Making the World A better place to live

SFO

August 2016

Facts about consumption (B777)

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APU
3.9 Kg Fuel
12.3 Kg CO_2
per min

Ground
23.3 Kg Fuel
73.4 Kg CO_2
per min

Flight
113.3 Kg Fuel
356.9 Kg CO_2
per min

Count Seconds, not minutes

Minimum Time Track (MTT) vs Minimum Cost Track (MCT)

- **Minimum Time Track (MTT)** – Taking advantage of the winds at best Efficient Speed.
- **Minimum Cost Track (MCT)** – Least Cost track considering time cost, fuel cost and overflight charges
- **Minimum Fuel Track (MFT)** – Normally the same or similar to the Minimum Flight Time, minimum fuel considering the Best Efficient speed.

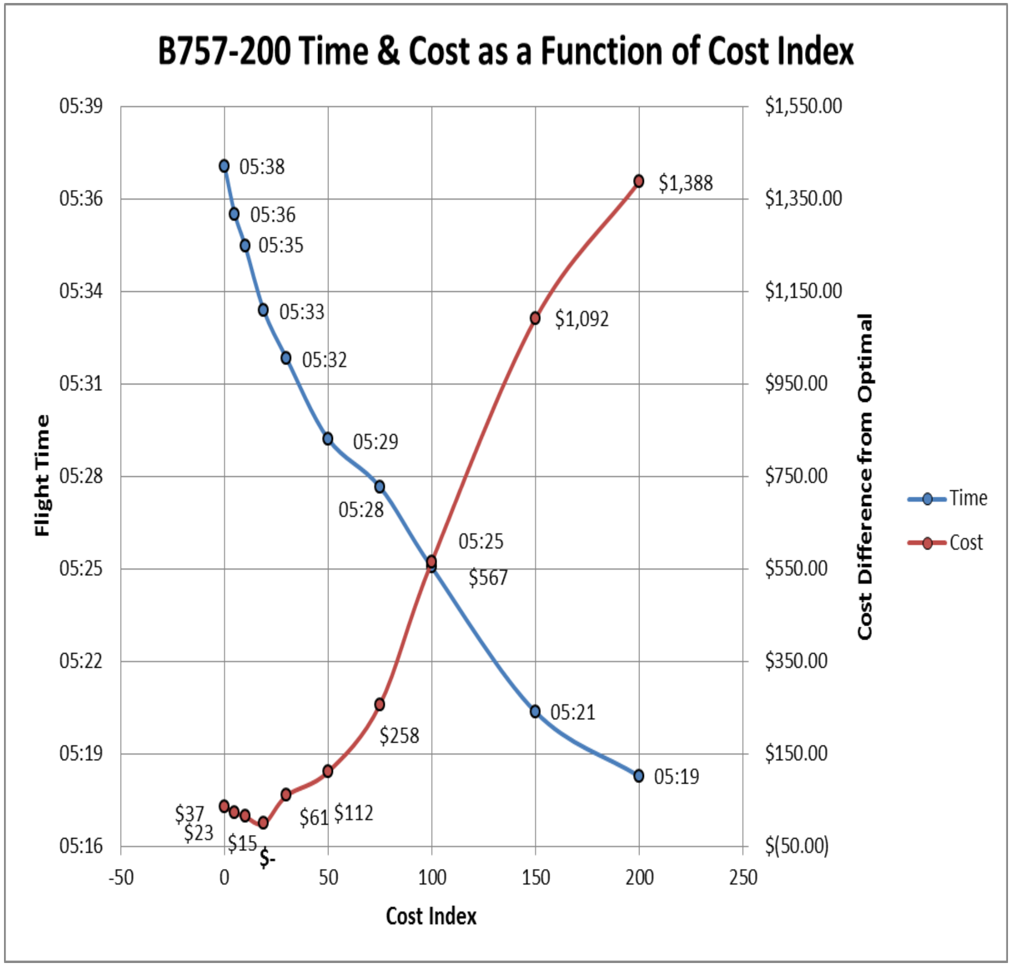
Cost Index concept

Cost Index

Cost Time : Fuel Cost

B757-200 Cost Index $ Difference

- Above CI250 minutes of gain reduce to about 1 minute of time gain but at a significant increase in fuel cost
- Usually is not worth it flying that fast – no return on the fuel investment.



Minimum Time Track (MTT) vs Minimum Cost Track (MCT) concept

ROUTE	MFT/R	MCT/R	MTT/R
OFP NO	7	8	9
FIN NO	327	327	327
FLT TIME	07:56	08:03	07:56
ETA	17:07	17:14	17:07
CRUISE	CI45	CI45	CI45
SAVINGS			
COSTS	24152	23228	24152
BURN OFF	84591	86012	84591
ALTN	KPBI	KPBI	KPBI
ALTNFUEL	3255	3255	3255
RESERVE	48	48	48
CONT			
ADD FUEL			
T/O FUEL	99526	101059	99526
EXTRA			
TTL FUEL	100496	102029	100496
LOAD	100000	100000	100000
MALTOW	408000	390741	408000
PLNTOW	380526	382059	380526
MALLW	326000	326000	326000
PLNLW	295935	296047	295935
MAXZFW	312300	312300	312300
PLNZFW	281000	281000	281000
ESTZFW	281000	281000	281000
DIST	3521	3602	3521
AVG WC	M010	M006	M010
MAX FL			

- Correct Cost Index usage
- Assign the expected SID / STAR / Approach for accurate fuel planning
- Optimized flight plan for the defined strategy Minimum Cost Track (MCT) or Minimum Time Track (MTT)
- Planning according to a CDM plan to approach Flight Planning to Execution

Pushback & Taxi-Out

- Aircraft ready on-time and according to a CDM plan to reduce APU & Engine use
- Coordinated surface movement between cockpit, ground personnel and ATC.
- From pushback to the runway, ATC "keeps traffic moving" allowing a better power management
- A-CDM plan - shortest route to runway, in some cases take advantage of the dominant turns for the Engine Out selection
- Use taxi out time statistics e.g. based on the day of the week, last 3 months, to review the flight plan and/or inform pilot

APU & Engine on Ground

- APU costs several times more than ground power
- On a taxi time of 10 min we can use one engine during 5 min
- Coordination between all parts allow a better power management

Approaching the Runway

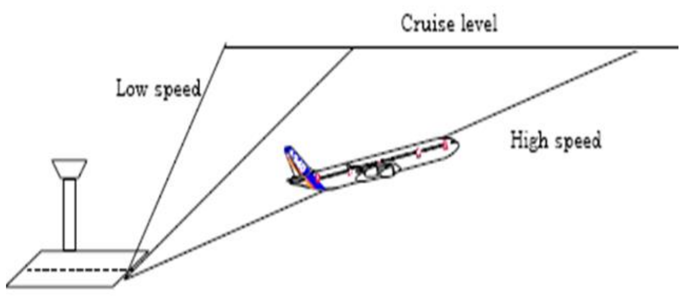
- ATC updates on take-off sequence to:
  - Allow pilots to complete pre-take off tasks reducing runway occupancy
  - In case of Engine Out Taxi Out calculate and even coordinate start-up/warm-up time
- Better traffic sequencing and RECAT can also reduce ground time if available
- Rolling take-off avoids or eliminates intermediate stop reducing runway occupancy time and hold periods
- Intersection take-offs when performance permits
- Runway direction linked to flight route

Runway Selection

- Savings per movement also improves overall airport throughput
- Each minute of flight in the 'wrong-direction' equals roughly to 9 minutes of taxi fuel burn

Take-Off

- Use minimum Reduced Acceleration Altitude when no regulatory restrictions exist
- Min clean speed if route more than 90 degrees
- Optimum FMS climb-out speed based on Cost Index after meeting low altitude regulatory speeds
- Day/Night rule set can allow significant savings and manage the noise at some time
- Once aircrafts are getting quieter it will be important to trial each aircraft type to apply restriction only when necessary



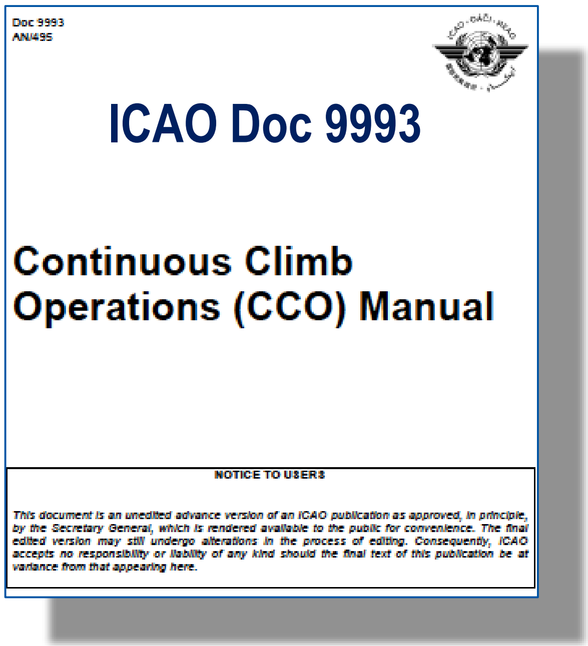
Climb profiles

The Need for speed

- Fuel consumption at take-off and missed approach is about three times higher than in arrival
- Reduced Flaps is usually a quick win initiative with high potential

Avoiding steps during climb

Track miles vs step climbs


Doc 9993
AN/495

ICAO Doc 9993

Continuous Climb Operations (CCO) Manual

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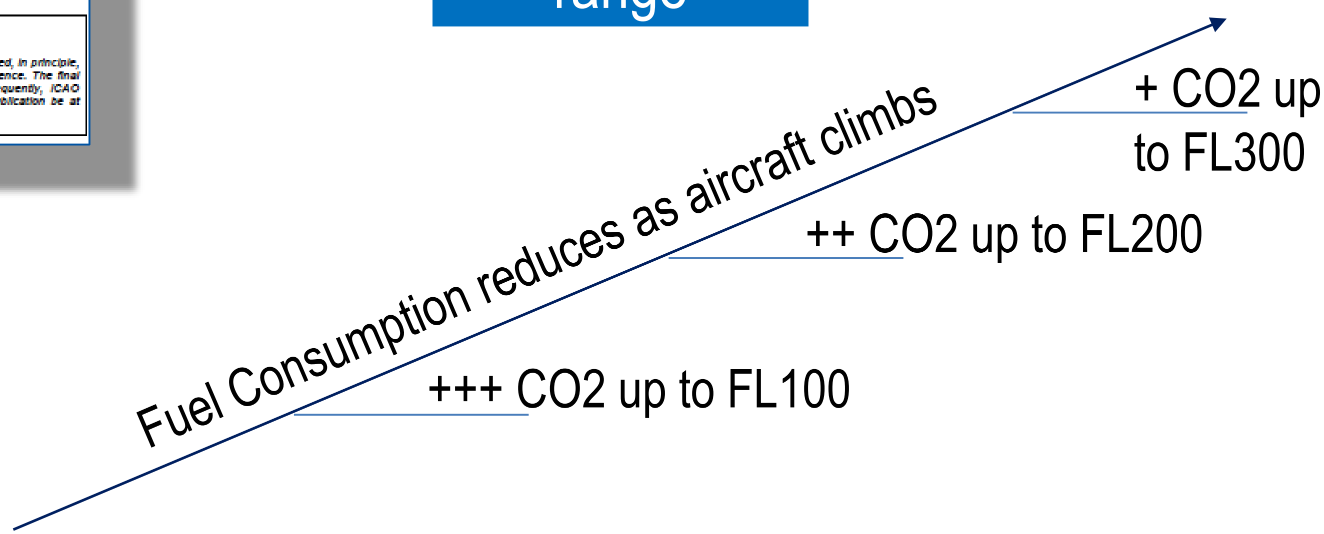
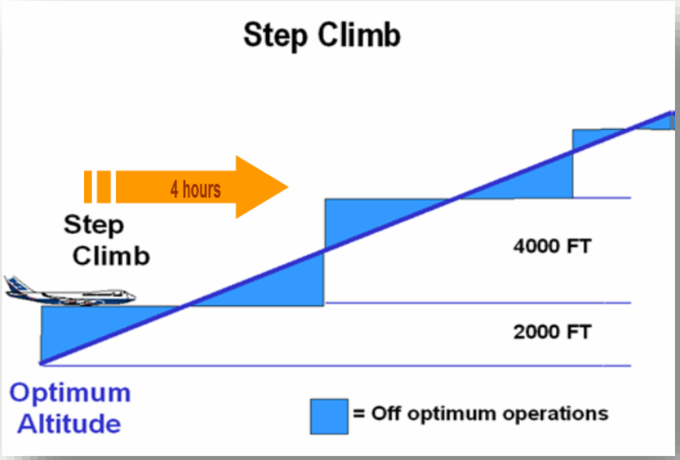
After implementing CCO track how many step climbs, per aircraft type, per FL range

Calculate:
CO2 saved



EnRoute

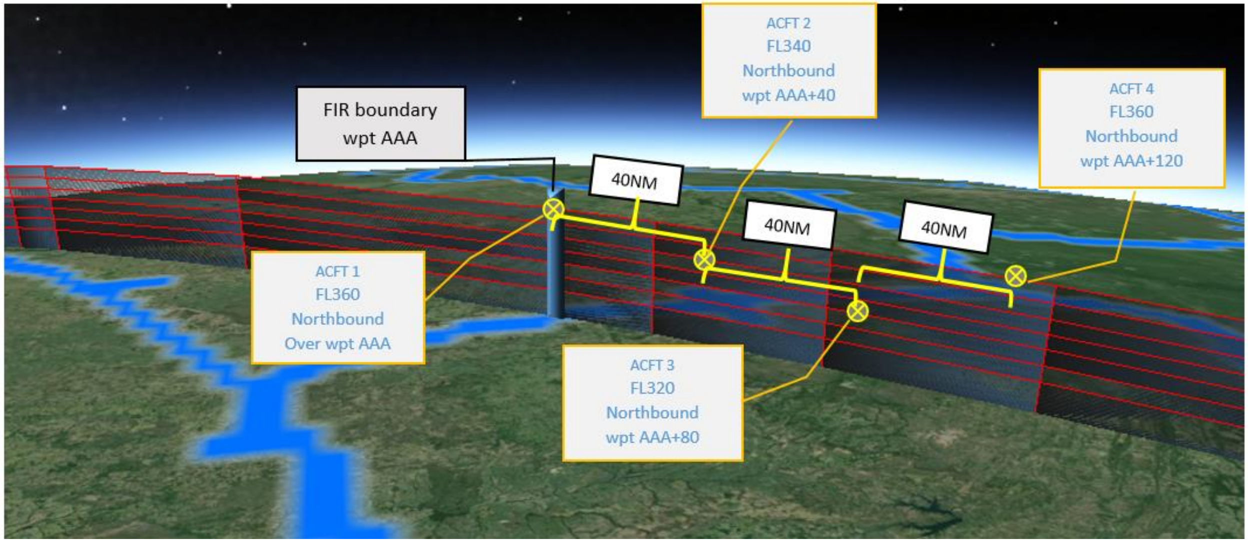
- After 4 hours, this aircraft is 24,000kg lighter and should climb to a higher optimum altitude
- If the flight plan is optimized and updated, use Flight Plan levels
- Challenge the coordination between sectors to achieve the pretended optimized level
- Use optimized speed based on Cost Index
- Update temperature and winds on the FMS for more accurate Cost Index speed and level

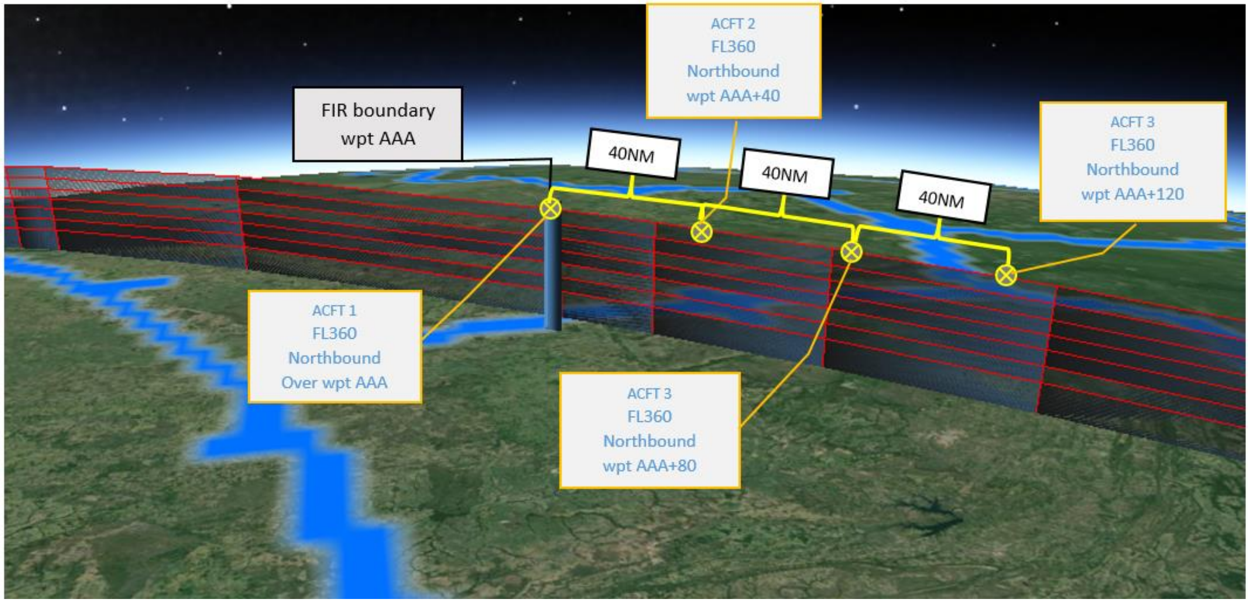


Optimum altitudes

- Flying 4000ft below optimum can increase the fuel burn ~350kg per hour
- Reducing Cost Index when ahead of schedule can additional fuel

Flight Level Flexibility





Allowing traffic to fly the optimized altitude

Potential savings calculation
Case Study

MD11 Fuel plan (lbs) / (flt time)	Ops	Unrestricted FL			Capped until: (MKJK FIR)					
		FL340			FL320			FL300		
VCP-MEM (Optimized route)		Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)	Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)	Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)
QTR1 (Capped until DIBOK)	60	207,719	09:16 / 556	22,416	207,823	09:15 / 555	22,467	208,431	09:14 / 554	22,574

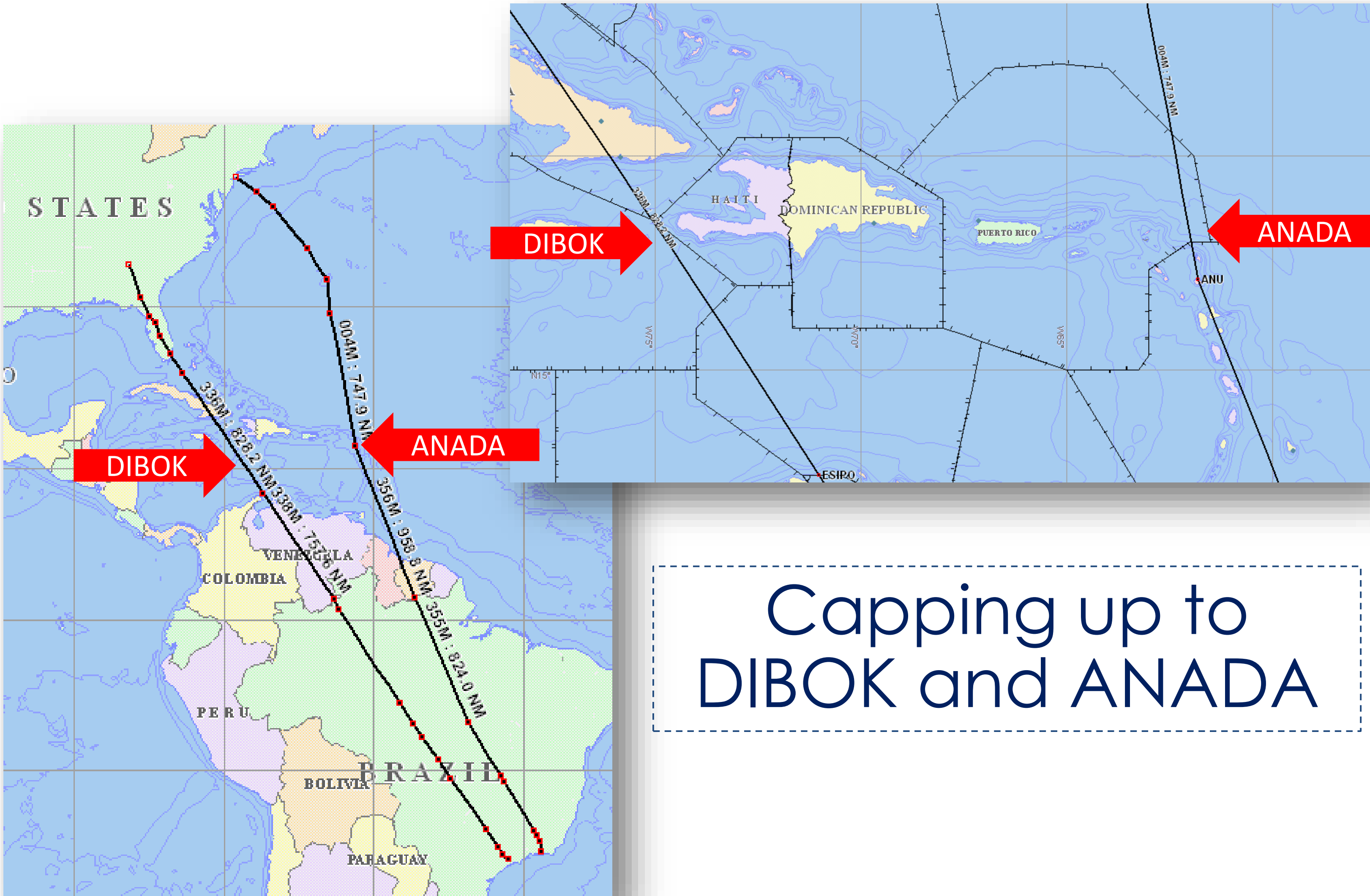
B764 Fuel plan (lbs) / (flt time)	Ops	Unrestricted FL			Capped until: (MKJK FIR)					
		FL320			FL300			FL280		
GRU-ATL (Optimized route)		Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)	Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)	Fuel (lbs)	Flt Time (hrs:mins / mins)	Fuel burn (lbs/hr)
QTR1 (Capped until DIBOK)	82	112,628	9:13 / 553	12,220	114,128	9:11 / 551	12,427	115,828	9:14 / 554	12,545
QTR2 (Capped until DIBOK)	5	112,908	9:12 / 552	12,272	113,732	9:10 / 550	12,407	115,132	9:11 / 551	12,537
QTR3 (Capped until DIBOK)	5	109,860	8:59 / 539	12,229	110,859	8:58 / 538	12,363	112,559	8:59 / 539	12,530
QTR4 (Capped until DIBOK)	57	112,841	9:13 / 553	12,243	113,641	9:10 / 550	12,397	115,140	9:12 / 552	12,515

- 3 airlines contributing to this study
- Aiming 1000 flights for an year period with B767 / B777
- 3 routes from Brazil to USA

Savings per annum in Fuel Kg and CO2 Ton

- South to North capping **FL 320** at DIBOK / ANU
- 609 Ton | 1,918 Ton CO2 | Year
- Brazil (VCP / GRU / GIG) to US (MEM / ATL / JFK)

South to North flights



Capping up to DIBOK and ANADA

Savings calculation methodology - lateral

Define city pairs to optimize

Below 1000NM use track miles

Beyond 1000NM use airline data

Airlines to provide optimal routes based on season winds

After implementing track how many flights used optimal route

Flight 113.3Kg Fuel 356.9Kg CO2 per min

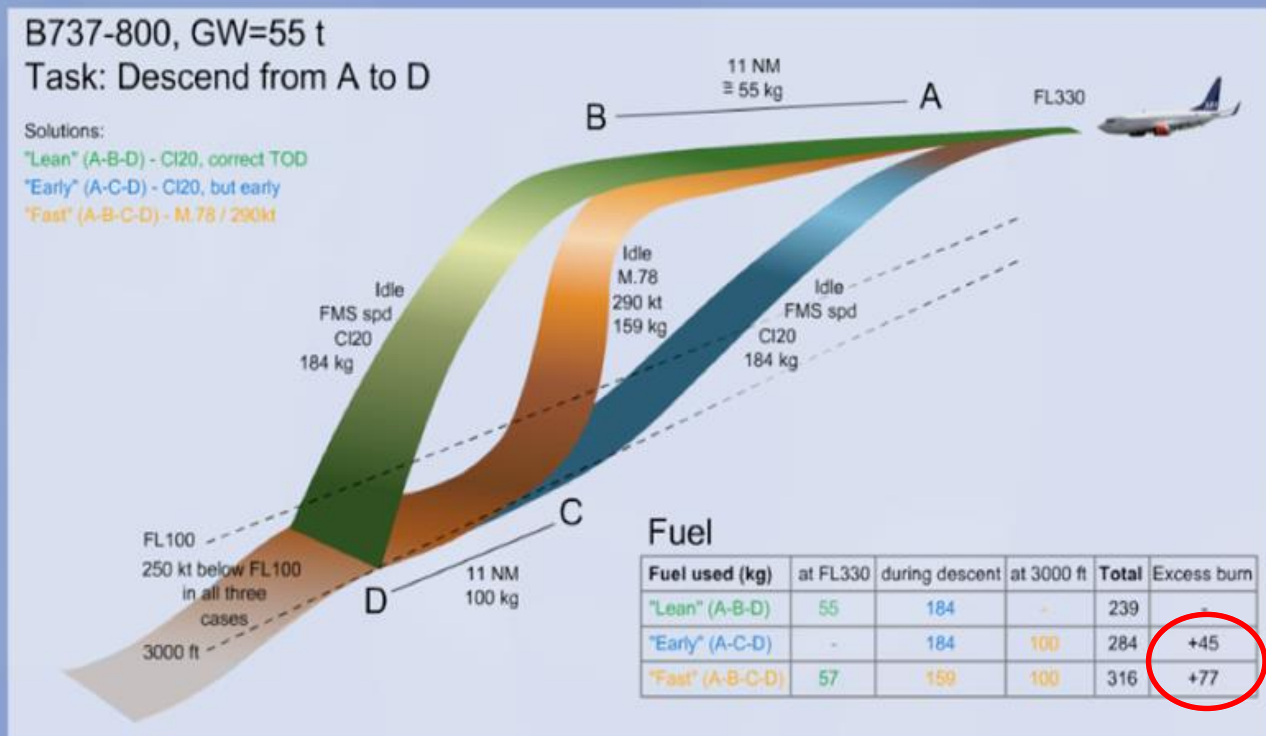
JFK-GRU					
JFK-GRU	Airline A	B777	3 min	530 Kg	1670 CO2
JFK-GRU	Airline B	A330	4 min	480 Kg	1512 CO2

Calculate:

Min saved

CO2 saved

Long term goals & High level Roadmap



Fuel used (kg)	at FL330	during descent	at 3000 ft	Total	Excess burn
"Lean" (A-B-D)	55	184	-	239	-
"Early" (A-C-D)	-	184	100	284	+45
"Fast" (A-B-C-D)	57	159	100	316	+77

The graphic you see here illustrates three different DES paths. The green path (A-B-D) is a fuel OPT DES path at IDLE thrust at Current Optimum CI. It is started at FMC calculated T/D and ends up at 3000 ft at the correct APR position.

Number R/T can mean vectoring or level-off, Track R/T number and level off per a/c type

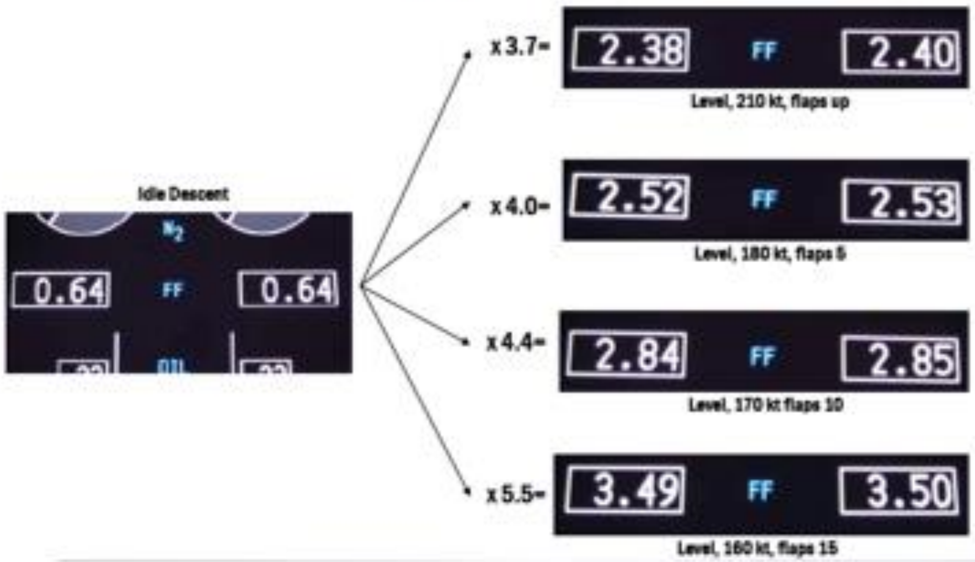
FMS optimized descend profile

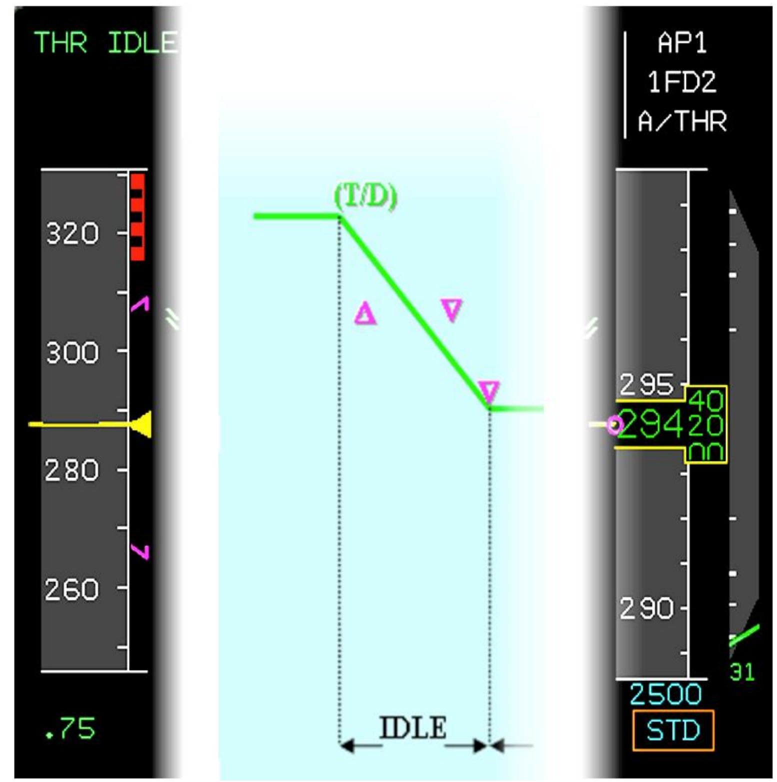
- The FMS will calculate the Top of Descend (TOD) as a function of the Cost Index
- On this case, up to 77kg burn difference when optimized profile is not flown, winds must be loaded on FMS

Calculate:
CO_2 saved

Descend - Continuous Descent Operations

Level-offs use 4 to 5 times more fuel than an idle descent!



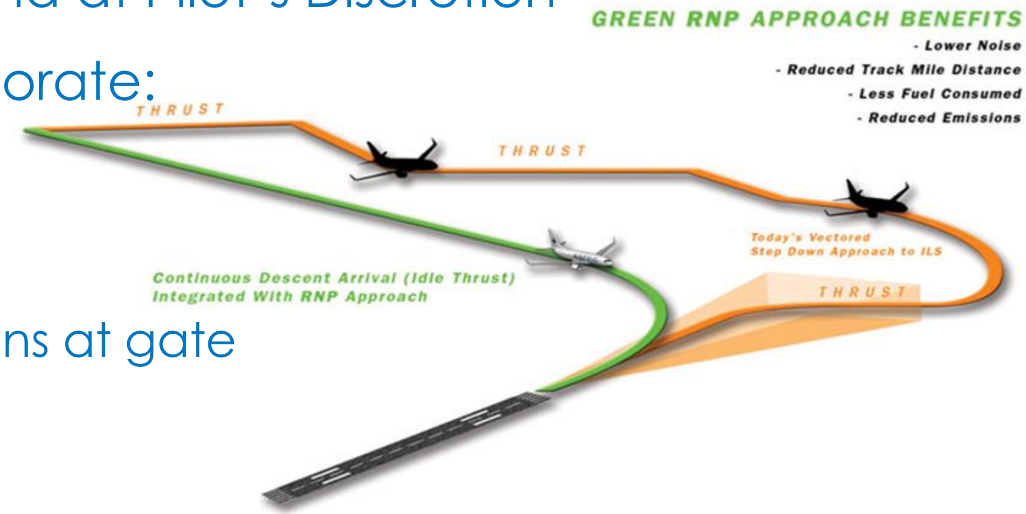


FMS Energy Management

- The FMS is continuously working toward the next altitude and/or speed restriction
- During descent and approach, use speeds that are most efficient based on the mission Cost Index as possible
- FMS is continuously trading speed for altitude or vice versa as required. Energy management and trade off should always be kept in mind

Descend - Continuous Descent Operations

- Continuous Descent Operation:
  - ATC clearance to descend at Pilot's Discretion
  - FMS / Flight Idle to incorporate:
    - Cost Index Speed
    - Rate of descent
    - Accurate time predictions at gate
- RNAV / RNP Approach
  - More direct approach reducing time and track miles
  - Reduced fuel burn, emissions and less noise
  - Fewer WX diversions



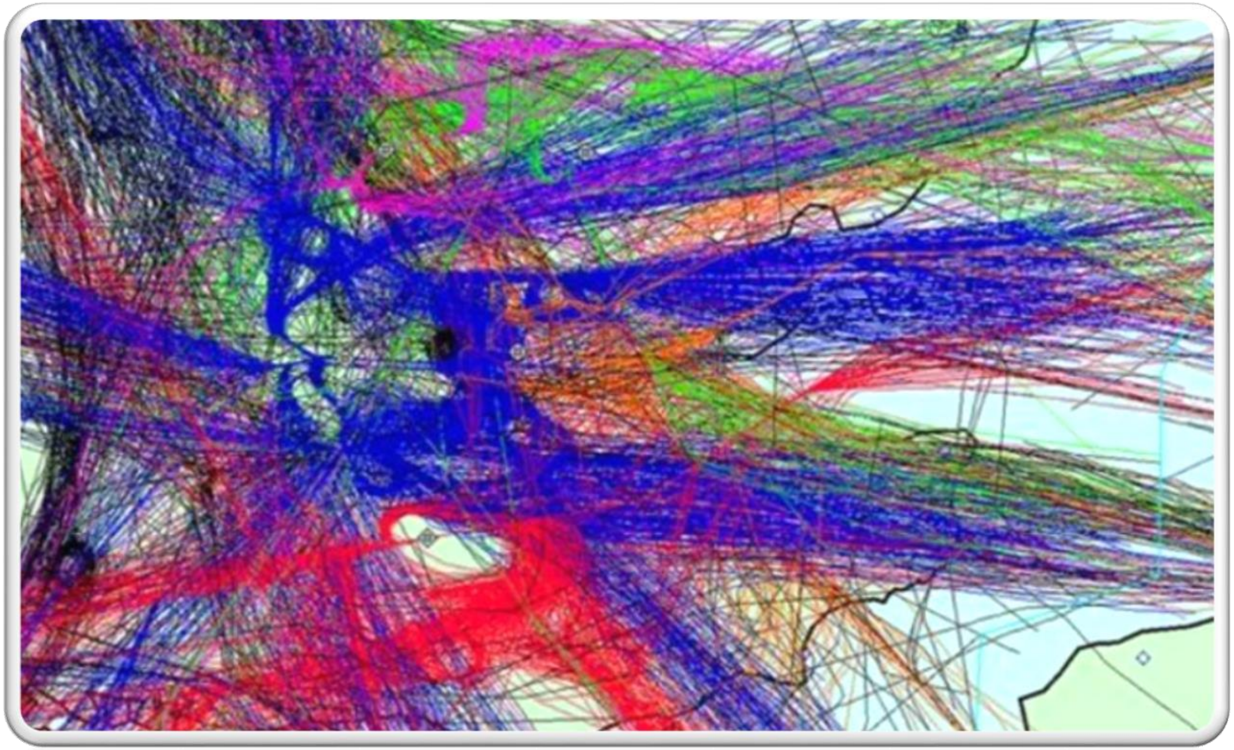
Continuous descent /approach can result in:

- Saving 1 min per flight means 30kg-156K tons CO_2 / 40% less noise
- RECAT and Time Base Separation increase capacity and increases efficiency

ATFM best practices

- **Timely communication** to stakeholders before and during disruption or services
  - Airlines
  - Airports
  - Other ATS or ATFM units
  - An option could be to use ITOP (IATA's "one stop shop" for tactical CDM) that could be used by all ATCs supervisors or FMPs/FMUs to share information.

Efficiency of the system is the clue



How?

- Predictability
- Collaborative Decision Making (CMD) between stakeholders
- Measure the ATM system and improve what is necessary according to the expected demand

THANK YOU

QUESTIONS?