Transport Canada Transports Canada

FUEL CONSERVATION

WG4 Workshop

Aviation Operational Measures

for Fuel & Emissions Reductions

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AIRBUS

Transport Canada Transports Canada

FUEL CONSERVATION

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

A permanent and omnipresent objective for Airbus

Flight Operations Panel
Ottawa, 5-6 November 2002

Canada

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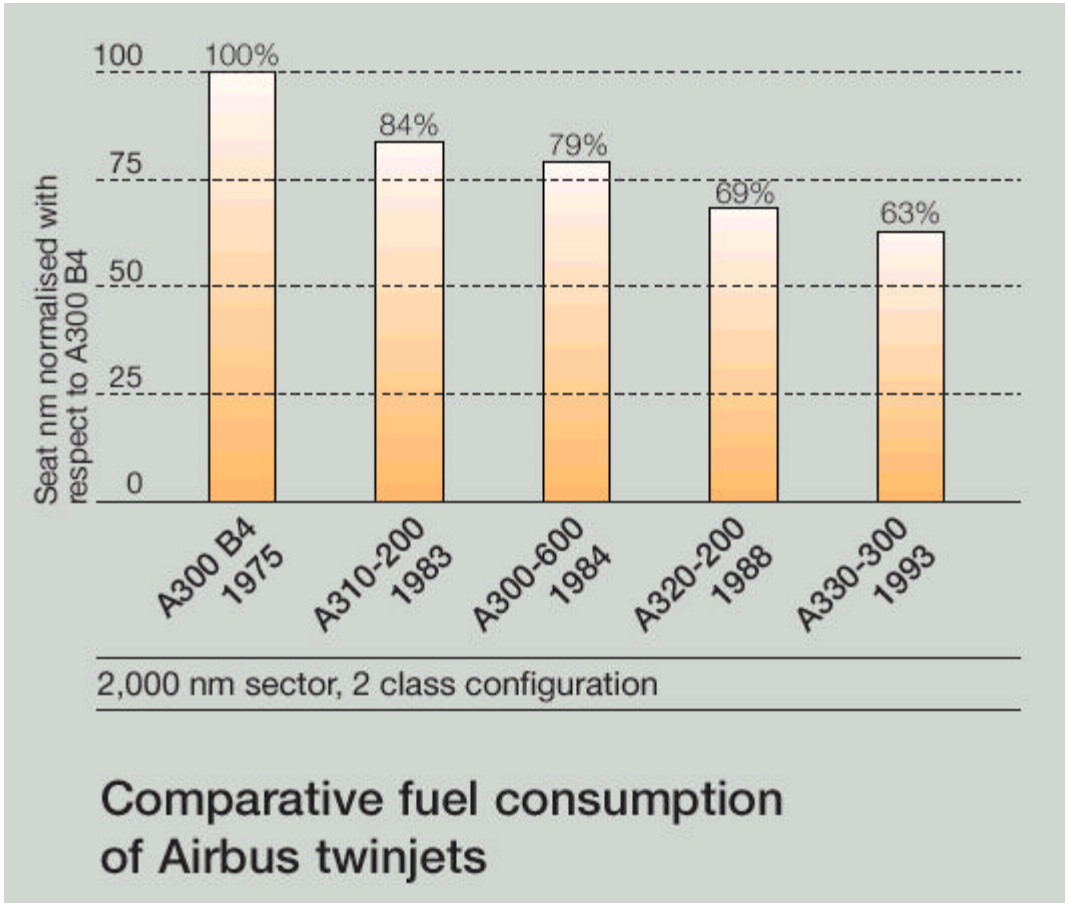

Comparative fuel consumption of Airbus twinjets

Source: The Airbus Way - Environment July 2002

Continual improvements for every new product

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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 conservation**
- **Incorporation of improvements in technologies, methodologies and modelling techniques, instrumentation, etc., as they become available**

Recommendations recalled in these slides are for general info only and not meant to replace any existing specific document

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Dedicated efforts in all fields of activity

- **Design, Production & Quality of A/C optimised to minimise fuel consumption and maximise performance retention.**
  - Close co-operation with Engine/Nacelle Manufacturers and Suppliers
- **Training and documentation include recommendations**
  - Specific brochures on fuel economy, cost index, performance monitoring.
- **In service support**
  - ad hoc support
  - periodic or ad hoc visits of crews and specialists, audits
  - Regular Performance and Operations conferences

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Dedicated efforts in every phase of product life (1)

Design

Procurement

Manufacturing, Assembly

Flight test, calibration

Delivery, in-service operations

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Dedicated efforts in every phase of product life (2)

Design

Design, Production & Quality of A/C optimised to minimise fuel consumption and maximise performance retention.

- Development of “Design for Environment” procedures and tools to ease incorporation of Environment, Health and Safety criteria into design.
- Systematic EHS assessment prior to investment or procurement
- Continuous improvements in order to reduce weight, fuel consumption, noise and emissions

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Dedicated efforts in every phase of product life (3)

Procurement

- **Close co-operation with Engine/Nacelle Manufacturers and Suppliers**
- **Aircraft and Engine Production acceptance processes**
  - Careful monitoring and data analysis (specific cases, trends and statistical analyses)
  - Propulsion system weight must remain within limits

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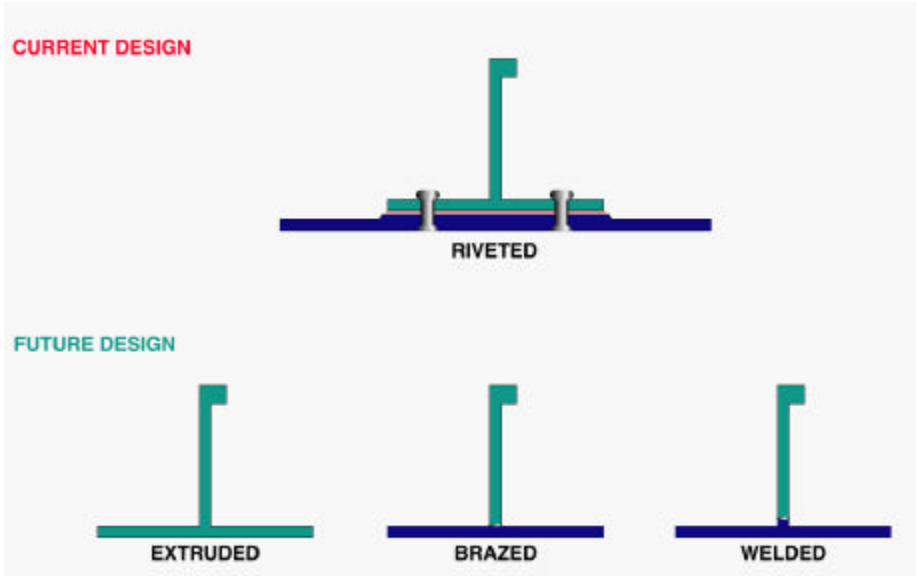
Dedicated efforts in every phase of product life (4)



- welding: Fuselage structures using integrally stiffened panels, extruded or with welded-on stringers, compare very positively in terms of weight and durability with today's riveted structures where additional thickness has to compensate for the rivet holes.

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Dedicated efforts in every phase of product life (5)

Flight test, calibration

Focusing on performance deterioration diagnosis and correction:

- sophisticated modelling of Aircraft and engine performance, adjusted and extrapolated to the full flight envelope leading to a consolidated performance baseline
- dedicated testing of Aircraft and nacelle sealing, etc.
- careful monitoring/analysis of performance gap
- Initial calibration and subsequent adjustments of In Flight Performance (IFP) computation programme
- corrective modifications defined and launched for Aircraft certification standard or earliest possible incorporation

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Dedicated efforts in every phase of product life (6)

Delivery, in-service operations

- **Delivery**
  - Support airlines for the Entry Into Service (EIS) of the aircraft
  - Familiarisation to the specific tools and procedures to minimise fuel burn.
- **In service Support (including documentation & training)**
  - Supply of adequate aircraft systems and software tools for aircraft and Engine performance monitoring; data analysis; further actions as required: APM software.
  - Monitoring of Aircraft-Engines operational, maintenance and overhaul procedures efficiency (engine wash, coke cleaning, aircraft cleaning, sealing restoration, rigging adjustments, etc.)

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Dedicated efforts in all parts of Aircraft (1)

(Efforts on initial design by Aircraft and Engine Manufacturers to be pursued by the Operators with the support from the Aircraft and Engine Manufacturers)

- **Materials and processes to reduce aircraft weight**
- **Aerodynamics**
- **Engines and Nacelles**
- **Aircraft Systems**

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Dedicated efforts in all parts of Aircraft (2)

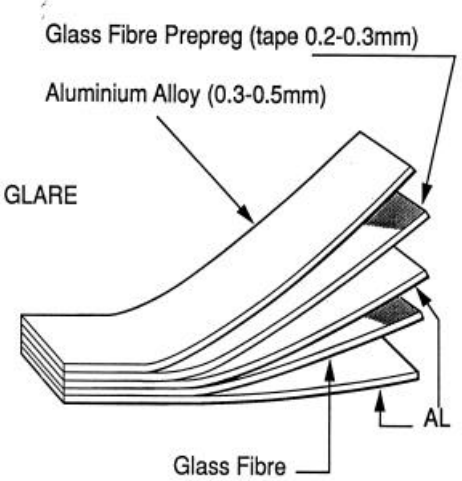
- **Materials and processes**
  - Use materials that guarantee the same or even better safety characteristics while reducing the aircraft weight
    - composites
      - carbon wheel brakes, landing gear door, furnishing and floor panels
      - 20 to 25 percent weight saving over metallic materials (1,800 lb for an A320)

FUEL CONSERVATION

Dedicated efforts in all parts of Aircraft (3)

- **Materials and processes**
  - Use materials that guarantee the same or even better safety characteristics while reducing the aircraft weight
    - composites
    - GLARE
  - newly developed glass fibre laminated composite
  - candidate to be used in the design of fuselage structure
- **Advantages (over Aluminium)**
  - 15 to 28% weight savings
  - higher strength, fatigue and damage tolerance
  - superior flame resistance
  - excellent impact, corrosion and lightning strike resistance
  - easy maintenance

● Typical lay-up of GLARE



FUEL CONSERVATION

Dedicated efforts in all parts of Aircraft (4)

- **Materials and processes**
  - Use materials that guarantee the same or even better safety characteristics while reducing the aircraft weight
    - composites
    - GLARE
    - CFRP
      - carbon-fibre re-inforced plastics
      - used in A340-600

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Dedicated efforts in all parts of Aircraft (5)

- **Materials and processes**
  - Use materials that guarantee the same or even better safety characteristics while reducing the aircraft weight
    - composites
    - GLARE
    - CFRP
    - fly-by-wire
    - paintings
  - Use materials that do not require additional heavy maintenance in order to prevent deterioration and then additional consumption.
  - Recommend some operations processes to operators in order to minimise the aircraft weight

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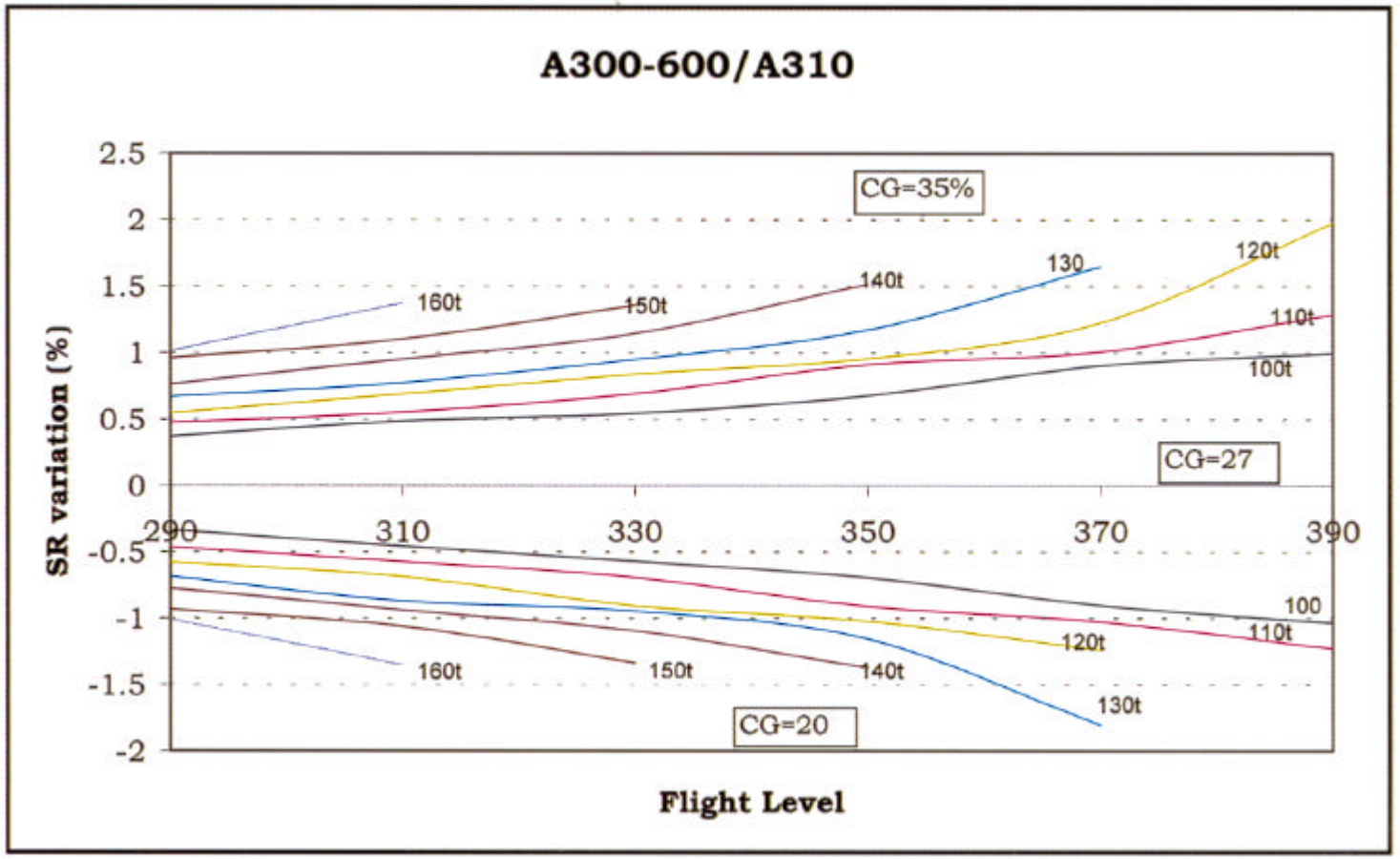
Dedicated efforts in all parts of Aircraft (6)

- Typical recommendations to Operators



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Dedicated efforts in all parts of Aircraft (7)

- **Typical recommendations to Operators**
  - Aircraft loading: further aft Centre of Gravity (CG) position (within allowable range) increases specific range
  - Avoid excess weight; eliminate unnecessary weight in order to have the lowest possible ZFW.
    - One ton excess weight can increase fuel burn by more than 200 kg.

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Dedicated efforts in all parts of Aircraft (8)

- **Typical recommendations to Operators**
  - Aircraft loading: further aft Centre of Gravity (CG) position (within allowable range) increases specific range
  - Avoid excess weight; eliminate unnecessary weight in order to have the lowest possible ZFW.
  - Minimise embarked/contingency fuel through accurate flight planning (individual route/A/C combination fuel consumption monitoring)

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Dedicated efforts in every phase of operation (1)

- **Ground running-Taxiing : typical recommendations**
  - limit use of APU whenever possible (depending on GSE availability and price, on turn-around time…)
  - Plan engine start-up in conjunction with ATC
  - 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.)
    - **FCOM requires APU start before engine shut down to avoid electrical transient**
    - **for HBPR engines, after reverse use, necessary cool-down time before shut down is vital**

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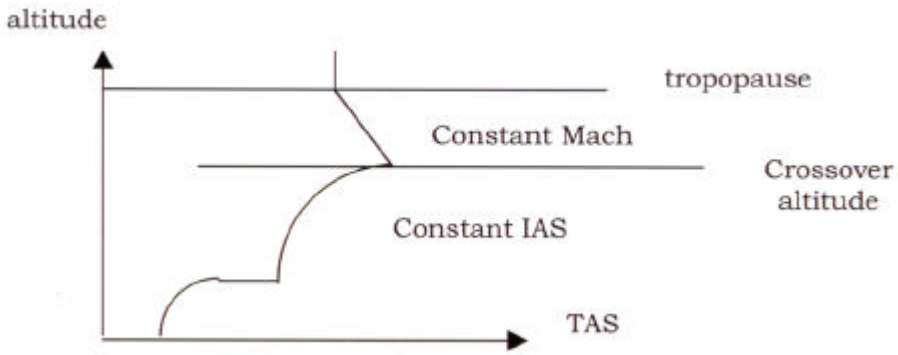
Dedicated efforts in every phase of operation (2)

- **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
  - The 1st optimum FL is above the cross-over altitude



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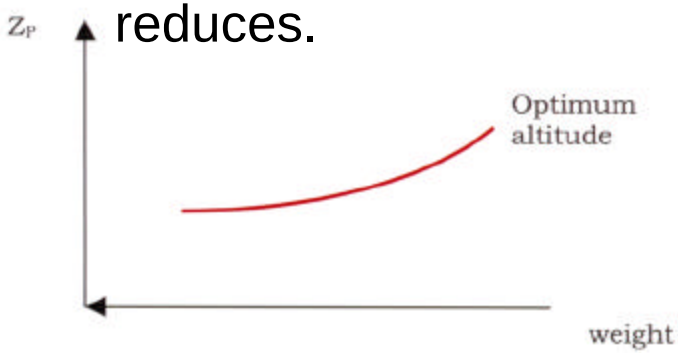
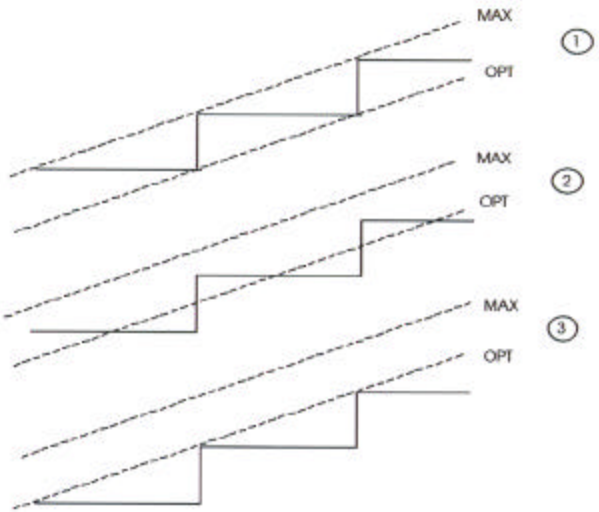
Dedicated efforts in every phase of operation (3)

- **Step 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.
  - Delaying climb to the next step should be avoided



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Dedicated efforts in every phase of operation (4)

- **Cruise**
  - Cruise is the most important phase in terms of fuel savings
  - 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, and the FCOM contains additional material to help the pilot in the optimisation process

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Dedicated efforts in every phase of operation (5)

- **Cruise**
  - When possible, it is recommended to fly in managed mode (using FMS). Indeed, flying at a given CI provides the ne,efit of flying at the Optimum Mach Number as a function of aircraft weight, flight level and wind component.
  - If ATC imposes MN, 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

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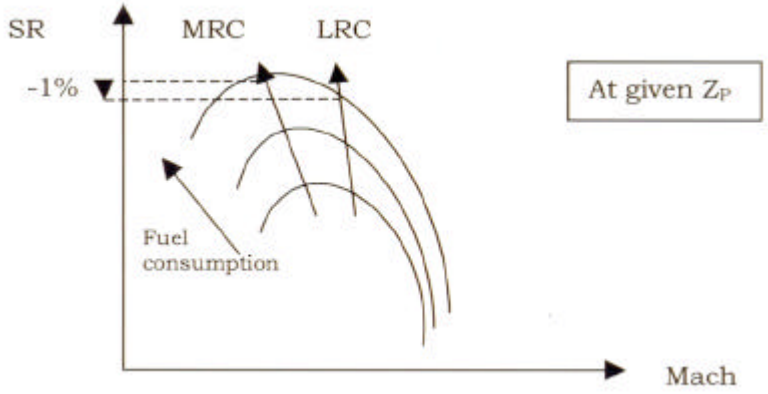
Dedicated efforts in every phase of operation (6)

- **Cruise**
  - 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-dep evaluated...



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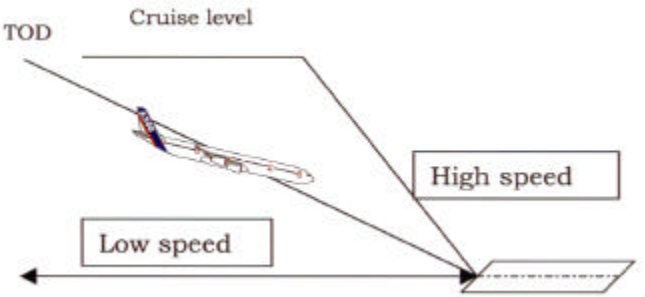
Dedicated efforts in every phase of operation (7)

- **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

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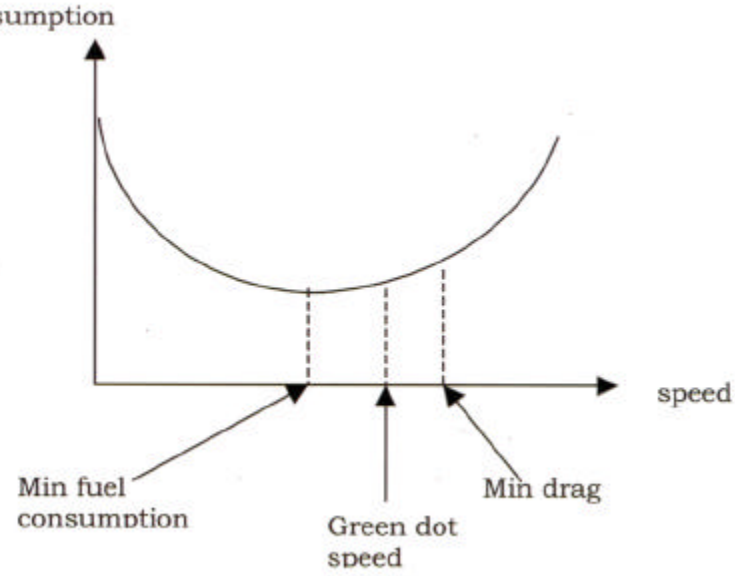
Dedicated efforts in every phase of operation (8)

- **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

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



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Dedicated efforts in every phase of operation (9)

- **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
    - **However, when weight increases and green dot speed exceeds the max recommended speed, it is advised to hold in config. 1 at S-speed to keep the same safety margin; otherwise, it could become hazardous in turbulent conditions)**
    - **There is an optimum holding altitude, but holding altitudes are often imposed by ATC**
    - **Linear holding at cruise level and at green dot speed and in as clean as possible configuration should be performed whenever possible (early recognition of holding delay helps to plan so as to minimise penalty)**

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Holding at cruise level

15 minutes at cruise speed

10 minutes holding at green dot

Holding optimisation

cruise at green dot speed

holding during remaining time at green

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Dedicated efforts in every phase of operation (10)

- **Approach**
  - Premature extensions (landing gear, slats, flaps) should be avoided to avoid fuel consumption penalty
  - A decelerated approach saves fuel in comparison to a stabilised one, conditions and safety permitting

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Additional present 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 A/C /route combinations**
- **RVSM (Reduced vertical separation minima) in Europe since Jan. 2002 allows to fly nearer the optimum altitude for fuel burn**

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Other considerations

- **In the design field, Airbus is involved in considerable research activities, currently in progress, relative to fuel consumption and emissions reduction. They are likely to have operational aspects associated with it.**
- **Trade-offs**
  - emissions-emissions (e.g. NOx vs CO2)
  - emissions-noise (e.g. Noise vs CO2 , Noise vs NOx)
- **Collaborative efforts (manufacturers, operators, airports, authorities, financiers, passengers) required to efficiently match ***supply*** air transport services to ***demand*** for an efficient passenger & cargo air transport**

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A permanent and omnipresent objective for Airbus