Fuel Conservation

Operational Procedures for Environmental Performance

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What is Fuel Conservation?

Fuel conservation means managing the operation and condition of an airplane to minimize the fuel used on every flight

Operational Procedures to Reduce Fuel Burn and Emissions

- CO_2 emissions are directly proportional to fuel burn
- Practicing fuel conservation will also reduce CO_2
- Reduction in other emissions depends on the specific procedure

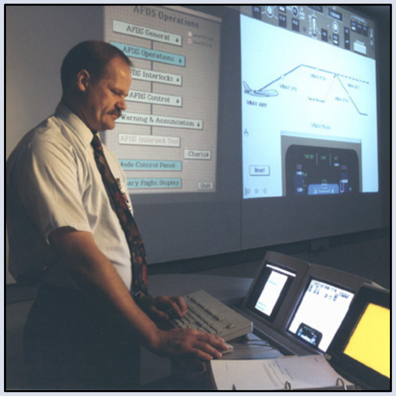
How Much Is A 1% Reduction In Fuel Worth?

Airplane type	**Fuel savings gal/year/airplane**
777	70,000 → 90,000
767	30,000 → 40,000
757	25,000 → 35,000
747	100,000 → 135,000
737	15,000 → 25,000
727	30,000 → 40,000

(Assumes typical airplane utilization rates)

Reducing Fuel Used Requires Everyone's Help

- Flight Operations
- Dispatchers
- Flight Crews
- Maintenance
- Management



Flight Operations / Dispatchers

Opportunities For Fuel Conservation

- Reduce Landing Weight
- Load Proper Fuel Reserves
- Load Airplane at Aft C.G.
- Select Minimum Flap that Meets all Requirements
- Fly Optimum Altitudes (wind-adjusted)
- Plan and Fly Efficient Speeds
- Select Most Favorable Routing

Reduced Landing Weight

1% reduction in landing weight produces:

- ≅ 0.75% reduction in trip fuel (high BPR engines)
- ≅ 1% reduction in trip fuel (low BPR engines)

Components Of Landing Weight

Fuel on board at landing

$$W_{LDG} = \underbrace{\text{OEW} + \text{Payload}}_{\text{Zero fuel weight}} + \overbrace{\text{Required reserve fuel} + \text{Additional fuel loaded but not used}}^{\text{Fuel on board at landing}}$$

Zero fuel weight

Reducing Unnecessary Fuel Reduces Landing Weight

- Practice cruise performance monitoring
- Flight plan by tail numbers
- Carry the appropriate amount of reserves to ensure a safe flight (extra reserves are extra weight)

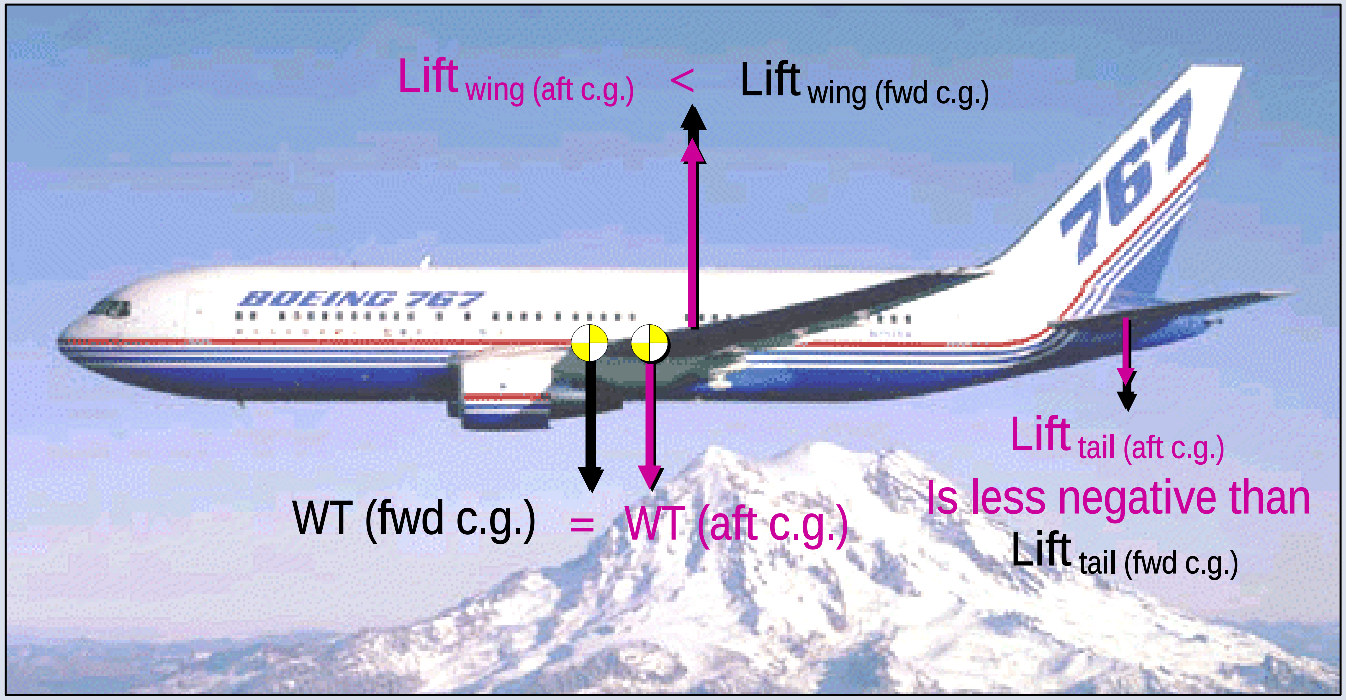
Fuel Reserves

The amount of required fuel reserves depends on:

- Regulatory requirements
- Choice of alternate airport
- Use of re-dispatch
- Company policies on reserves
- Discretionary fuel

Airplane Loading

Maintain C.G. In The Mid To Aft Range



- At aft c.g. the lift of the tail is less negative than at forward c.g. due to the smaller moment arm between $Lift_{wing}$ and WT
- Less angle of attack, α, is required to create the lower $Lift_{wing}$ required to offset the WT plus the less negative $Lift_{tail}$
- Same $Lift_{total}$, but lower $Lift_{wing}$ and therefore lower α required

Airplane Loading

Maintain C.G. in the Mid to Aft Range

- Examples of change in drag due to C.G. can be found in the various Performance Engineer's Manuals

Aircraft type 1

Δ trim drag at cruise Mach

CG range	ΔC_D trim
8% to 12%	+2%
13% to 18%	+1%
19% to 25%	0
26% to 33%	-1%

Aircraft type 2

Δ trim drag at cruise Mach

CG range	ΔC_D trim
14% to 19%	+2%
19% to 26%	+1%
26% to 37%	0
37% to 44%	-1%

- Actual variation in drag due to C.G. depends on airplane design, weight, altitude and Mach

Flap Setting

Choose lowest flap setting that will meet takeoff performance requirements:

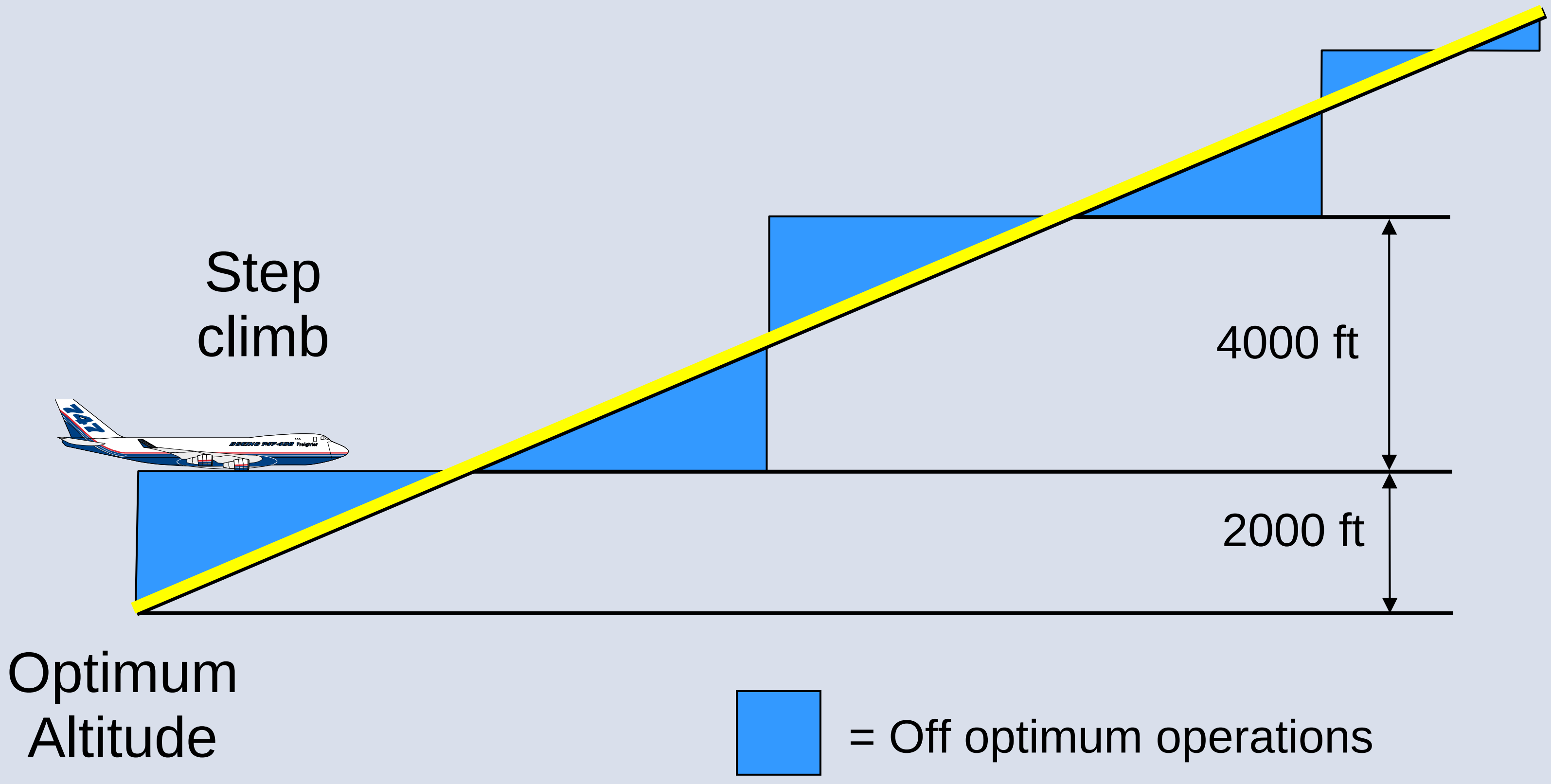
- Less drag
- Better climb performance
- Spend less time at low altitudes, burn less fuel

Altitude Selection

Optimum Altitude Definition

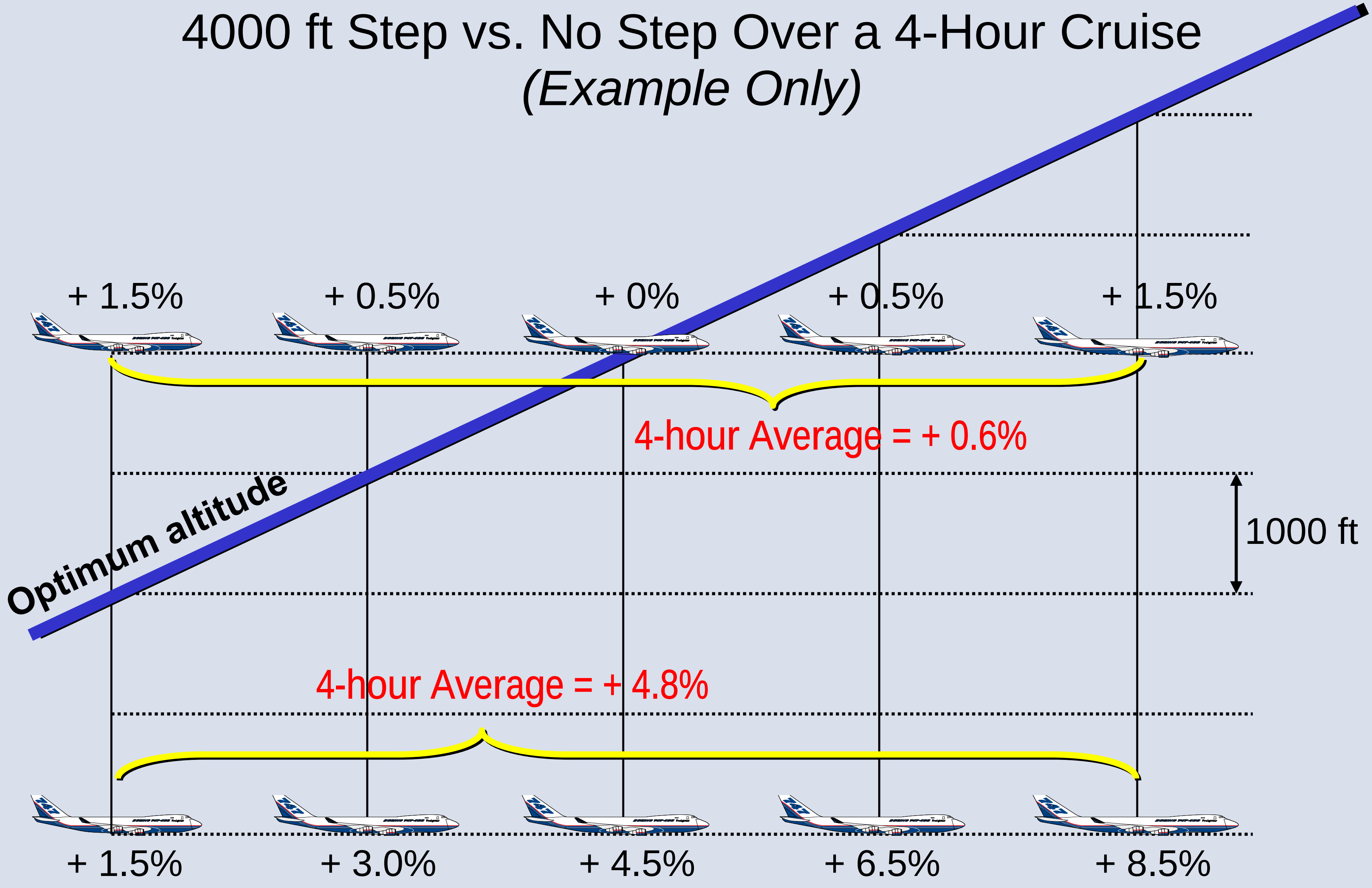
Pressure altitude for a given weight and speed schedule that produces the maximum air miles per unit of fuel

Step Climb


Step
climb
4000 ft
2000 ft
Optimum
Altitude
= Off optimum operations

Off-Optimum Fuel Burn Penalty

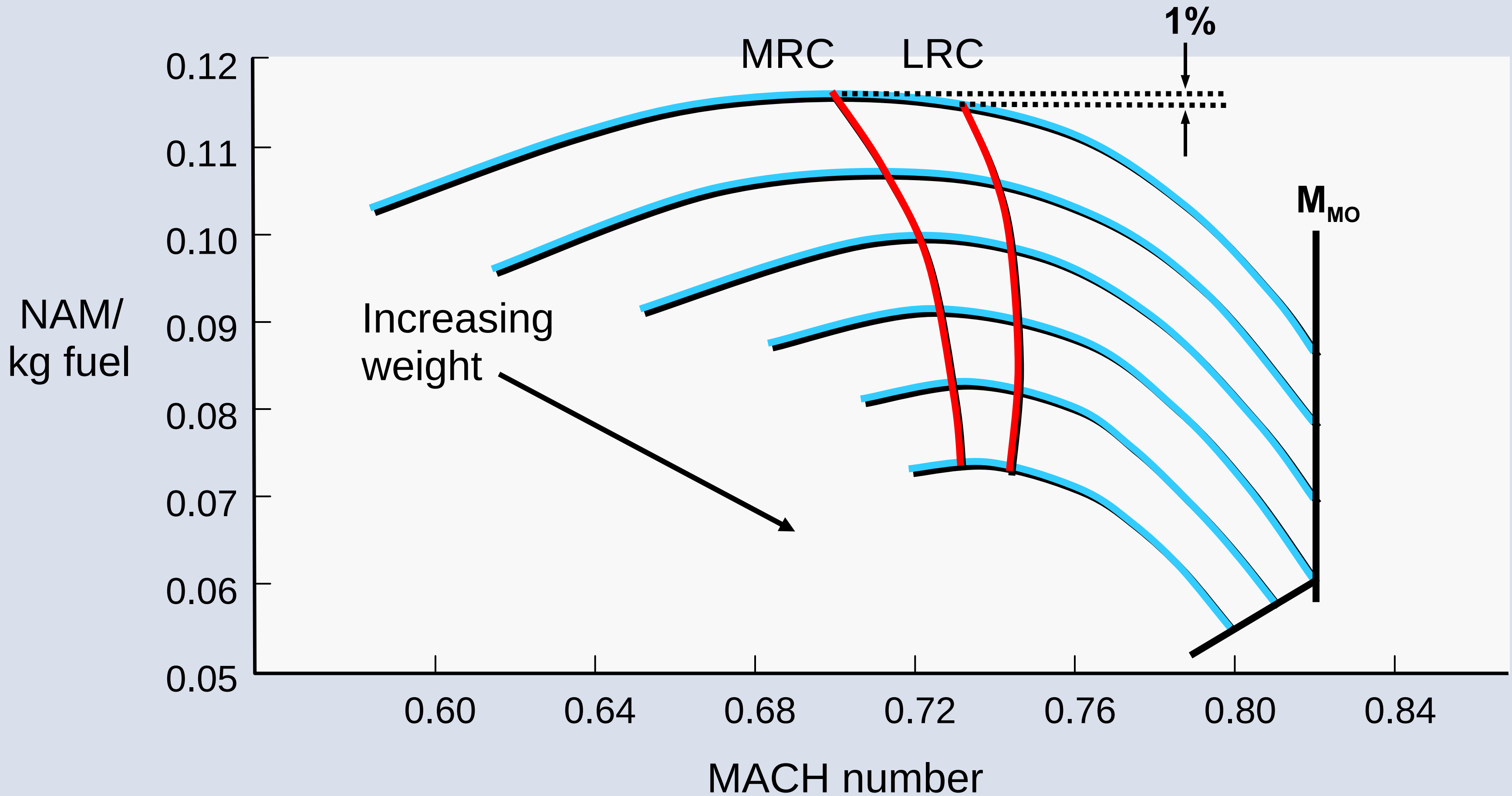
4000 ft Step vs. No Step Over a 4-Hour Cruise
(Example Only)



Speed Selection

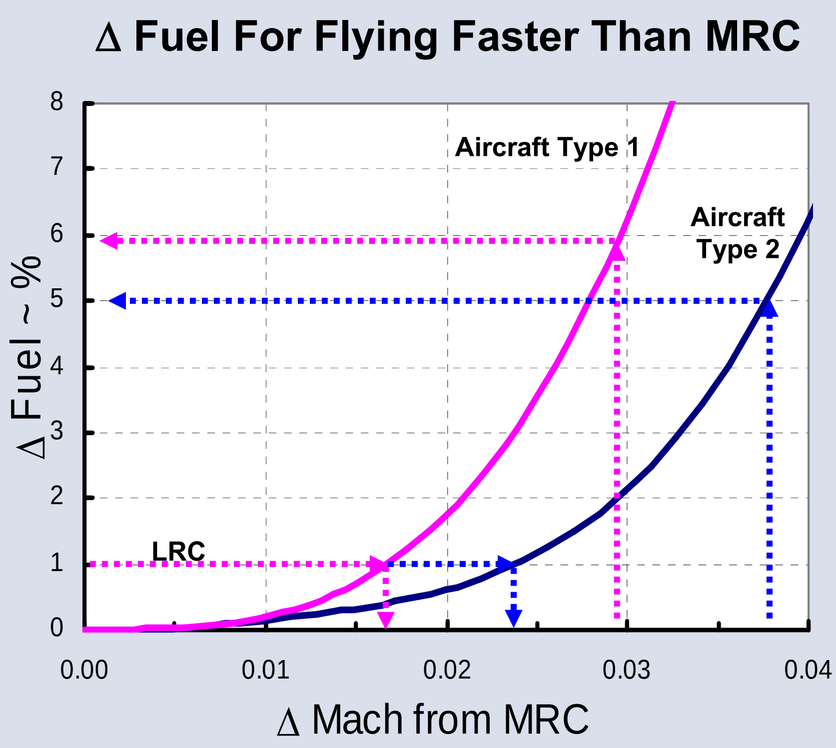
LRC Versus MRC

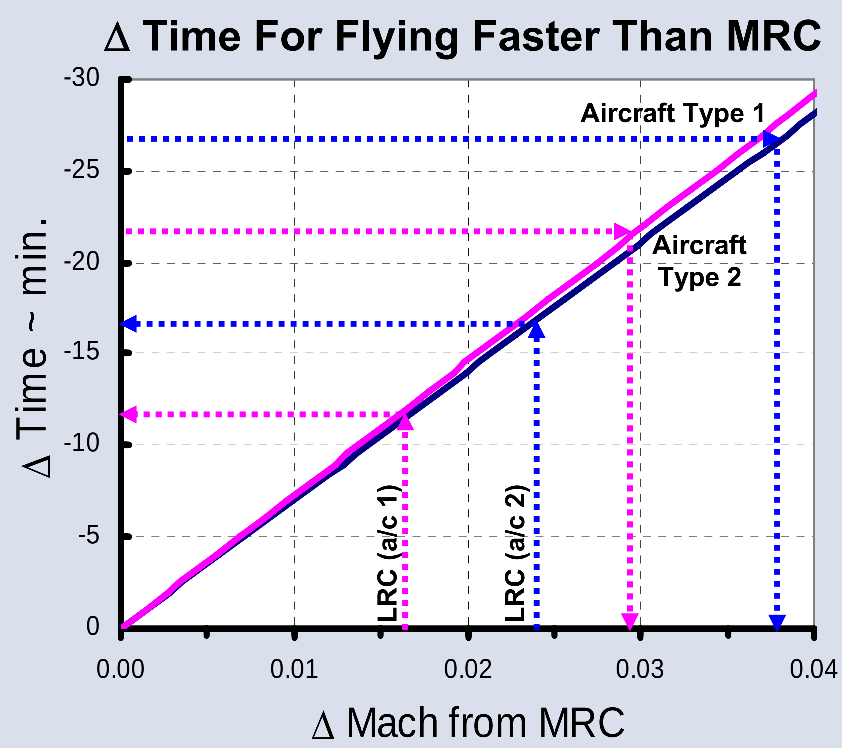
MRC = Maximum range cruise
LRC = Long Range cruise



Flying Faster Than LRC?

5000 NM cruise





Speed Selection - Other Options

- Cost Index = 0 (maximize ngm/kg
  = wind-adjusted MRC)
- Selected Cost Index (minimize costs)

$$\mathbf{CI = \frac{Time\ cost \sim \$/hr}{Fuel\ cost \sim cents/lb}}$$

High CI ⇨ high speed, high trip fuel, low trip time
Low CI ⇨ low speed, low fuel burn, high trip time

- Maximum Endurance (maximize time/lb)

Route Selection

- Choose the most favorable route available including the effects of winds
- ‘Great Circle’ is the shortest ground distance between 2 points on the earth’s surface
- Great Circle may not be the shortest air distance (time) when winds are included

Flight Crew

Opportunities for Fuel Conservation:

- Practice fuel economy in each phase of flight
- Understand the airplane's systems - Systems Management

Engine Start

- Start engines as late as possible, coordinate with ATC departure schedule
- Take delays at the gate if possible
- Minimize APU use if ground power available

Taxi

- Take shortest route possible
- Use minimum thrust and minimum braking

Taxi – One Engine Shut Down Considerations

- After-start and before-takeoff checklists delayed
- Reduced fire protection from ground personnel
- High weights, soft asphalt, taxi-way slope
- Engine thermal stabilization - warm up and cool down
- Pneumatic and electrical system requirements
- Slow/tight turns in direction of operating engine(s)
- Cross-bleed start requirements

Balance fuel conservation and safety considerations

Takeoff

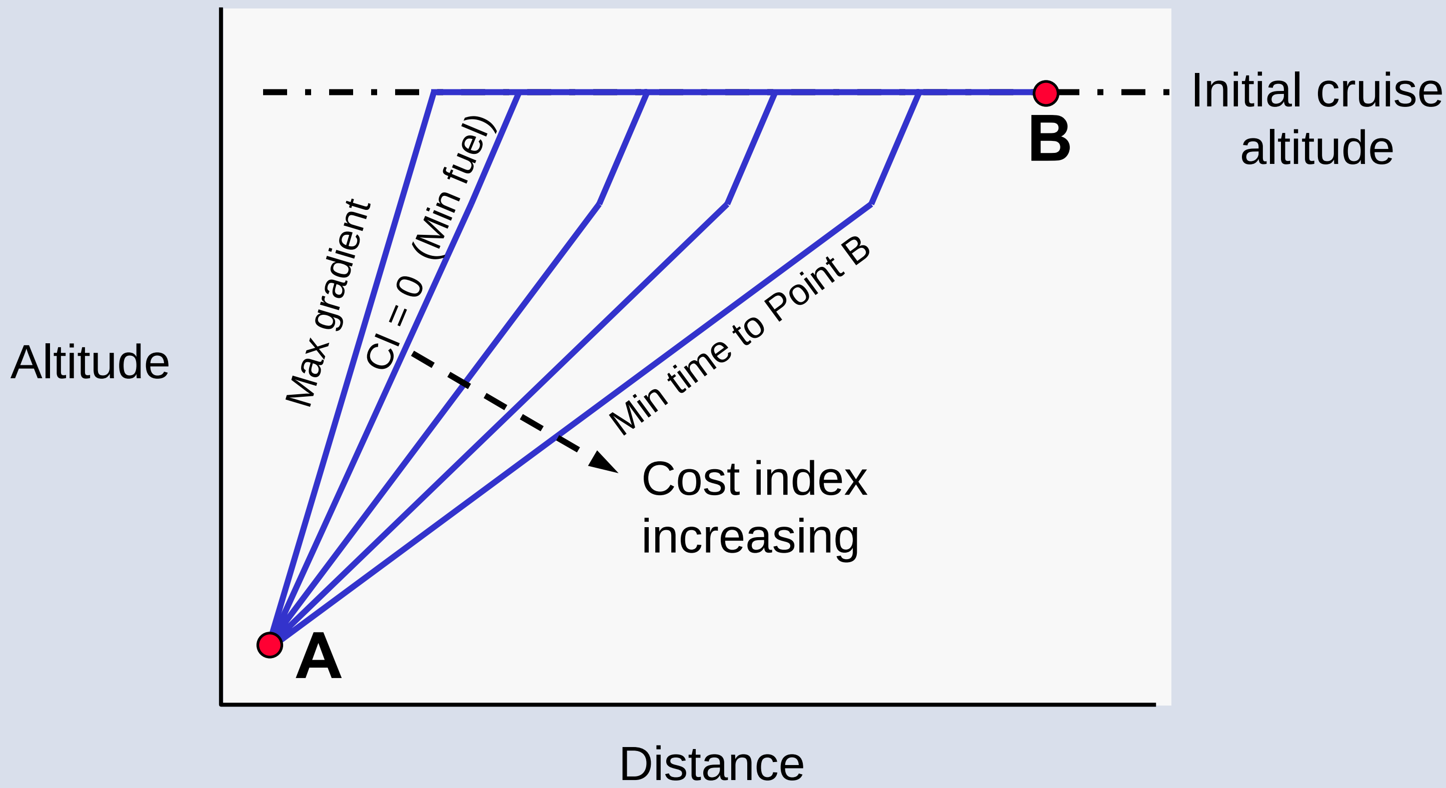
- Retract flaps as early as possible

  (but, no lower than the minimum recommended flap retraction height)

- Using full rated thrust will save fuel relative to derated thrust – but will increase overall engine maintenance costs

Climb

Cost Index = 0 minimizes fuel to climb and cruise to a common point in space



Cruise

Lateral - Directional Trim Procedure

- A plane flying in steady, level flight may require some control surface inputs to maintain lateral-directional control
- Use of the proper trim procedure minimizes drag
- Poor trim procedure can result in a 0.5% cruise drag penalty on a 747
- Follow the procedures provided in the Flight Crew Training Manual

Cruise

Systems Management

- A/C packs in high flow typically produce a 0.5 - 1 % increase in fuel burn
- Do not use unnecessary cargo heat
- Do not use unnecessary anti-ice
- Maintain a balanced fuel load

Cruise

Winds

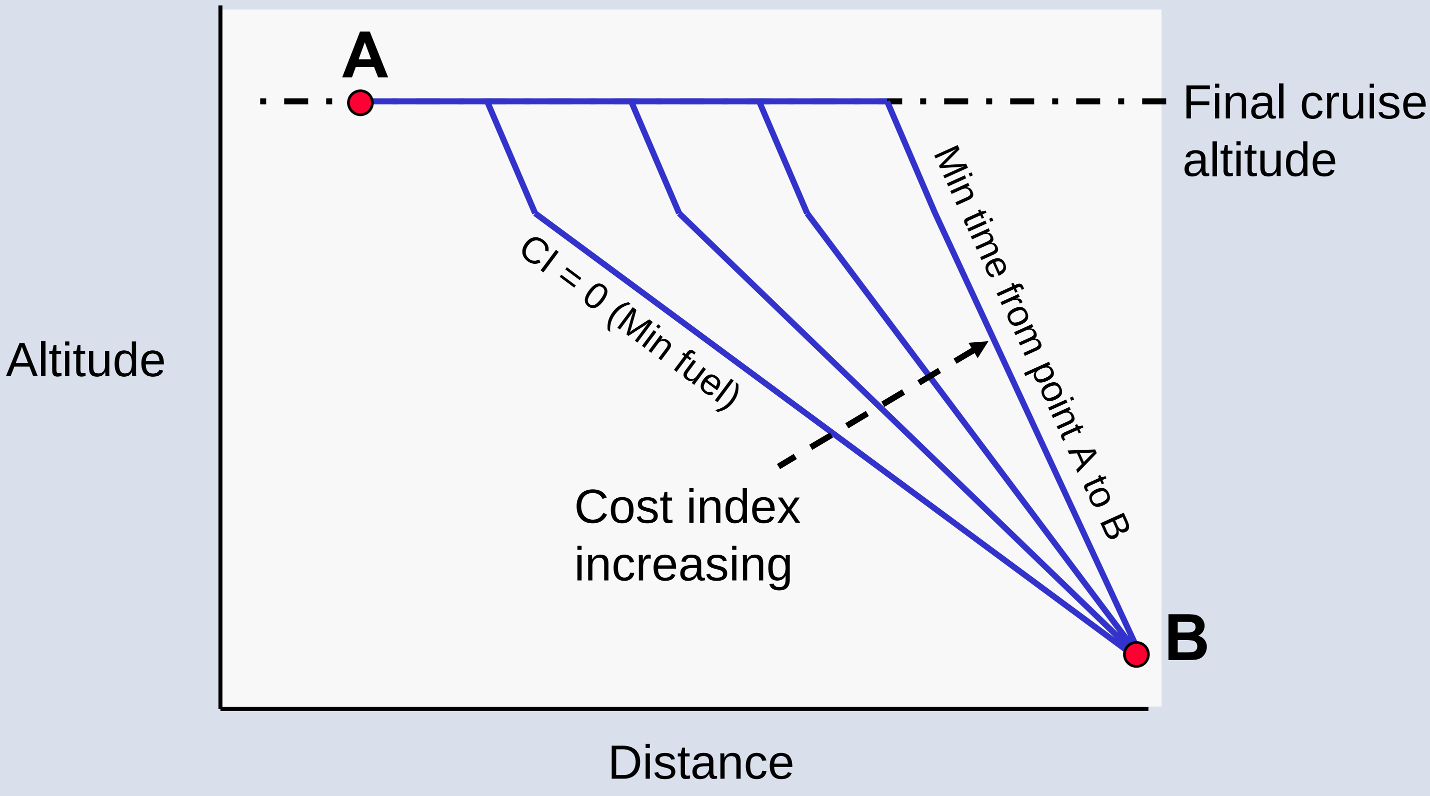
- Wind may be a reason to choose an “off optimum” altitude
- Want to maximize <u>ground</u> miles per unit of fuel burned
- Wind-Altitude trade tables are provided in the operations manual

Descent

- Penalty for early descent - spend more time at low altitudes, higher fuel burn
- Optimum top of descent point is affected by wind, ATC, speed restrictions, etc.
- Use information provided by FMC
- Use idle thrust (no part-power descents)

Descent

Cost Index = 0 minimizes fuel between a common cruise point and a common end of descent point



Approach

- Do not transition to the landing configuration too early
- Fuel flow in the landing configuration is approximately 150% of the fuel flow in the clean configuration

Summary Of Operational Practices

Flight Operations / Dispatchers

- Minimize landing weight
- Do not carry more reserve fuel than required
- Use aft C.G. loading if possible
- Use lowest flap setting required
- Target optimum altitude (wind-corrected)
- Target LRC (or cost index)
- Choose most favorable routing

Summary Of Operational Practices

Flight Crews

- Minimize engine/APU use on ground
- Retract Flaps as early as possible
- Fly the flight-planned speeds for all phases of flight
- Use proper trim procedures
- Understand the airplane’s systems
- Understand wind/altitude trades
- Don’t descend too early (or too late)
- Don’t transition to landing configuration too early

Conclusions

It Takes the Whole Team to Win

- Large fuel (and emissions) savings results from the accumulation many smaller fuel-saving actions and policies
- Dispatch, flight operations, flight crews, maintenance, management, **all need to contribute**

Thank You!

FLIGHT
OPERATIONS
ENGINEERING

End of Fuel Conservation

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