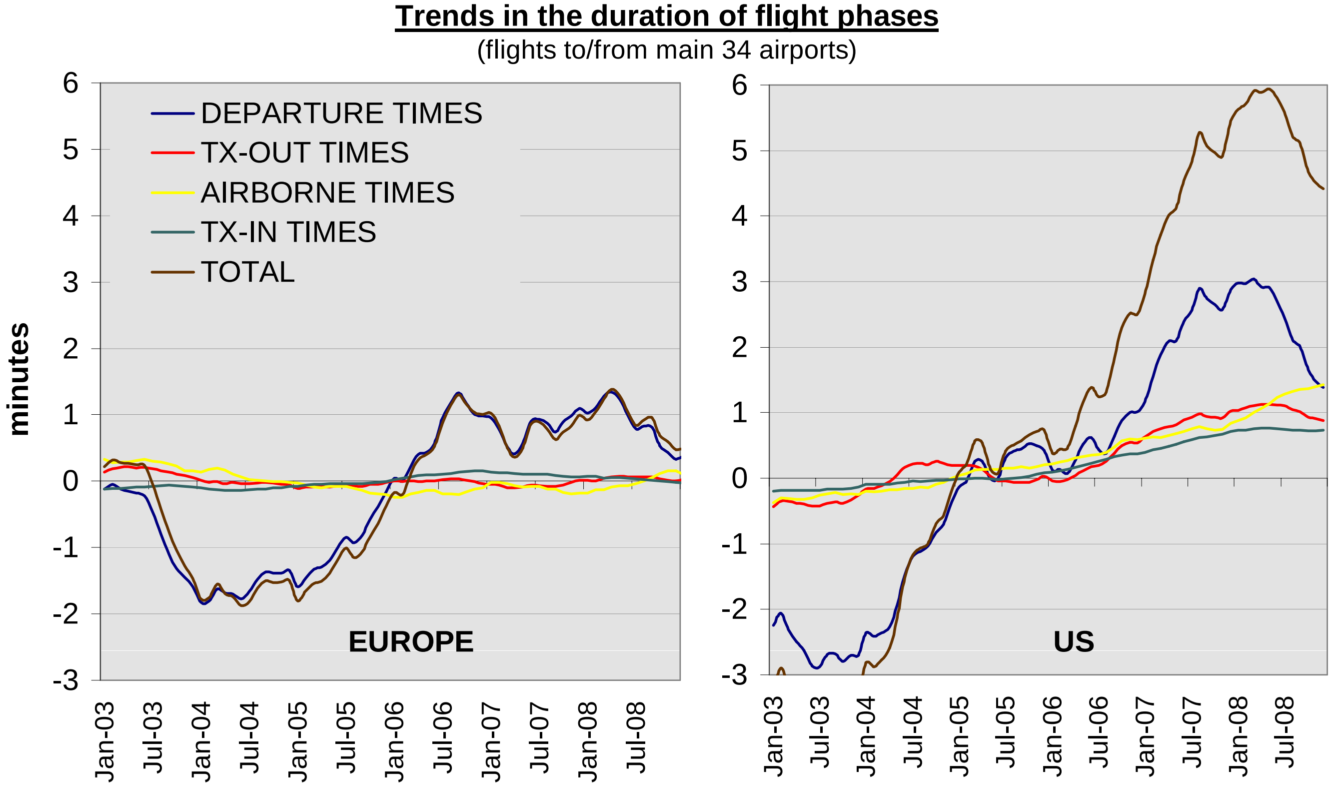


- *Predictability is measured in from the single flight perspective (i.e. airline view) as the difference between the 80th and the 20th percentile for each flight phase.*

➔ Arrival predictability is mainly driven by departure predictability.

➔ With the exception of taxi-in, variability for all flight phases is higher in the US.

Efficiency: Trends in the duration of flight phases



Actual times are compared to the long term average for each city pair.

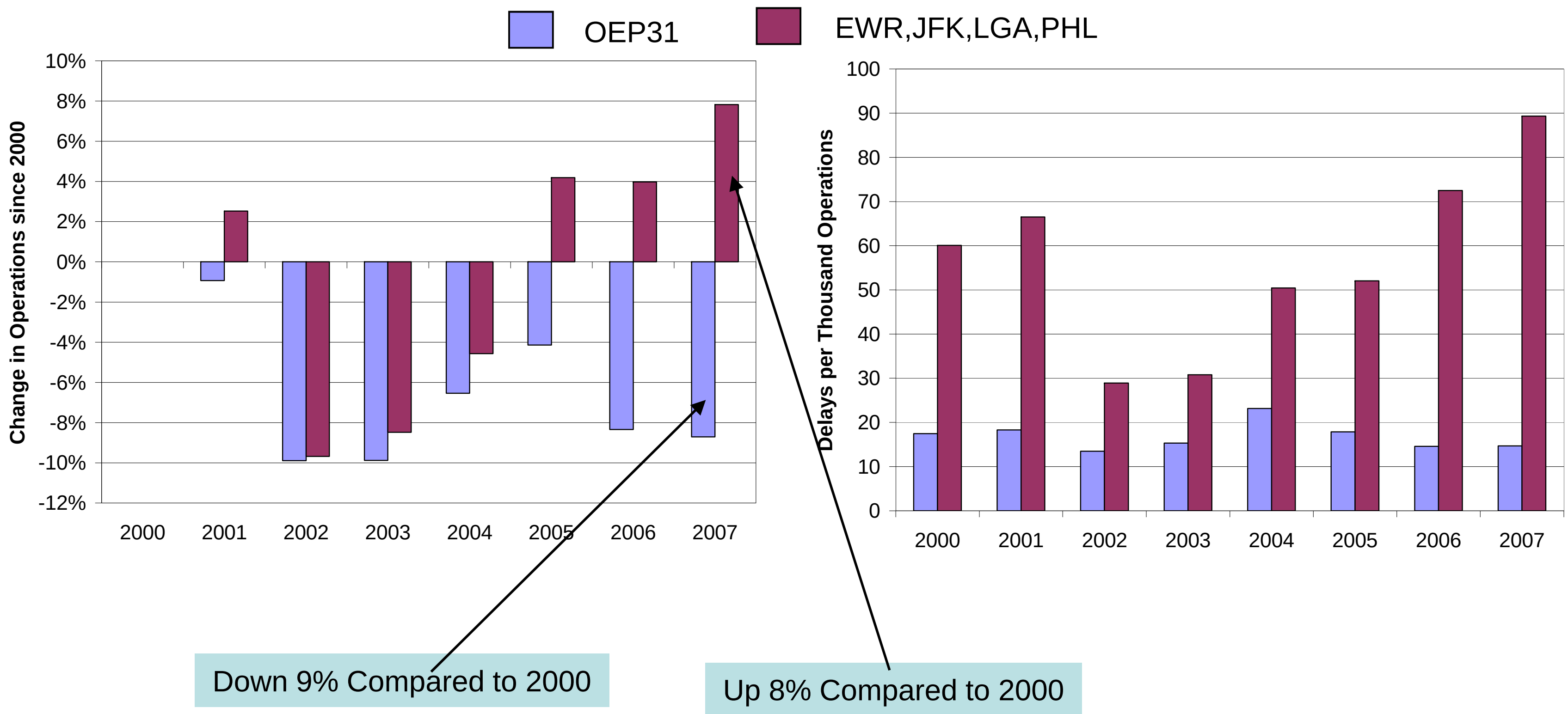
Data Source: CODA/ FAA

- ➔ **Europe:** performance is driven by departure delays with only very small changes in the gate-to-gate phase.
- ➔ **US:** in addition to a deterioration of departure times, there is a clear increase in average taxi times and airborne times.

Schedule Growth Shifts Delays

Traffic Change

Delayed Flights



October-July

Comparison of operational performance by phase of flight

Consistent measures being established in the US and Europe

IFR flights To/from Main 34 airports

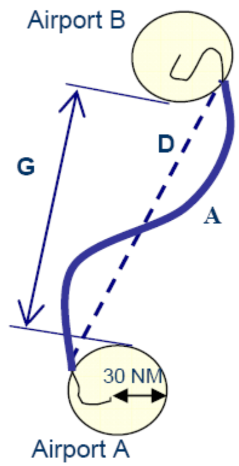
DEPARTURE

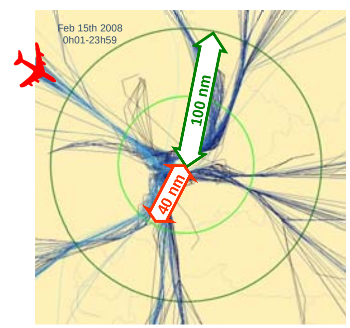
- ANS-related Holding at the Gate (ATFM/ EDCT)

GATE-to-GATE

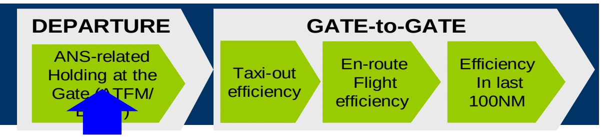
- Taxi-out efficiency
- En-route Flight efficiency
- Efficiency In last 100NM
- Taxi-in efficiency

IFR flights To/from Main 34 airports





Efficiency: ANS-related departure delays



- **ATFM/EDCT delays are delays taken on the ground at the departure airports (mostly at the gate)**
- **Both systems use ground delays programs to manage traffic but to a various extent**
  - Mainly used in US in case of severe capacity constraints at the arrival airports
  - Extensively used in Europe to manage both En-route and airport capacity limitation

Efficiency: ANS-related departure delays

	2008	En-route related delays >15 min. (EDCT/ATFM)			Airport related delays >15 min. (EDCT/ATFM)		
	IFR flights (M)	% of flights delayed>15 min.	delay per flight (min.)	delay per delayed flight (min.)	% of flights delayed>15 min.	delay per flight (min.)	delay per delayed flight (min.)
US	9.2	0.1%	0.1	57	2.6%	1.8	70
Europe	5.6	5.0%	1.4	28	3.0%	0.9	32

- ➔ **US:** En-route delays are much lower per flight, but the delay per delayed flight is significantly higher;
- ➔ **Europe:** Higher share of flights affected (than US) but with a lower average delay.
- ➔ In the US, ground delays (EDCT) are used when other options such as MIT are not sufficient, whereas, in Europe ground delays (ATFM) are the main ATM tool for balancing demand with capacity

Additional time in the taxi out phase

DEPARTURE: ANS-related Holding at the Gate (ATFM/ EDCT)

GATE-to-GATE: Taxi-out efficiency | En-route Flight efficiency | Efficiency In last 100NM

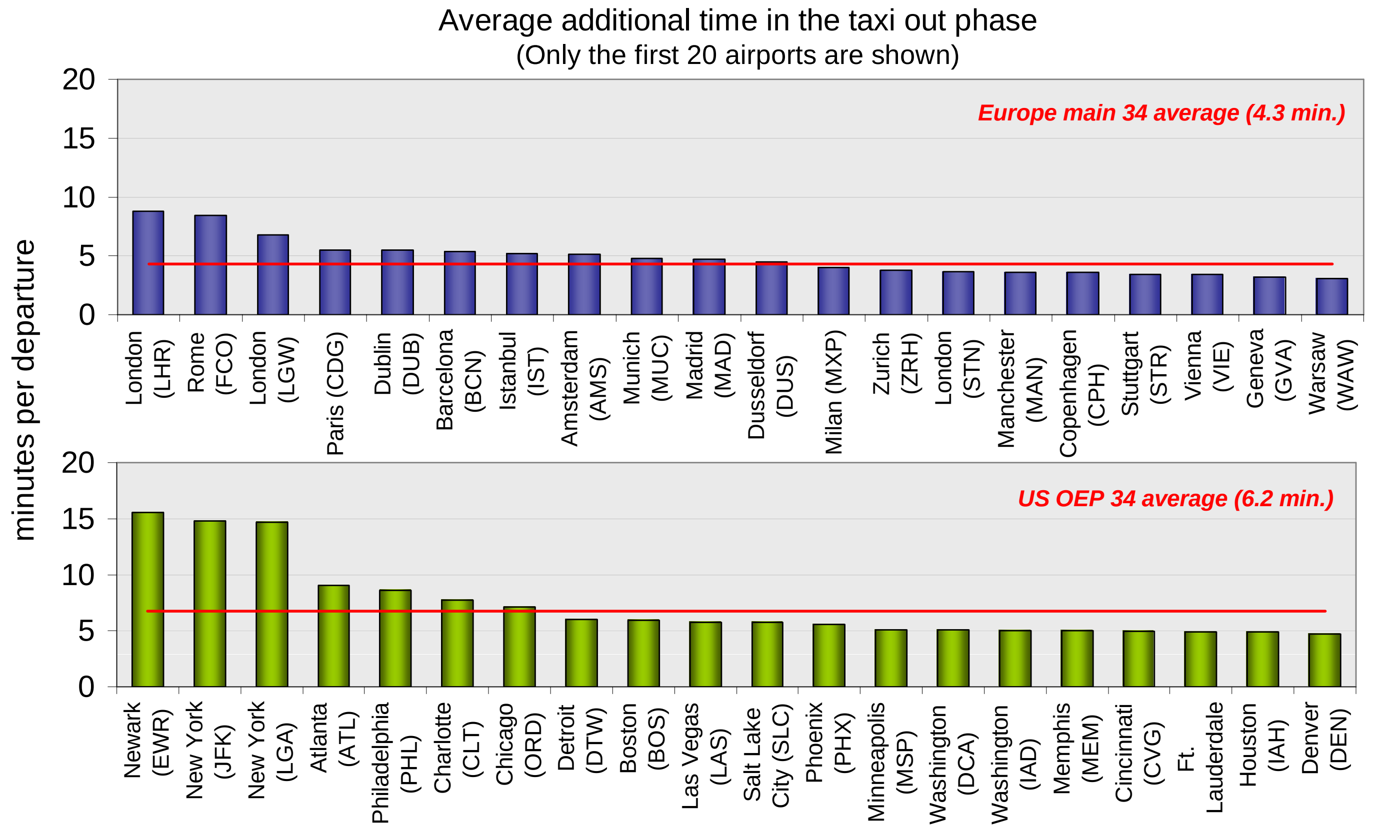
- **Measured as the time from off-block to take-off in excess of an unimpeded time.**
  - Unimpeded time is representative of the time needed to complete an operation in period of low traffic
  - Unimpeded time may not be a realistic reference in period of high traffic

- **Additional time in the taxi-out phase may be due to runway capacity constraints or results from local en-route departure and miles in trails restriction**

Additional time in the taxi out phase

DEPARTURE: ANS-related Holding at the Gate (ATFM/ EDCT)

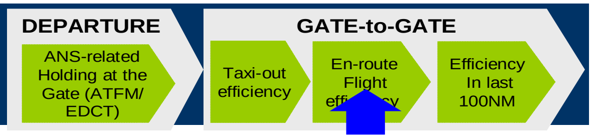
GATE-to-GATE: Taxi-out efficiency | En-route Flight efficiency | Efficiency In last 100NM

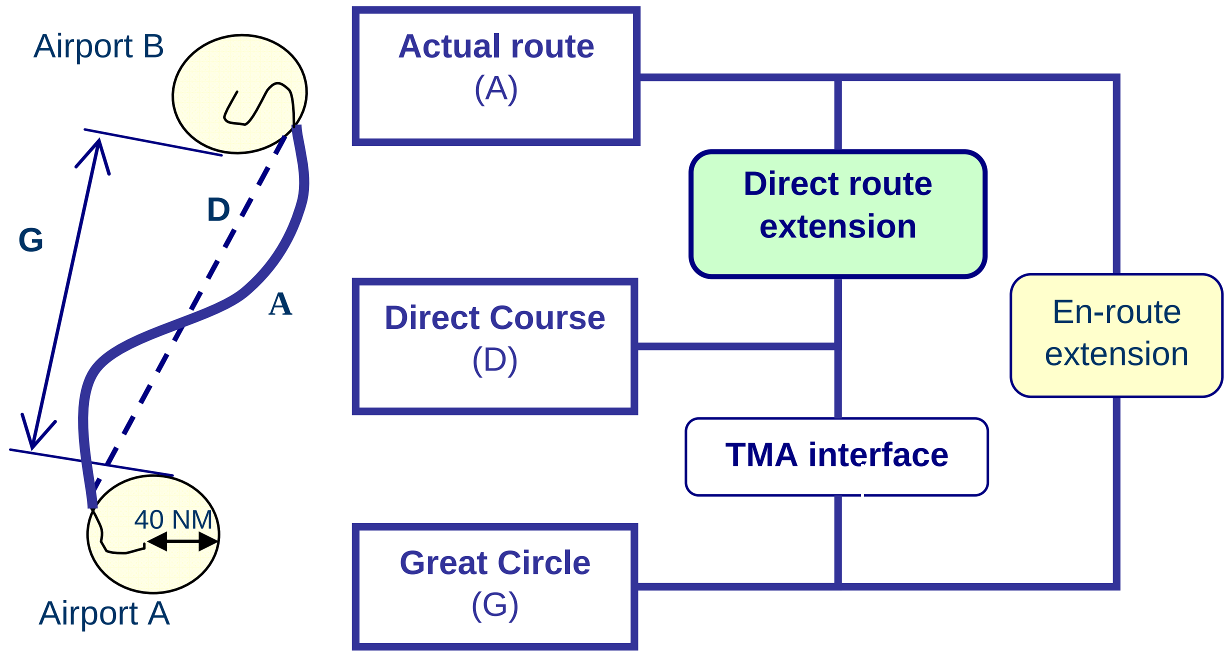


Source: FAA/ PRC analysis/ CODA/ CFMU

- ➔ Additional times in the taxi out phase are higher in the US (6.2 min.) than in Europe (4.3 min.)
- ➔ For the US, excess times also include delays due to local en-route departure and miles in trail restrictions. .

En-route flight Efficiency: Approach

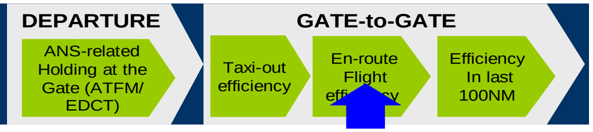




- *Focus on horizontal flight efficiency*
- *Distance based approach*

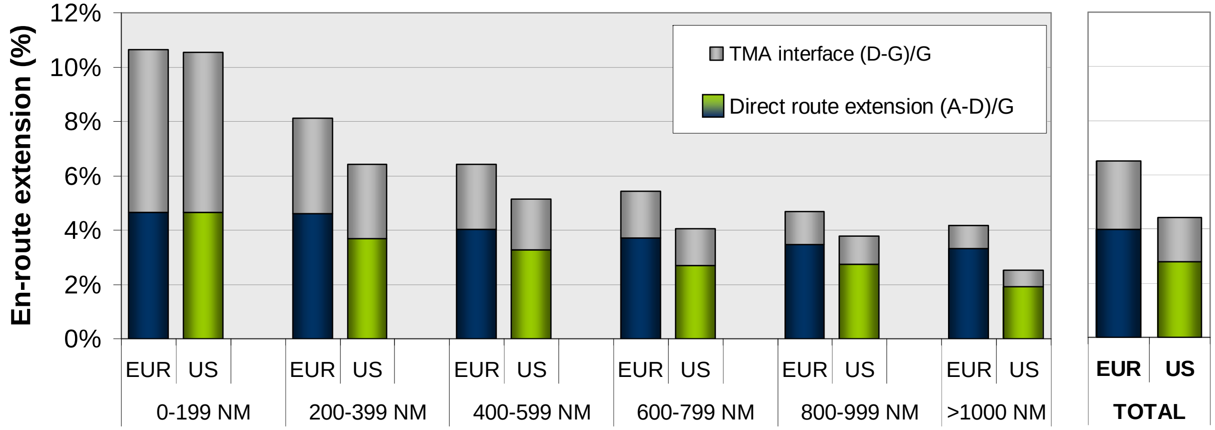
- Indicator is the difference between the length of the actual trajectory (A) and the Great Circle Distance (G) between the departure and arrival terminal areas.
- Direct route extension is measured as the difference between the actual route (A) and the direct course between the TMA entry points (D).
- This difference is an ideal (and unachievable) situation where each aircraft would be alone in the sky and not subject to any constraints (i.e. safety, capacity).

Flight efficiency: Direct Route Extension

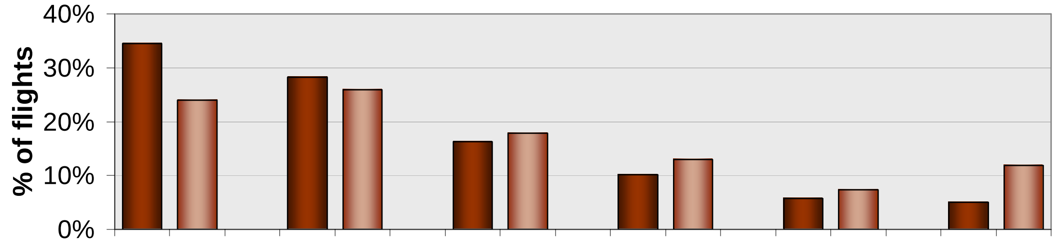


En-route extension

flights to/from the main 34 airports (2008)



Great circle distance between 40 NM circles (D40-A40)

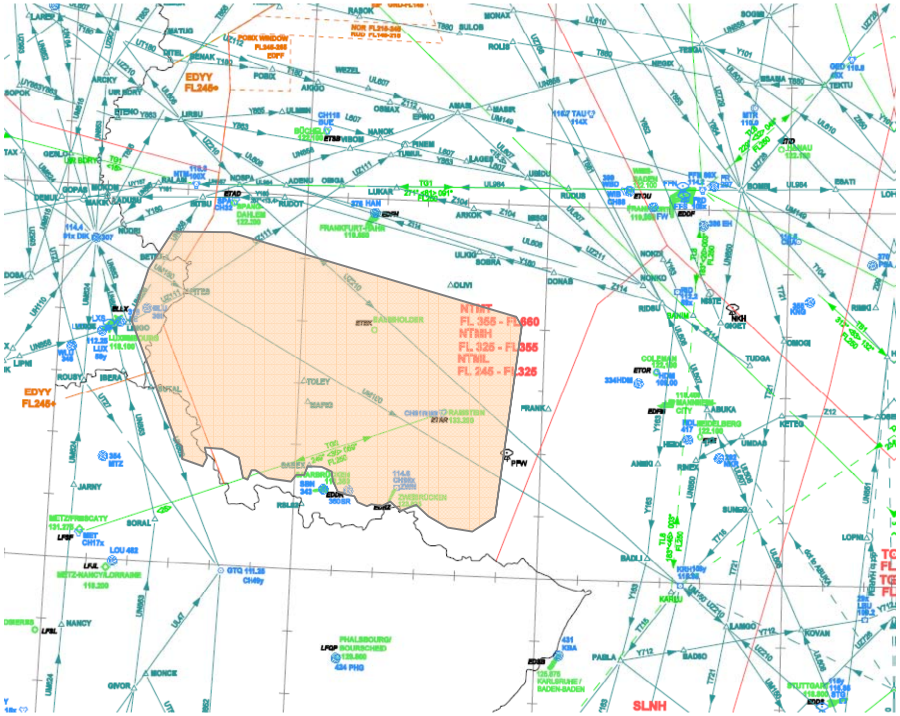


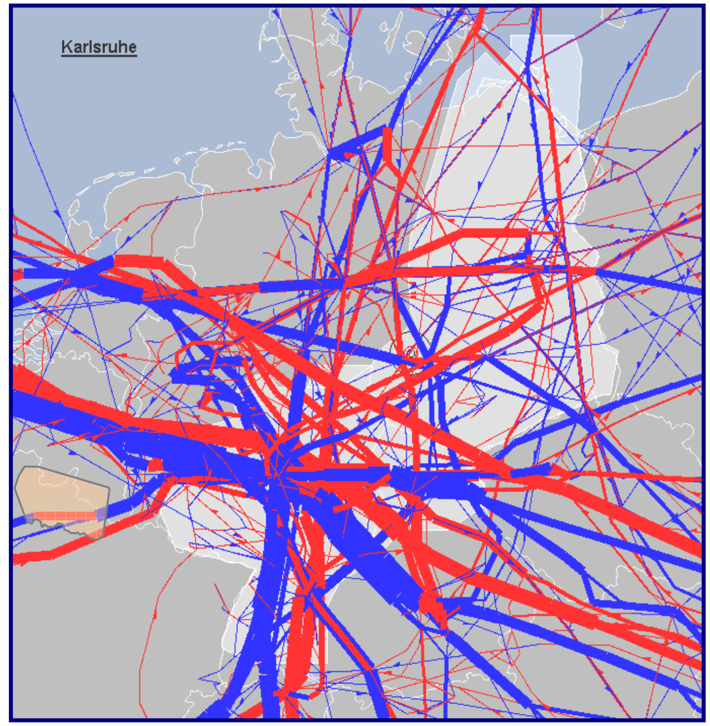
- Direct route extension is approximately 1% lower in the US
- **US:** Miles in trail restrictions are passed back from constrained airports
- **Europe**: Fragmentation of airspace, location of shared civil/military airspace

Impact of Military Airspace SW of Frankfurt

DEPARTURE
ANS-related Holding at the Gate (ATFM/ EDCT)

GATE-to-GATE
Taxi-out efficiency
En-route Flight efficiency
Efficiency In last 100NM



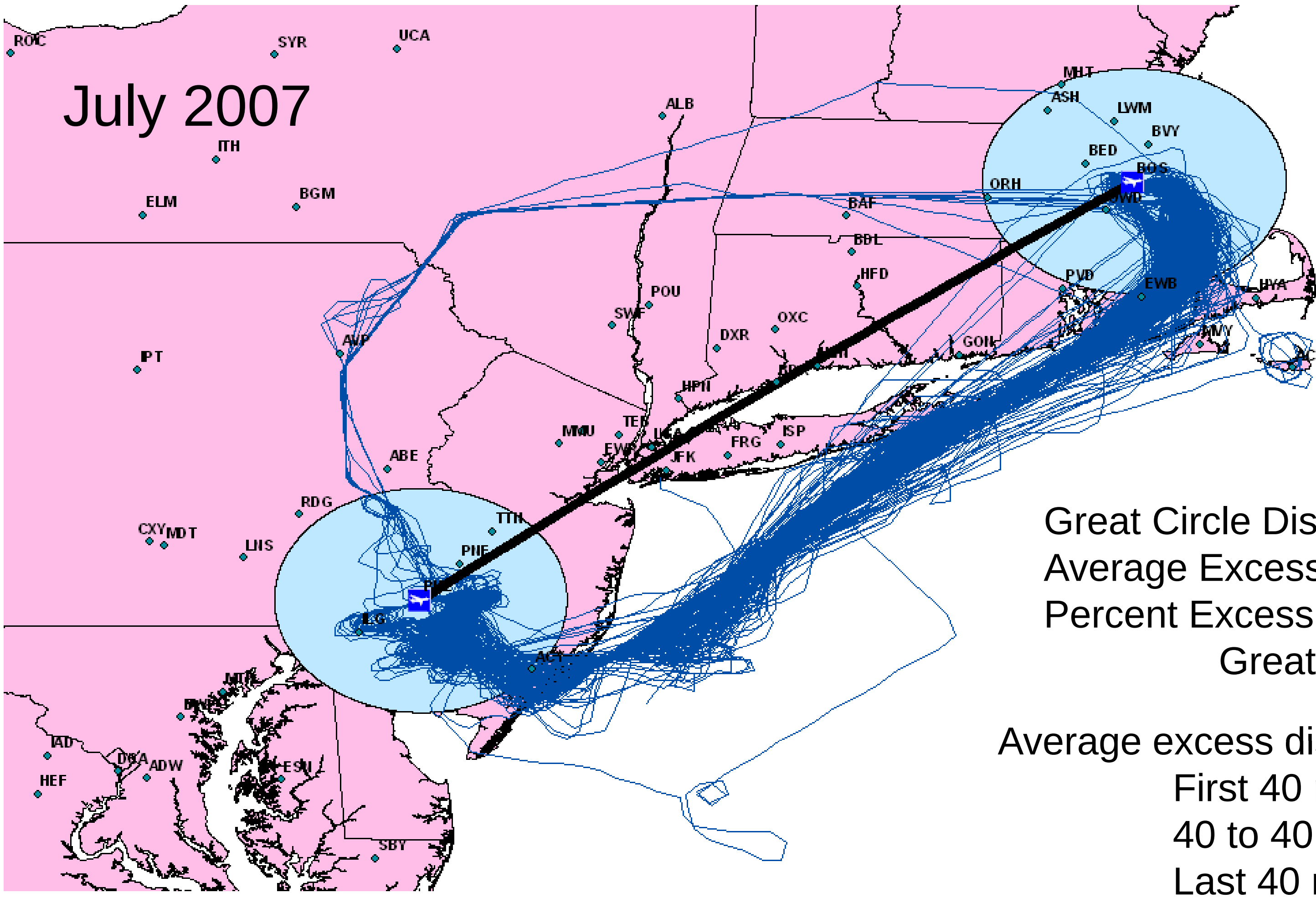


- Military airspace is a significant driver of excess distance
- Area southeast of Frankfurt is a major contributor
- Adjoining French Military airspace further increases problem

Boston (BOS) to Philadelphia (PHL) Flights

DEPARTURE
ANS-related Holding at the Gate (ATFM/ EDCT)

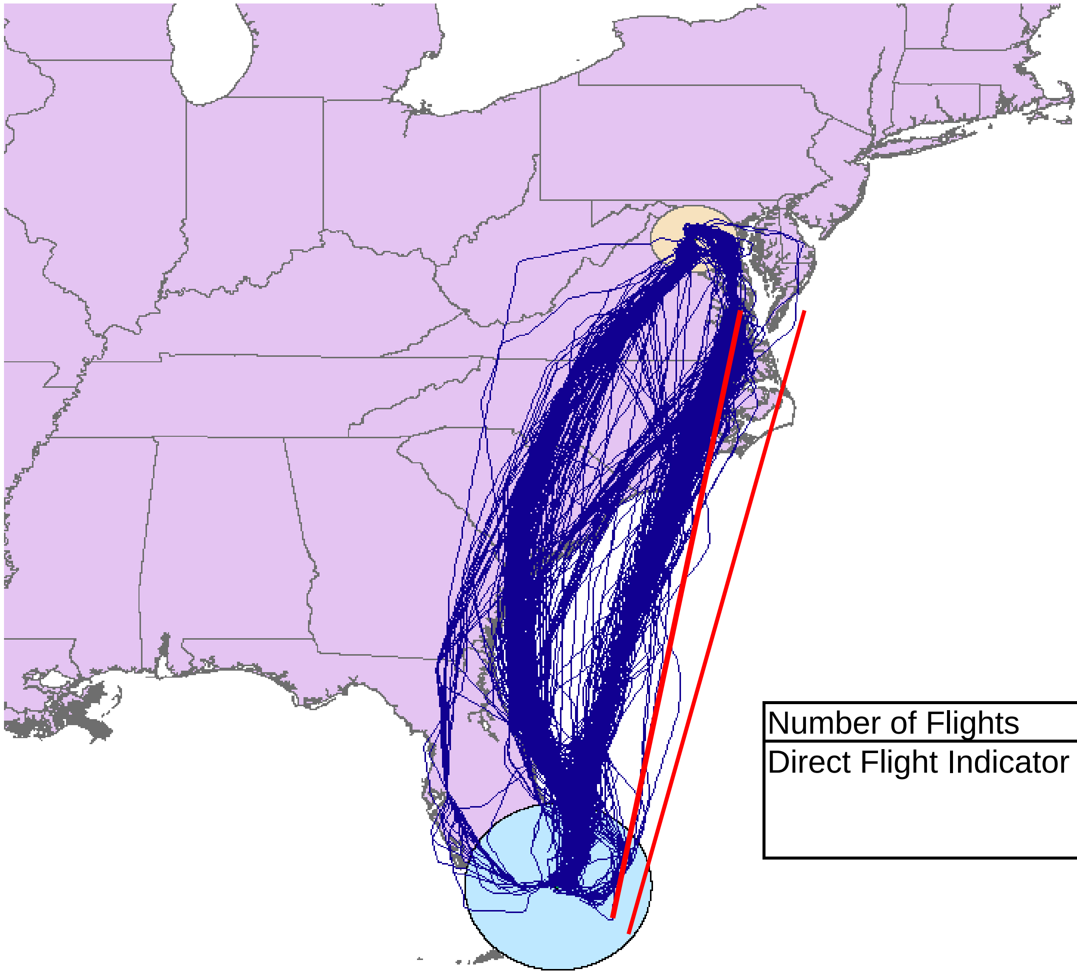
GATE-to-GATE
Taxi-out efficiency
En-route Flight efficiency
Efficiency In last 100NM



Great Circle Distance: 242 nmi
Average Excess Distance: 102 nmi
Percent Excess Distance over Great Circle: 42.1%

Average excess distance per stage:
First 40 nmi: 12 nmi
40 to 40 nmi circles: 63 nmi
Last 40 nmi: 27 nmi

IAD to FLL

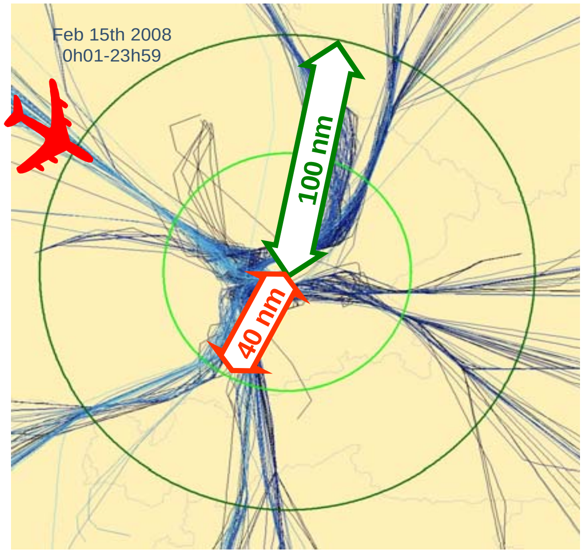


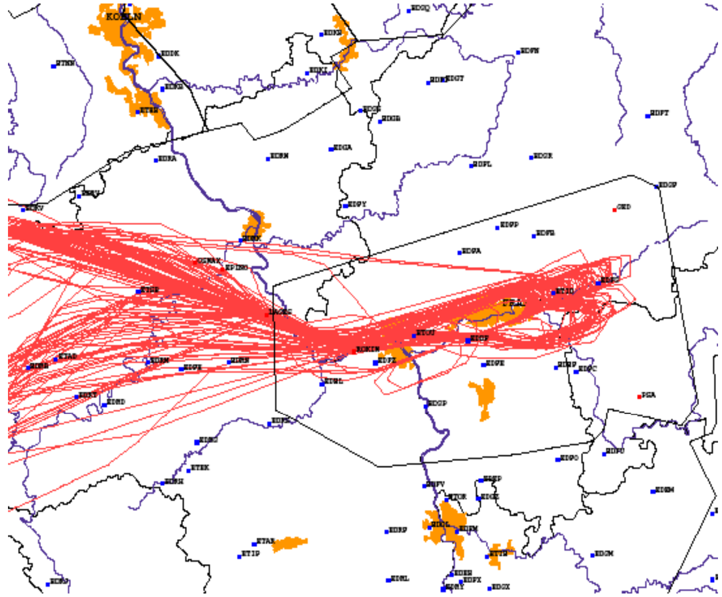
Number of Flights		1488
Direct Flight Indicator	Total (A-G)	41.9
	Direct Between TMA (A-D)	20.3
	TMA Interface (G-D)	21.5

Efficiency: Additional time in the last 100NM

DEPARTURE: ANS-related Holding at the Gate (ATFM/ EDCT)

GATE-to-GATE: Taxi-out efficiency | En-route Flight efficiency | Efficiency In last 100NM

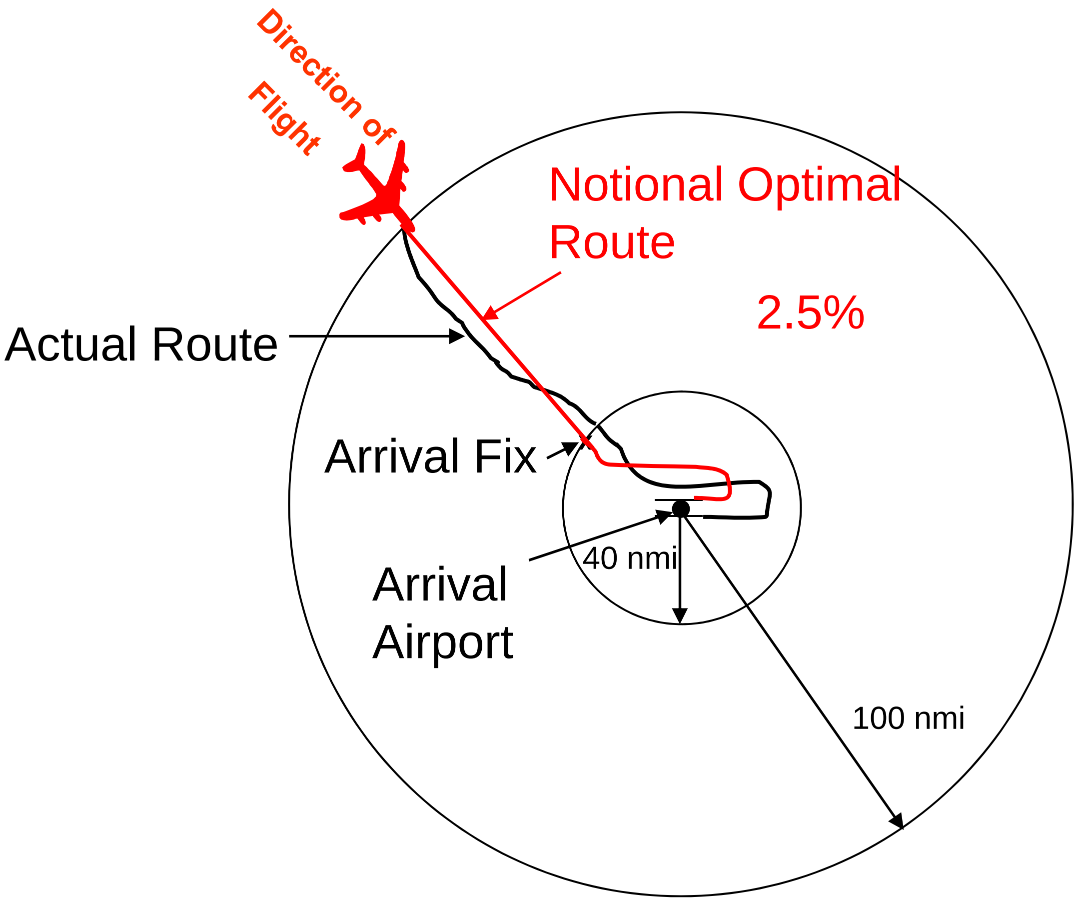




- At Frankfurt as much as an extra 15 minutes can be absorbed inside the Terminal Airspace
- Long Final alternative to holding stacks like in Heathrow

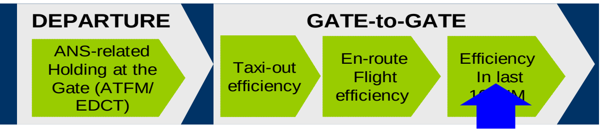
- Capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.), irrespective of local strategies.
- Standard “Arrival Sequencing and Metering Area” (ASMA) is defined as two consecutive rings with a radius of 40NM and 100NM around each airport.
- In Europe delay absorption at departure airport or around the arrival airport while in the US sequencing can span back to the departure airports (MIT)

Efficiency: Excess time in the last 100NM



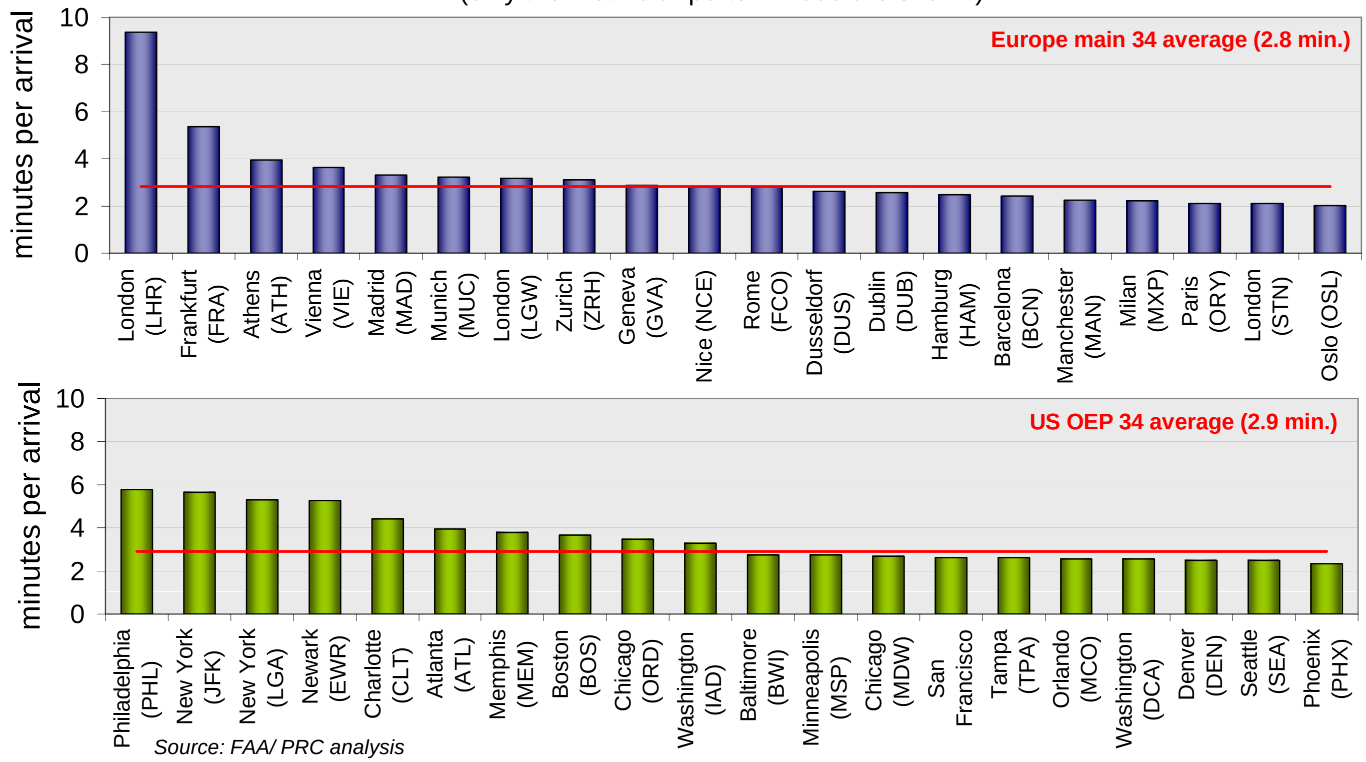
- **Time based measure**
- **Captures type of A/C**
- **ARC Entry point and runway configuration**
- **Nominal derived from 20th percentile**
- **Excess – time above nominal for each category**

Additional time within the last 100NM



Average additional time within the last 100NM miles

(only the first 20 airports in 2008 are shown)



Source: FAA/ PRC analysis

- ➔ Average additional time is similar in Europe (2.8 min.) and the US (2.9 min.)
- ➔ Mainly driven by London Heathrow (LHR) which is clearly an outlier
- ➔ Performance at LHR is consistent with the 10 minute average delay criteria agreed by the airport scheduling committee.

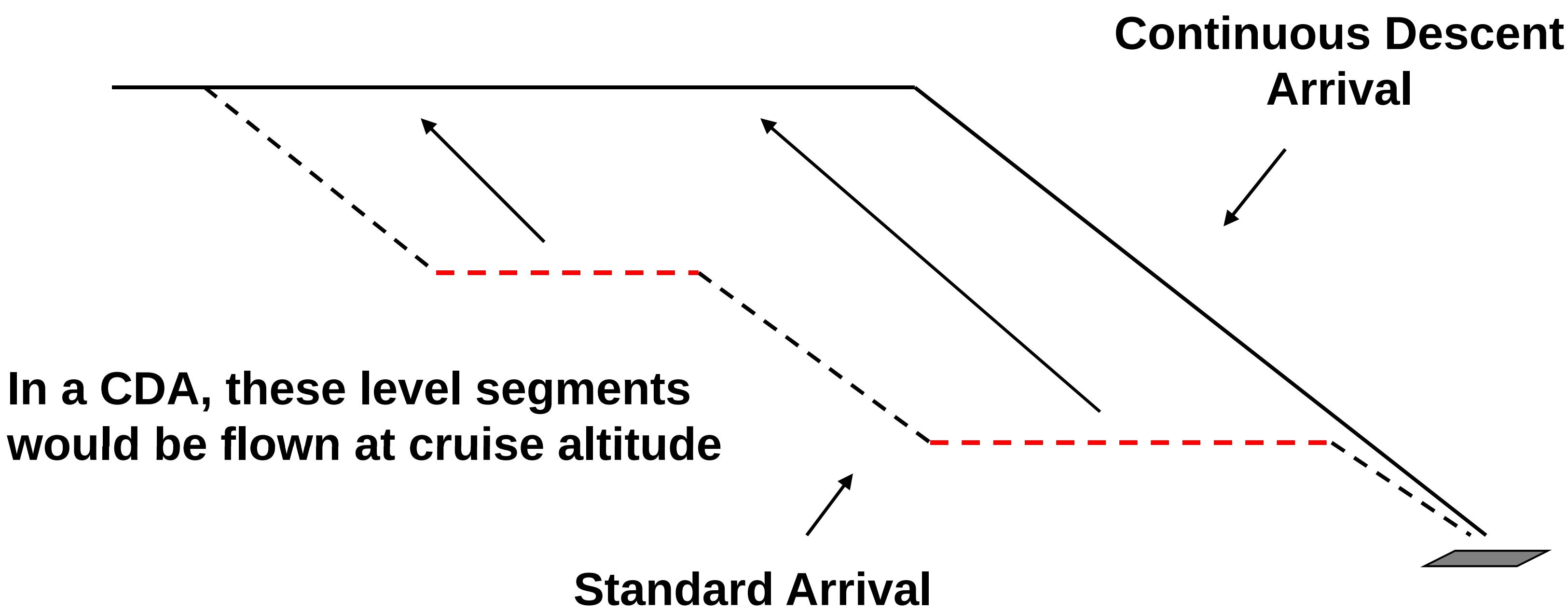
Estimated benefit pool actionable by ATM (typical flight)

Estimated benefit pool actionable by ANS for a typical flight (2008) (flights to/from the main 34 airports)		Estimated additional time (avg. per flight in min.)		Predictability (% of flights affected)		Fuel burn	Est. fuel burn (kg)[27]	
		EUR	US	EUR	US	engines	EUR	US
Holding at gate per departure (only delays >15min. included)	en-route-related	1.4	0.1	5.0%	0.1%	OFF	≈0	≈0
	airport-related	0.9	1.8	3.0%	2.6%	OFF	≈0	≈0
Taxi-out phase (min. per departure)		4.3	6.2	100%		ON	65 kg	93kg
Horizontal en-route flight efficiency		2.1-3.9	1.4-2.6	100%		ON	180kg	118kg
Terminal areas (min. per arrival)		2.8	2.9	100%		ON	115kg	119kg
Estimated benefit pool actionable by ANS		≈11.5-13.3	≈12.4-13.6				360kg	330kg

- The benefit pool represents a theoretical optimum. Safety and capacity constraints limit the practicality of ever fully recovering these “inefficiencies”
- The estimated inefficiency pool actionable by ANS and associated fuel burn is similar in the US and Europe (estimated to be between 6-8% of the total fuel burn) but with notable differences in the distribution by phase of flight.
- Inefficiencies have a different impact (fuel burn, time) on airspace users, depending on the phase of flight (airborne vs. ground) and the level of predictability (strategic vs. tactical).

Continuous Descent Arrival

CDA is an arrival procedure designed to eliminate level segments flown below cruise altitude, thus minimizing fuel burn, emissions and noise.



What ATM can do ?

ATM can help improving performance by :

- **Maximizing throughput so as to minimize total delay**
  - Making the best use of capacity available
  - Optimizing Departure/landing sequences
- **Minimizing the impact of delay**
  - Priority between flights
  - Minimizing fuel impact by managing the Phase of Flight where necessary delay is applied
- **But be careful**
  - Delaying aircraft on the ground (engine off) is not always more fuel efficient than airborne delays !
  - Continuous descent approach can burn more fuel than interrupted Descent

Conclusions

- High value in global comparisons and benchmarking in order to optimise performance and identify best practice;
- Arrival punctuality is similar in the US and in Europe, albeit with a higher level of variability in the US.
- The estimated inefficiency pool actionable by ANS and associated fuel burn appear to be similar in the US and Europe (estimated to be between 6-8% of the total fuel burn) but with notable differences in the distribution by phase of flight.
- Inefficiencies have a different impact (fuel burn, time) on airspace users, depending on the phase of flight (airborne vs. ground) and the level of predictability (strategic vs. tactical). Further work is needed to assess the impact of efficiency and predictability on airspace users, the utilisation of capacity, and the environment.
- A more comprehensive comparison of service performance would also need to address Safety, Capacity and other performance affecting factors such as weather and governance.

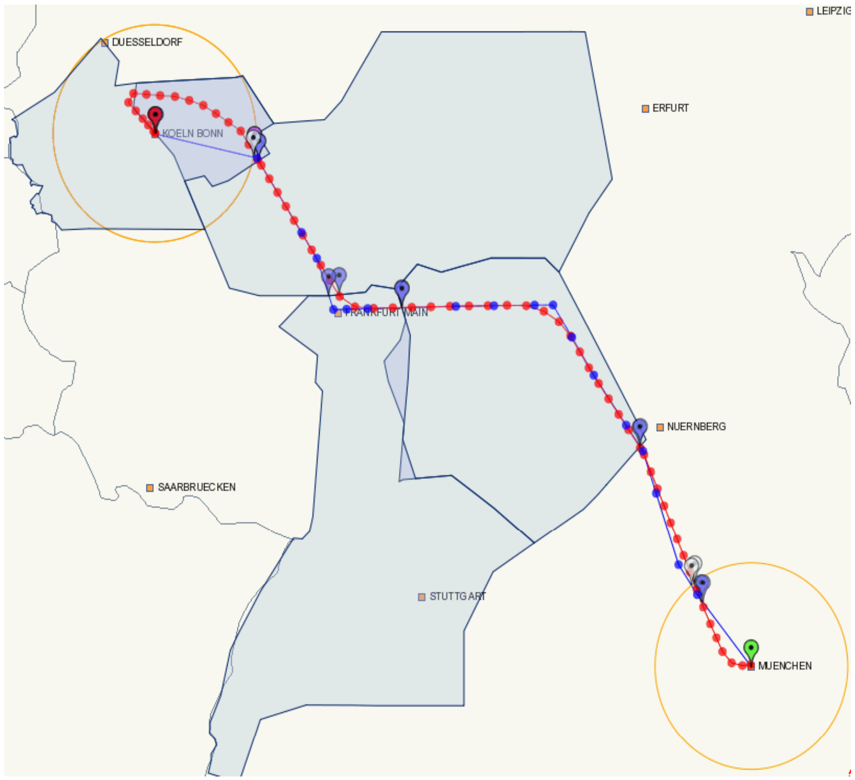
Backup

Impact of altitude on fuel flow

Flight Level	50	100	150	200	250	300	350	400
A300B4-605R	4	2	1	0	3	8	16	
A310-324	11	5	2	0	0	5	9	23
A318-111	13	8	4	2	1	0	0	5
A319-112	19	11	3	1	0	1	0	4
A320-214	13	5	3	1	1	1	0	2
A320-232	7	5	5	5	2	0	4	11
A321-211	14	11	8	3	0	1	5	
A330-203	2	1	0	0	2	4	8	18
A330-223	9	9	5	2	0	1	6	14
A340-343	10	5	1	0	0	2	7	16
A340-212	3	2	0	0	2	3	5	
A340-313E	2	1	0	0	2	3	5	
A340-642	6	2	0	1	2	3	4	11

Difference in % compared to fuel flow at optimum altitude (in pink)

Sample „Inefficient“ DFS Routes



Select flight date and arcid or filter

Flight date **2009-03-18**

ARCID: BER344

Evaluate

ADEP: ADES: CAT: all

DFS En-route Quality	actual (A)	filed (F)	a_dc (D_A)	f_dc (D_F)	enr-xt (A-D_F)	enr-xt %	atc-xt (A-F)	atc-xt %	rsd-xt (F-D_F)	rsd-xt %	a_traffic	f_traffic
GB_CC *(non splitted)*	536.3	493.1	436.5	436.5	99.8	22.9	43.2	9.9	56.6	13.0	1	1
GB_CC	536.3	493.1	436.5	436.5	99.8	22.9	43.2	9.9	56.6	13.0	1	1
LANGEN	397.1	357.7	314.8	314.8	82.3	26.2	39.4	12.5	42.9	13.6	1	1
GG_EBG02	37.2	45.8	35.8	41.1	-3.9	-9.5	-8.5	-20.7	4.6	11.2	1	1
GG_EBG03	82.1	80.1	82.1	79.7	2.4	3.0	2.0	2.5	0.4	0.5	1	1
GG_EBG04	169.2	172.7	151.9	151.9	17.3	11.4	-3.6	-2.3	20.8	13.7	1	1
GG_EBG07	108.7	59.1	58.6	58.7	50.0	85.3	49.6	84.5	0.5	0.8	1	1
MUENCHEN	139.2	135.4	133.4	133.5	5.7	4.3	3.8	2.9	1.9	1.4	1	1
MM_APP	49.6	44.7	45.2	44.7	4.9	11.0	4.9	11.0	0.0	0.0	1	1
MM_NORD	89.6	90.7	89.5	89.9	-0.3	-0.4	-1.1	-1.3	0.8	0.9	1	1

DFS Efficiency	actual (A)	filed (F)	a_dc (D_A)	f_dc (D_F)	A Eff. (D_A/A)	F Eff. (D_F/F)	a_time	f_time
GB_CC *(non splitted)*	536.3	493.1	436.5	436.5	81.4	88.5	3685	2920
GB_CC	536.3	493.1	436.5	436.5	81.4	88.5	3685	2920
LANGEN	397.1	357.7	314.8	314.8	79.3	88.0	2728	2071
GG_EBG02	37.2	45.8	35.8	41.1	96.1	89.9	219	192
GG_EBG03	82.1	80.1	82.1	79.7	100.0	99.5	569	435
GG_EBG04	169.2	172.7	151.9	151.9	89.8	87.9	1003	860
GG_EBG07	108.7	59.1	58.6	58.7	54.0	99.2	937	584
MUENCHEN	139.2	135.4	133.4	133.5	95.8	98.6	957	849
MM_APP	49.6	44.7	45.2	44.7	91.0	100.0	394	404
MM_NORD	89.6	90.7	89.5	89.9	99.9	99.1	563	445