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Best Practices for Fuel Economy

Presented by:

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AIRBUS

Best practices for Fuel Economy

- 28 October 1972: Maiden flight of the A300
- 1973: First energy crisis
- Airbus is fully committed to fuel economy since the beginning of its existence

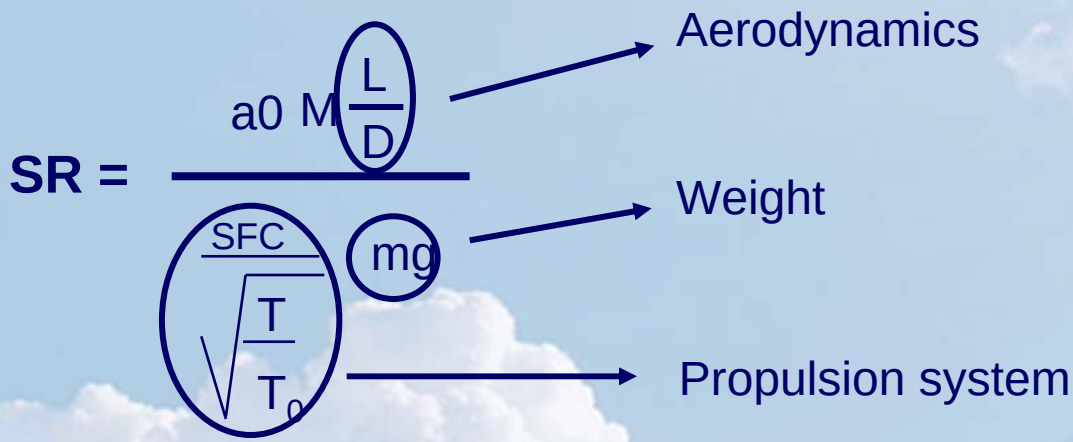
A permanent and omnipresent objective for Airbus

Best practices for Fuel Economy

- Background
  - A permanent and omnipresent objective for Airbus
  - Dedicated efforts made by Airbus
    - in all fields of activity
    - in every phase of product life
    - in all parts of Aircraft
    - in every phase of Aircraft operation
  - Experience accumulated jointly by Airbus, Suppliers and Operators has permitted to reach maturity in actually optimising fuel economy
  - Incorporation of improvements in technologies, methodologies and modelling techniques, instrumentation, etc., as they become available

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - What are the physics in operations ?



Best practices for Fuel Economy

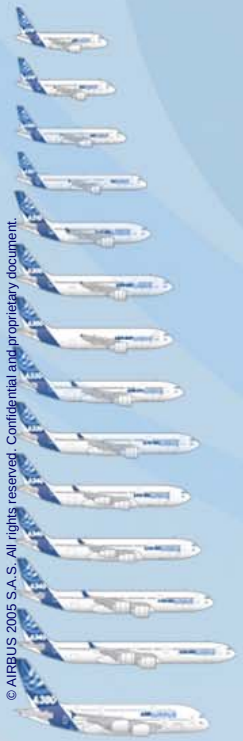
- Dedicated efforts in every phase of operation
  - To maximise fuel economy, the following is required:
    - An aerodynamically clean aircraft
    - Well maintained engines
    - Good flight planning
    - Good flight procedures

Unfortunately there is no magic formula

Just the diligent application of well established practices & procedures

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Weight and balance
      - Aircraft loading: further aft Centre of Gravity (CG) position (within allowable range) increases specific range
      - Automatic centre of gravity management through FCMC (Fuel Control and Management Computer)



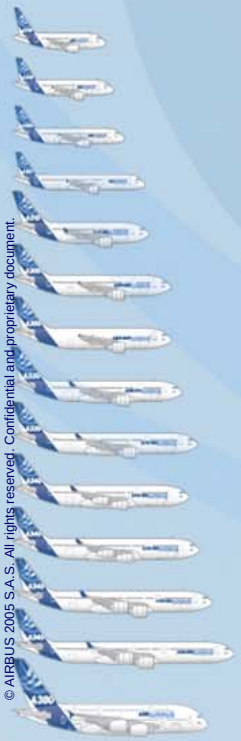
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Weight and balance

Aircraft types	Fuel increment KG/1000nm/10%CG	Typical Sector distance (nm)	Fuel increment per sector (kg)
A300-600	240	2000nm	710
A310	110	2000nm	330
A319/A320/A321	Negligible	1000nm	Negligible
A330-200	70	4000nm	480
A330-300	90	4000nm	600
A340-200	90	6000nm	900
A340-300	80	6000nm	800
A340-500	150	6000nm	1550
A340-600	130	6000nm	1300

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Weight and balance
      - Aircraft loading: further aft Centre of Gravity (CG) position (within allowable range) increases specific range
      - Automatic centre of gravity management through FCMC (Fuel Control and Management Computer)
      - Avoid excess weight; eliminate unnecessary weight in order to have the lowest possible ZFW.



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      - Avoid excess weight; eliminate unnecessary weight in order to have the lowest possible ZFW.

A330-300
1300 nm per sector

Extra weight or fuel in Kg	Extra Fuel Used (Kg)	Fuel used over a year in Kg
100	6	5650
500	26	24500
1000	52	49000

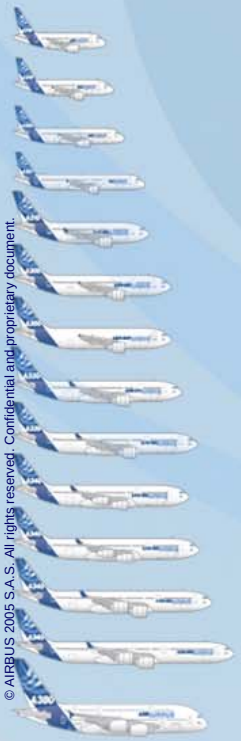
A340-500
6300 nm per sector

Extra weight or fuel in Kg	Extra Fuel Used (Kg)	Fuel used over a year in Kg
100	45	14694
500	226	73800
1000	453	147900

per aircraft

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Quality Flight Planning System features:
      - Good Quality Data:
        - Temperature, wind, aircraft weight, payload, fuel uplift, etc
      - Optimised Speeds and Flight Levels:
        - Flight profiles based on speeds and cruise flight levels that are in accordance with the operators economic criteria
        - For aircraft that can fly in FMGS managed mode, use flight profiles based on operators cost index
      - Optimised Route in terms of track, speed and altitudes:
        - Compliant with ATC requirements and with the operators economic criteria (fuel & time)

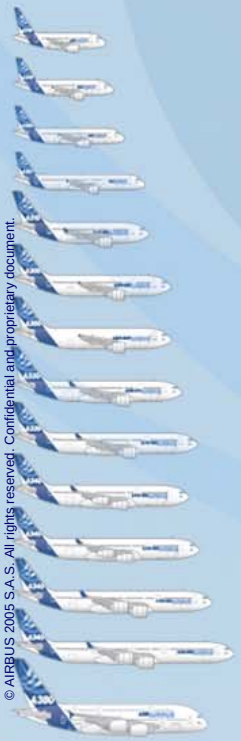


Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Example of optimised routing
      - Bilateral negotiation, or via IATA, with some local Airworthiness Agencies enables to create more direct routes.
      - As a recent example : a new route in China has been opened. This could save up to 30 mn on the China-Europe flights

Best practices for Fuel Economy

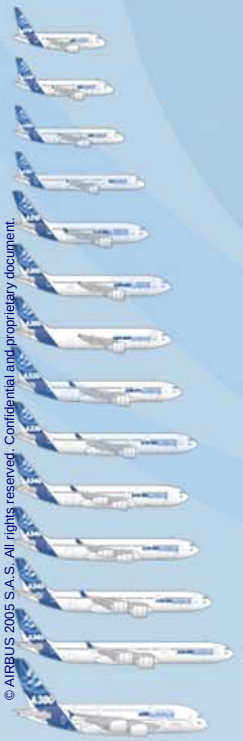
- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Quality Flight Planning System features:
      - Caracterize aircraft and engine ageing
        - Conduct aircraft performance monitoring program
        - Use factor appropriate to the individual tail number or fleet
        - For more information see «Getting to Grips with Aircraft Performance Monitoring»
      - Minimise Contingency Fuel:
        - Use en-route alternate airports or redispatch procedure when possible
      - Minimise Alternate Fuel:
        - Choose alternate airport close to the destination airfield



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - –Quality Flight Planning System Benefits:
      - Fuel requirements minimised
        - Minimise embarked/contingency fuel through accurate flight planning
      - Achievable Flight Profiles
      - Flight plan prediction of fuel at destination generally achieved (if flight flown as planned)
      - Aircrew have confidence in the flight plan - No surprises

        - No need to add extra fuel



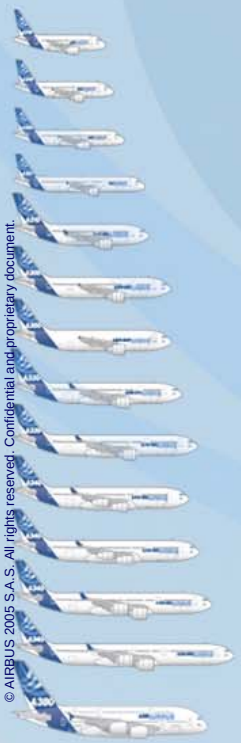
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - MEL, for an airline, provides flexibility in A/C operations

      But…

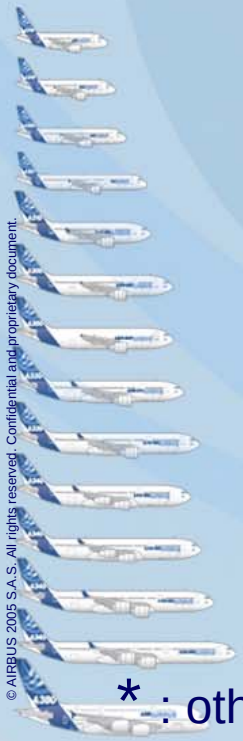
    - For some MEL or CDL items, this flexibility results in higher fuel burn

    - So Airbus recommends to rectify these items quickly.



Best practices for Fuel Economy

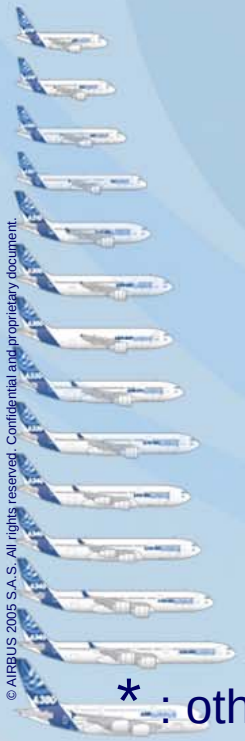
- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - MMEL examples*
      - Nacelle anti-ice valve blocked open :
        - 0.25% per engine A340/RR,
        - up to 2% on A330/GE,
        - 0.3% up to 1.7% on A330/PW
        - 0.5% on A330/RR
      - Wing anti-ice valve blocked open :
        - 2% increase in fuel consumption on A340/CFM,
        - 1.5% on A330/GE,
        - up to 6% on A330/PW
        - up to 5.5% on A330/RR.



*: other limitations might be imposed in the MMEL operational part or CDL

Best practices for Fuel Economy

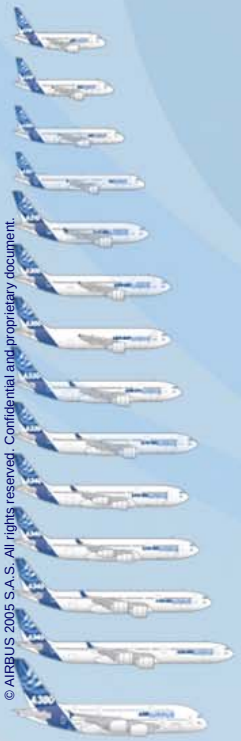
- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - MMEL examples*
      - Fuel auto-transfert inoperative :
        - 1% on A330,
        - from 1.7 to 3.2% for an A340-500
        - from 2 to 3.7% for an A340-600.
    - CDL examples*
      - Boomerang seal on aft pylon fairing : 0.4%
      - Winglet :1.2% for an A340-500
      - Bearver tails : 2.1% for A340/RR



*: other limitations might be imposed in the MMEL operational part or CDL

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Ground Equipment and the APU:
      - Limit use of APU whenever possible (depending on GSE availability and price, on turn-around time…)
      - APU and engine start up time needs careful planning in conjunction with ATC
      - Keep passenger comfort in mind

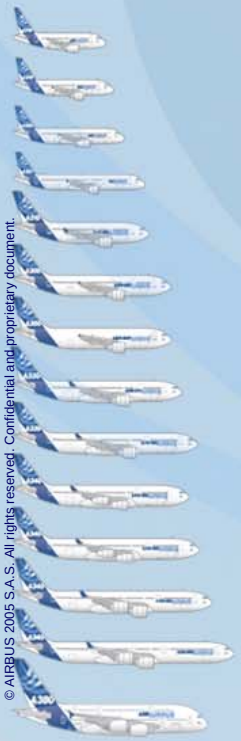


Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - Pre-flight procedures
    - Taxying:
      - Taxiing with one (2) engine (s) out saves fuel but some drawbacks to be considered: operators must base their policy on airport config. (taxiways, runways, ramps, etc.)
      - Consider uphill taxiway slope and high weights, reduced redundancy, warm up & cool down times, problems away from gate, etc

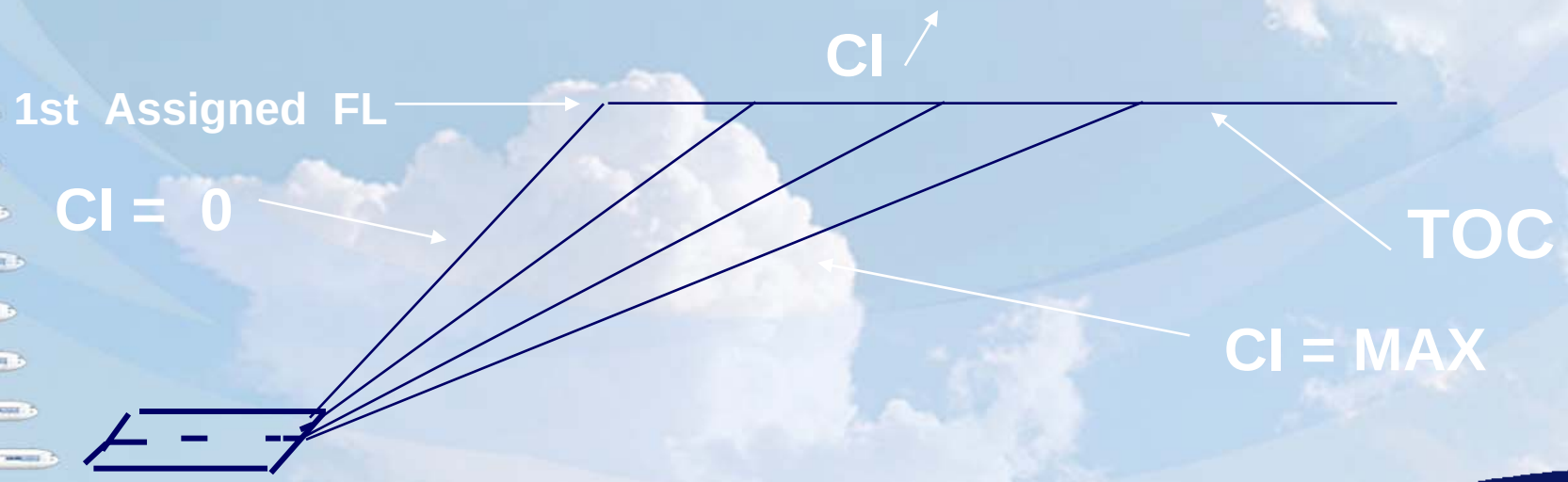
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Take-off Flap
      - Lowest flap/slat setting will give lowest fuel burn and best flight profile
      - Other priorities such as maximising TOW, maximising flex temp, etc may require other flap settings
    - Take-off Acceleration Altitude
      - The minimum acceleration altitude required by regulations will optimise fuel consumption
    - Computerised Flight Plan
      - As much as possible, stick to CFP flight levels and climb, cruise and descent techniques



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Climb
      - Optimum climb law is depending on the Aircraft, on selected modes and cost indices
      - In general, it is not profitable to climb at high-speed laws except for time imperatives, neither to climb at very slow climb laws



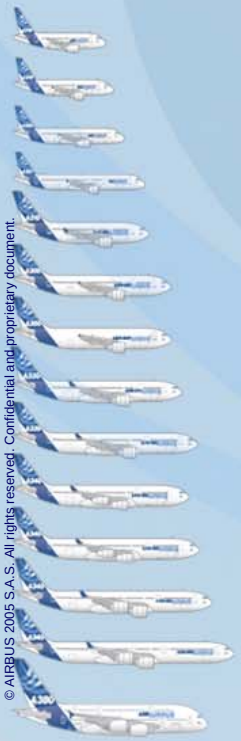
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Climb
      - Optimum climb law is depending on the Aircraft, on selected modes and cost indices

Aircraft	Climb Mach No.	ΔFuel – kg				
		270KT	280 KT	300 KT	320 KT	330 KT
A300	0.78	+40	+15	0	+5	+10
A310	0.79		+5	0	+5	+15
A318/A319/A320	0.78		-15	0	+30	+70
A321	0.78		-10	0	+25	+60
A330	0.80	+15	+5	0	+20	+35
A340–200	0.78	+45	+20	0	+10	+25
A340-300	0.78	+105	+50	0	-5	+20
A340-500/600	0.82		+135	0	-5	-10

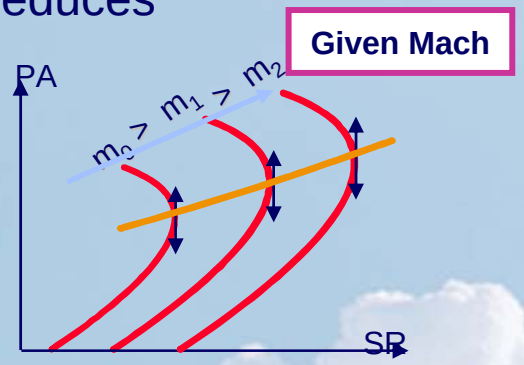
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise
      - Cruise is the most important phase in terms of fuel savings
      - Fuel efficiency during cruise can be optimised by
        - Cruise with stepped climb
        - Cruise with an economic speed



Best practices for Fuel Economy

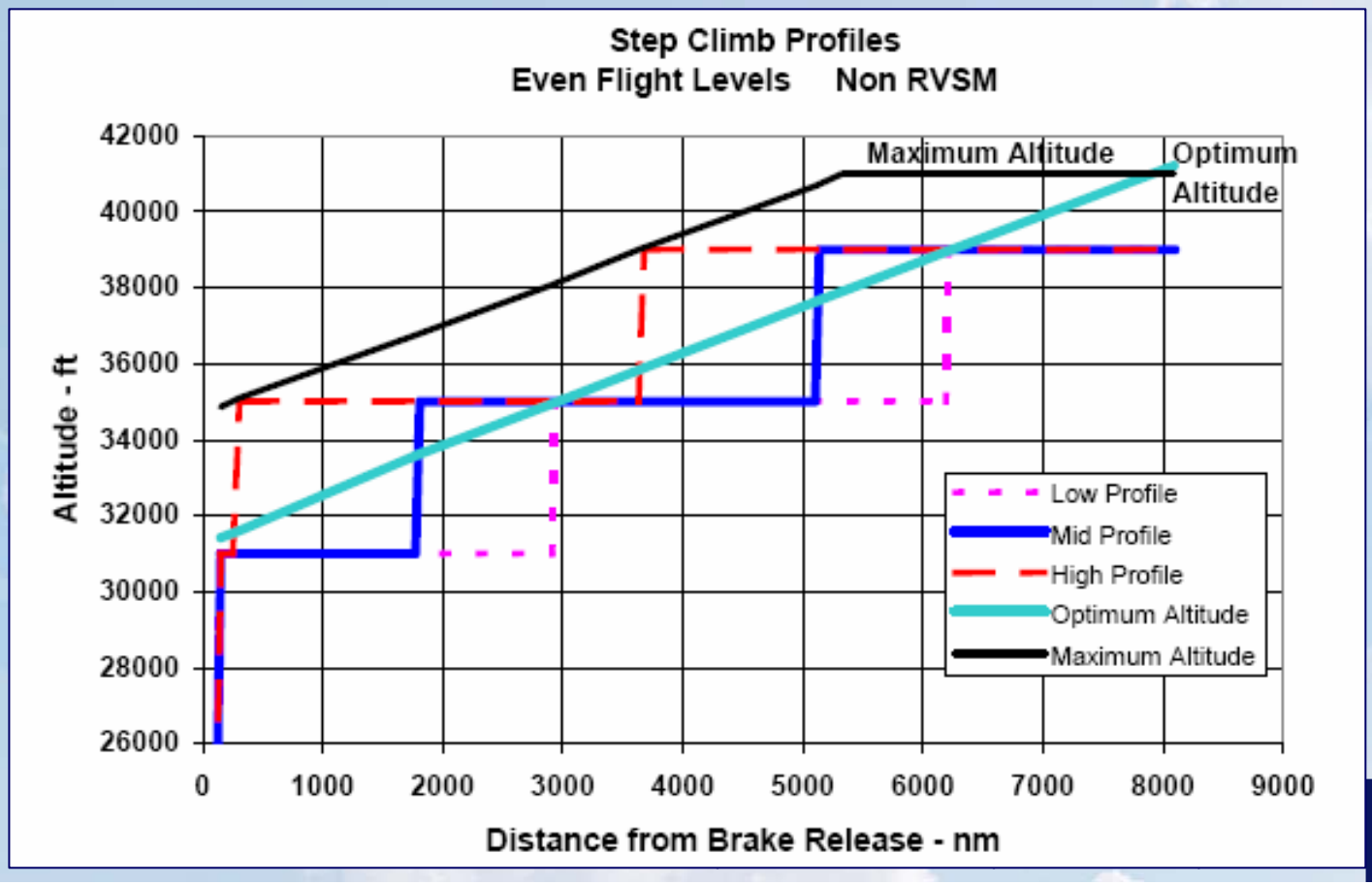
- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with stepped climb
      - Optimum altitude (for time and costs) increases as weight reduces



      - When ATC allows them, step climbs are performed to stay close to the optimum.

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with stepped climb



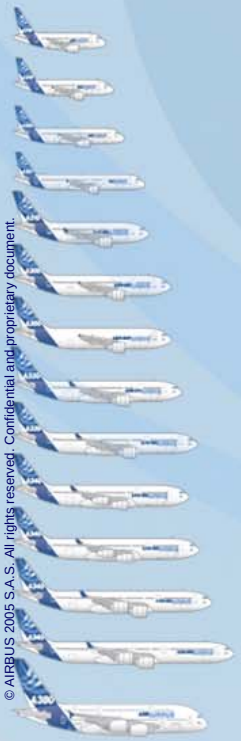
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with stepped climb
      - Delaying climb to the next step should be avoided

Excess fuel burn for a 500NM flight segment

Flight at FL330 with Optimum FL FL370

Aircraft Type	Fuel Increase (kg)	Fuel Increase (%)
A300B4-605R	238	5.2
A310-324	221	5.3
A318-111	150	6.2
A319-132	184	7.9
A320-211	158	6.2
A320-232	187	7.9
A321-112	155	5.5
A330-203	324	5.5
A330-343	342	5.6
A340-212	393	6.2
A340-313E	378	6.0
A340-500/600	336	4.1



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with an economic speed

      - When possible, it is recommended to fly in managed mode (using FMS).

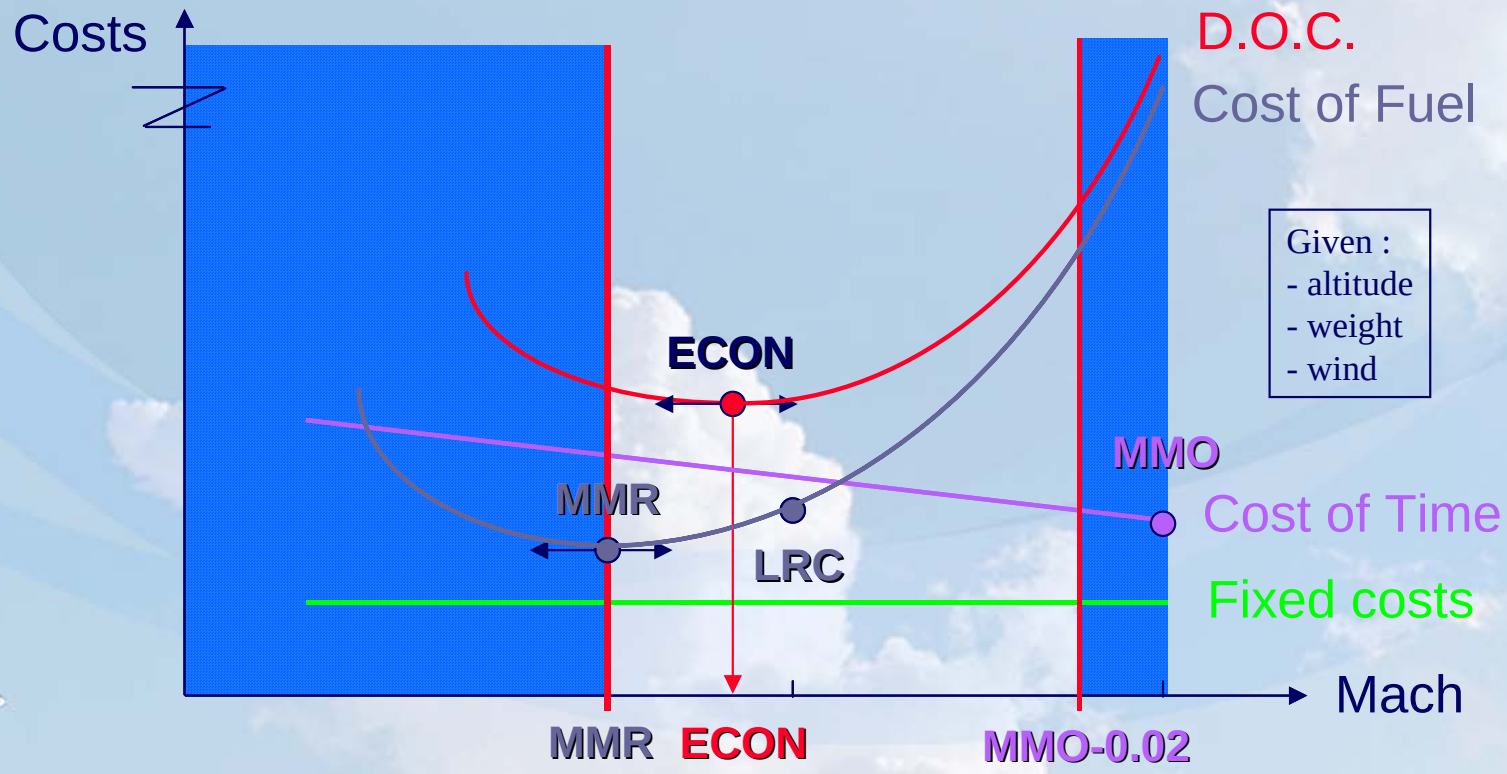
      - Indeed, flying at a given Cost Index provides the benefit of flying at the Optimum Mach Number as a function of aircraft weight, flight level and wind component.

$$C.\,I. = \frac{\text{Cost of Time}}{\text{Cost of Fuel}}$$

Best practices for Fuel Economy

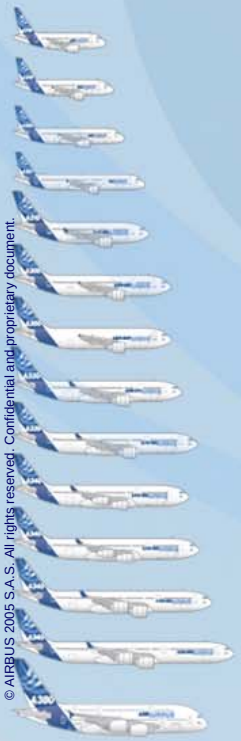
- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with an economic speed

$$C.I. = \frac{\text{Cost of Time}}{\text{Cost of Fuel}}$$



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise with an economic speed
      - Optimum cruise altitude and airspeed depend on Aircraft, weight, wind, and cost index (CI)
      - Lowest fuel consumption is obtained at the lowest cost index (however the time penalty has to be watched)
        - A330 at FL350, 50kg of fuel is saved for 10 minutes of additional flight time between CI=0 and CI=20.
      - FMS optimises the flight plan (including the flight profile) accordingly



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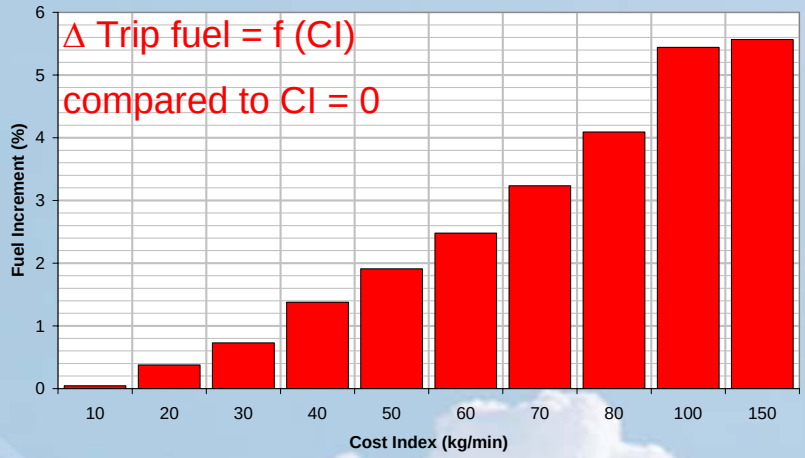
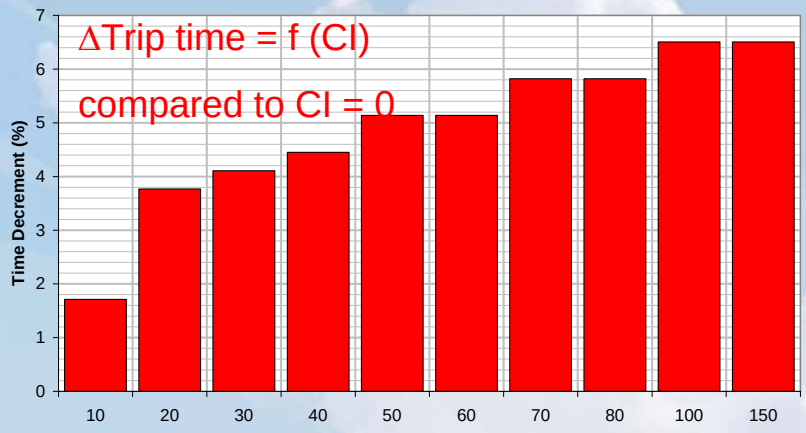


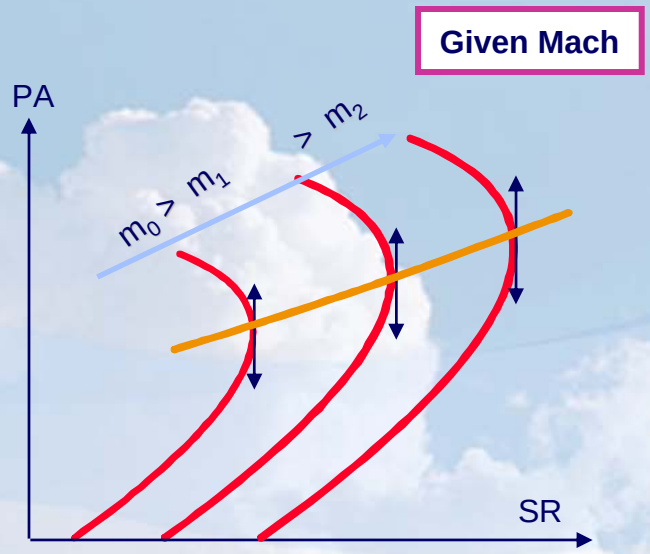


Assumptions

- A320-232
- TOW = 73500kg
- ISA, no wind
- 2000 Nm

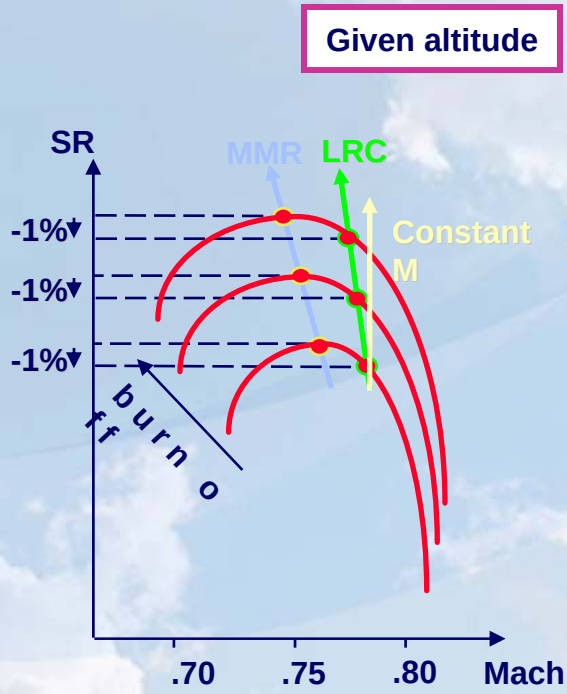
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise optimization
      - If ATC imposes Mach Number, crew can only optimise altitude and fly on selected mode. Information and recommendations are given in FCOM
        - a step climb is worthwhile only if the cruise time is long enough



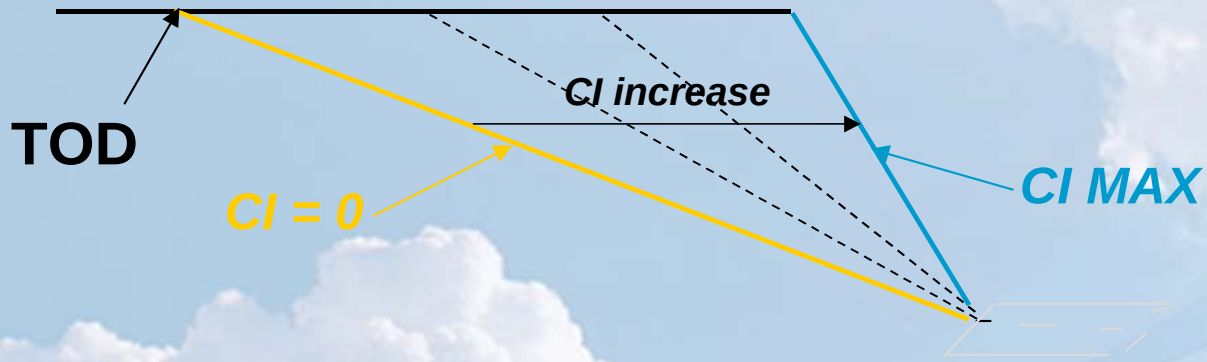
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Cruise optimization
      - If ATC imposes Flight Level, crew can only optimise speed and fly on selected mode. Information and recommendations are given in FCOM
        - flying at LRC is recommended
        - wind must be in-depth evaluated...



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Descent
      - Fuel consumption increases significantly with airspeed and also in case of a premature descent
        - Descent performance depends on A/C, weight and cost index



        - The lower the cost index, the lower the speed, the less steep the descent path, the longer the descent distance, the greater the descent time, the earlier the top of descent (TOD) point, the lower the fuel consumption
        - The FMS computes the TOD as a function of cost index

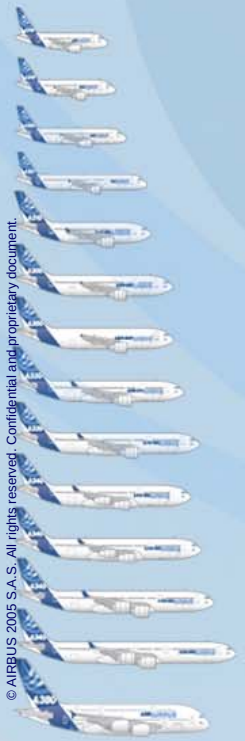
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Descent
      - From FL350

Type	ΔFuel – kg					
	240KT	260 KT	280 KT	300 KT	320 KT	330/340KT *
A300	-55	-60	-30	0	25	35
A310	-55	-60	-30	0	25	40
A318, 319, 320	-50	-40	-20	0	20	25
A321	-35	-40	-20	0	20	35
A330	-110	-105	-60	0	50	70
A340–200/300	-70	-90	-50	0	50	75
A340-500/600	-125	-130	-70	0	70	100

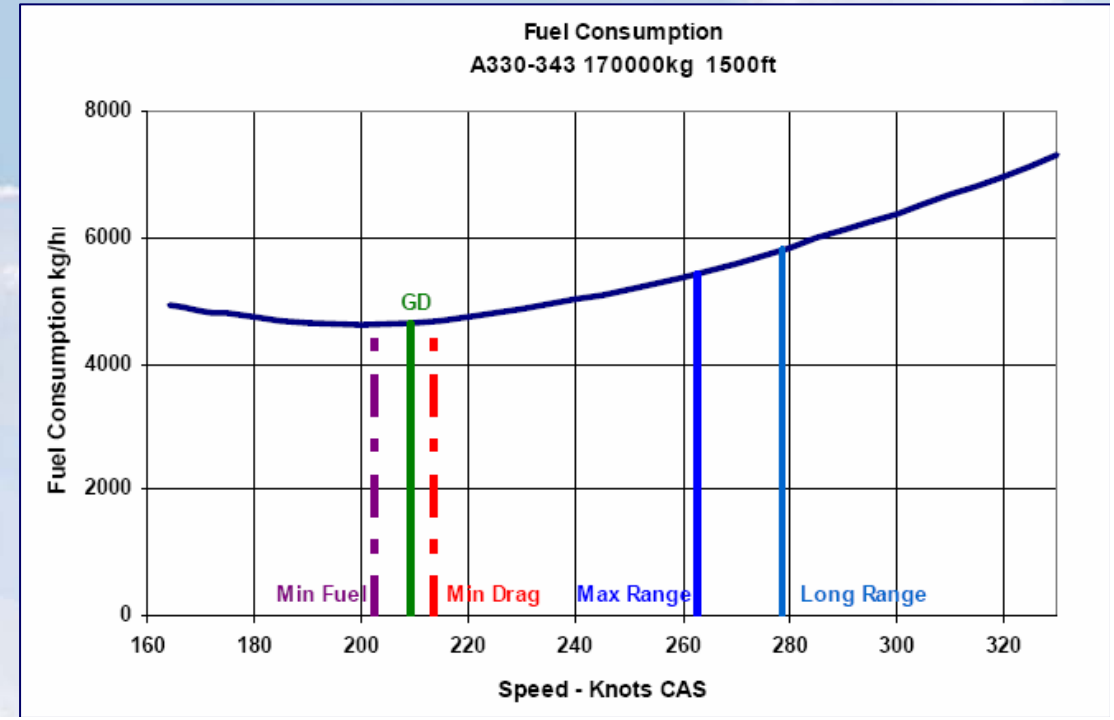
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Holding
      - Green dot speed is the one or 2 engine out operating speed in clean configuration; being approximately the best lift to drag ratio speed, it provides in general the lowest fuel consumption



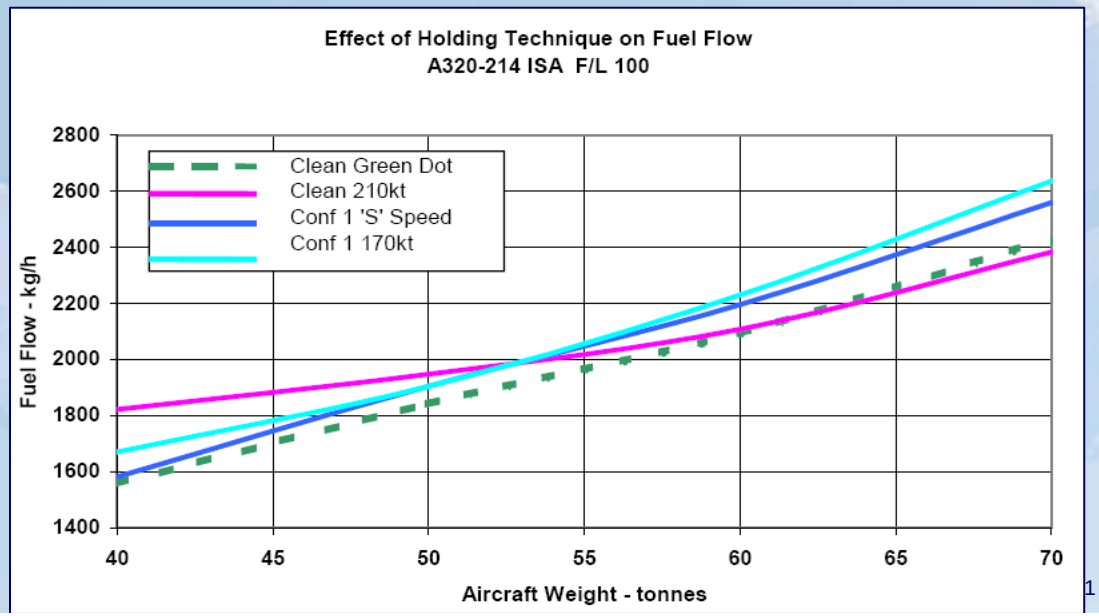
Fuel Efficiency

Actually, Green Dot speed allows a significant increase in speed at the expense of a very limited fuel consumption increase



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Holding
      - Green dot speed is the one or 2 engine out operating speed in clean configuration; being approximately the best lift to drag ratio speed, it provides in general the lowest fuel consumption
        - **Green Dot Speed may not be appropriate at some airports. it is then advised to hold at a lower speed, or in FLAP 1 at S speed**



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Holding
      - Green dot speed is the one or 2 engine out operating speed in clean configuration; being approximately the best lift to drag ratio speed, it provides in general the lowest fuel consumption
        - **There is an optimum holding altitude, but holding altitudes are often imposed by ATC**

Assumptions

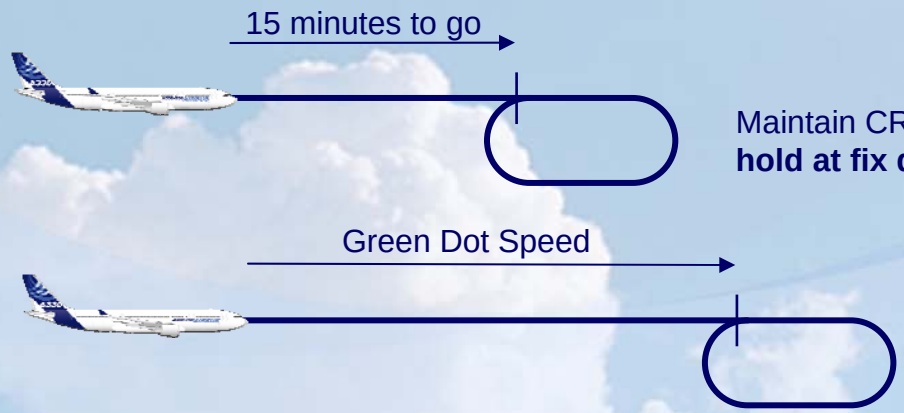
- FLAP 0
- Green Dot Speed
- Increase of fuel flow (kg/h) in percent

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		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

Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Holding
      - Green dot speed is the one or 2 engine out operating speed in clean configuration; being approximately the best lift to drag ratio speed, it provides in general the lowest fuel consumption
        - **<u>Holding optimization</u> : linear holding at cruise level and at green dot speed should be considered**

If ATC informs 15 minutes before reaching fix that 10 minute holding are necessary



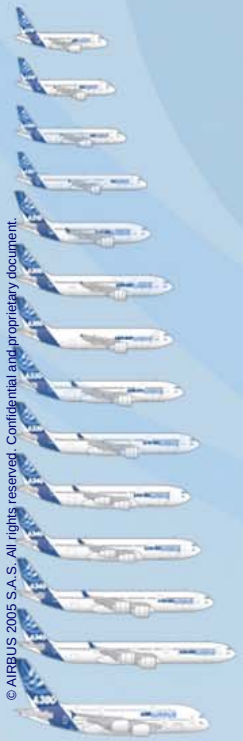
Maintain CRZ speed, cruise to fix, **hold at fix during 10 minutes**

Reduce CRZ speed to Green Dot Speed, cruise to fix, hold at fix

Best practices for Fuel Economy

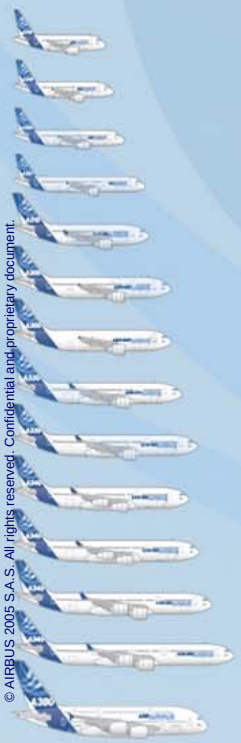
- Dedicated efforts in every phase of operation
  - In flight procedures
    - Holding
      - Green dot speed is the one or 2 engine out operating speed in clean configuration; being approximately the best lift to drag ratio speed, it provides in general the lowest fuel consumption
        - **<u>Holding optimization</u> : linear holding at cruise level and at green dot speed should be considered**

Aircraft type	Weight kg	Cruise Flight Level	Cruise Speed	Fuel savings kg
A300	120000	350	0.8	95
A310	110000	350	0.8	115
A318	50000	350	0.78	120
A319	50000	350	0.78	135
A320	60000	350	0.78	80
A321	70000	350	0.78	50
A330	180000	390	0.82	95
A340-200	200000	390	0.82	10
A340-300	200000	390	0.82	45
A340-500/600	270000	390	0.82	5



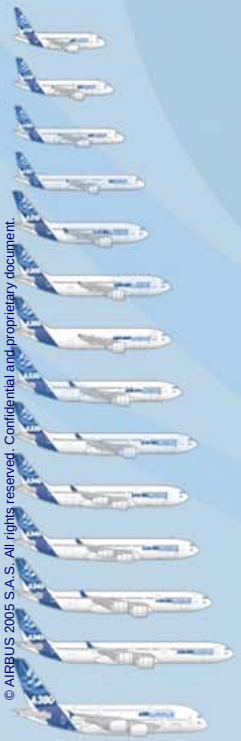
Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Approach:
      - Keep in clean configuration as long as possible
      - Delay gear selection
      - A continuous descent approach saves fuel
      - Visual approach from downwind saves fuel
      - However, do not compromise the stabilised approach philosophy



Best practices for Fuel Economy

- Dedicated efforts in every phase of operation
  - In flight procedures
    - Landing Flap:
      - The lower flap setting will save fuel
      - However consider runway length, exit point, occupancy time, runway surface conditions, tailwind, brake cooling, no Cat 2 or 3 landings, etc

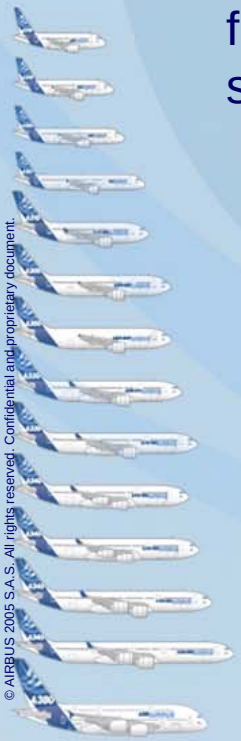


Best practices for Fuel Economy

- Additional opportunities
  - Aircraft family concept, extensive use of concurrent engineering processes, of virtual mock-ups, more sophisticated simulation testing means (software, laboratory, simulators), increased system reliability, reduce the ground and flight test time, the number of ferry flights, some of the continued airworthiness flight tests
    - CCQ/MFF allows short transition training for crew and training flights can be replaced by simulator sessions
  - FMS improvements and bad weather detection improvements
  - Maximised load factors, with optimised aircraft /route combinations
  - RVSM (Reduced Vertical Separation Minima) in Europe since Jan. 2002 allows to fly nearer the optimum altitude for fuel burn

Best practices for Fuel Economy

- Other considerations
  - In the design field, Airbus is involved in considerable research activities, currently in progress, relative to fuel consumption and emissions reduction.
  - Collaborative efforts (manufacturers, operators, airports, authorities, finances, passengers) required to efficiently match supply air transport services to demand for an efficient passenger & cargo air transport



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