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AVIATION OPERATIONAL MEASURES FOR FUEL AND EMISSIONS REDUCTION WORKSHOP

Fuel Conservation

Operational Procedures for Environmental Performance

David Anderson

Flight Operations Engineer

Boeing Commercial Airplanes

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

What is Fuel Conservation?

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

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How Much is a 1% Reduction in Fuel Worth?

Airplane Type	Fuel Savings * Gal/Year/Airplane
737	15,000
727	30,000
757	25,000
767	30,000
777	70,000
747	100,000

(* Assumes typical airplane utilization rates)

Saving Fuel Requires Everyone’s Help

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

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Operational Practices for Fuel Conservation

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Flight Operations Panel
Ottawa, 5-6 November 2002

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Flight Operations / Dispatchers

Opportunities for fuel conservation:

- Landing weight
- Fuel reserves
- Airplane loading
- Flap selection
- Altitude selection
- Speed selection
- Route selection

Effect of Reducing Landing Weight

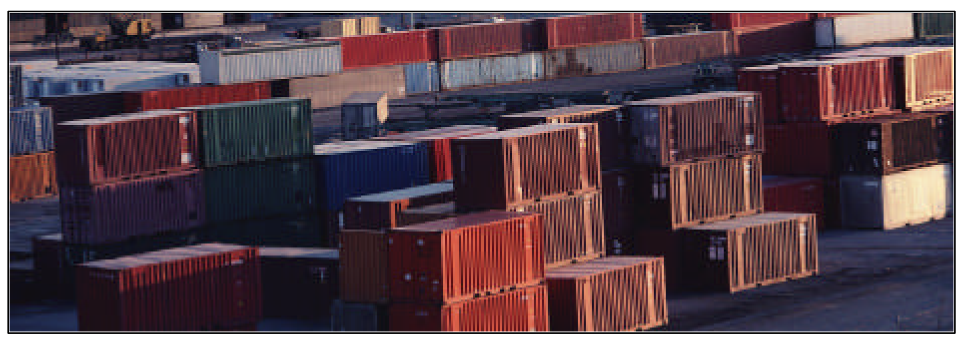
%Block Fuel Savings per 1000 LB ZFW Reduction

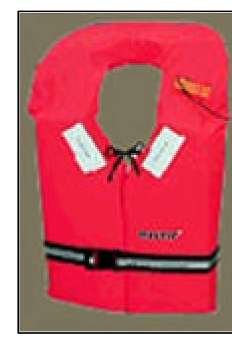
737-3/4/500	737-6/7/800	757-200/-300	767-200/300	777-200/300	747-400
.7%	.6%	.5%	.3%	.2%	.2%

Reducing OEW Reduces Landing Weight

Items to consider:

- Passenger service items
- Passenger entertainment items
- Cargo and baggage containers
- Emergency equipment
- Potable water





Reducing Unnecessary Fuel Reduces Landing Weight

- **Flight plan by tail numbers**
- **Practice cruise performance monitoring**
- **Carry the appropriate amount of reserves to ensure a safe flight**

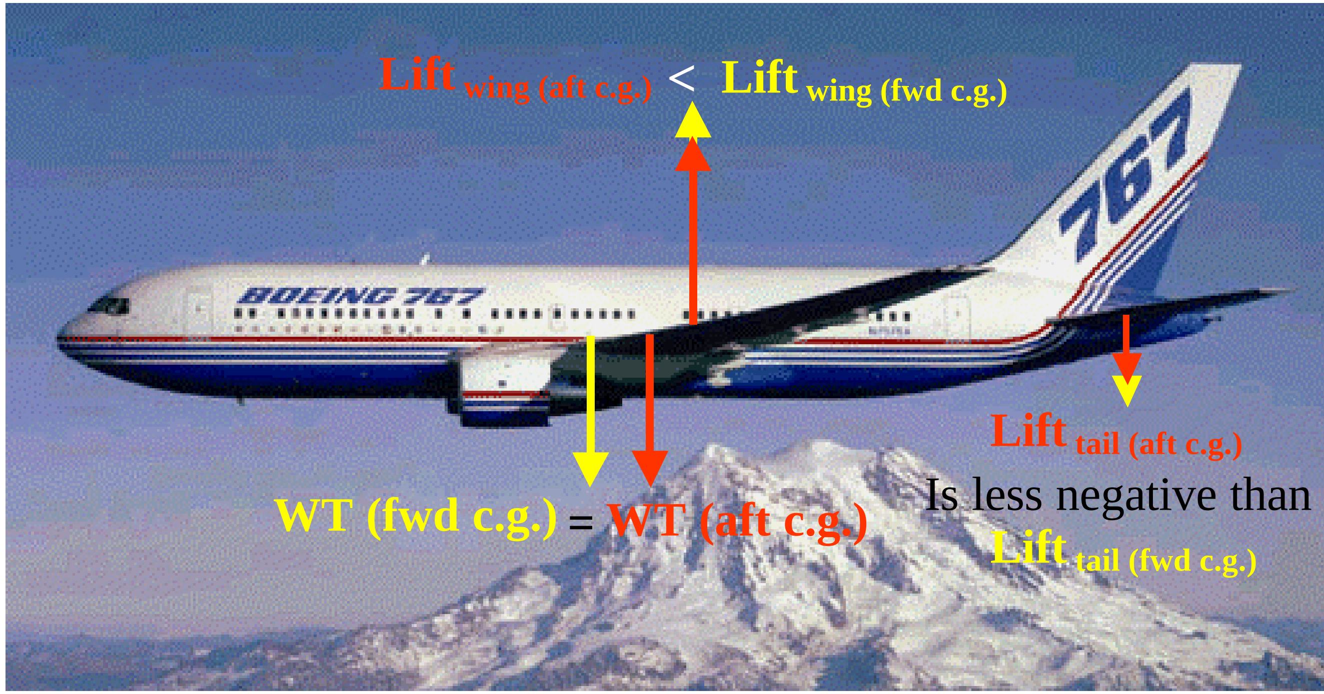
(Extra reserves are extra weight)

Fuel Reserves

The amount of required fuel reserves depends on:

- Regulatory requirements
- Choice of alternate airport
- Use of redispatch
- 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 a required.

Airplane Loading

Examples of change in drag due to c.g. can be found in the various Performance Engineer's Manuals

737-700

.78M Trim Drag

CG RANGE	DC_D TRIM
8% TO 12%	+2%
13% TO 18%	+1%
19% TO 25%	0
26% TO 33%	-1%

777-200

.84M Trim Drag

CG RANGE	DC_D TRIM
14% TO 19%	+2%
19% TO 26%	+1%
26% TO 37%	0
37% TO 44%	-1%

Flap Setting

Choose lowest flap setting that will meet performance requirements:

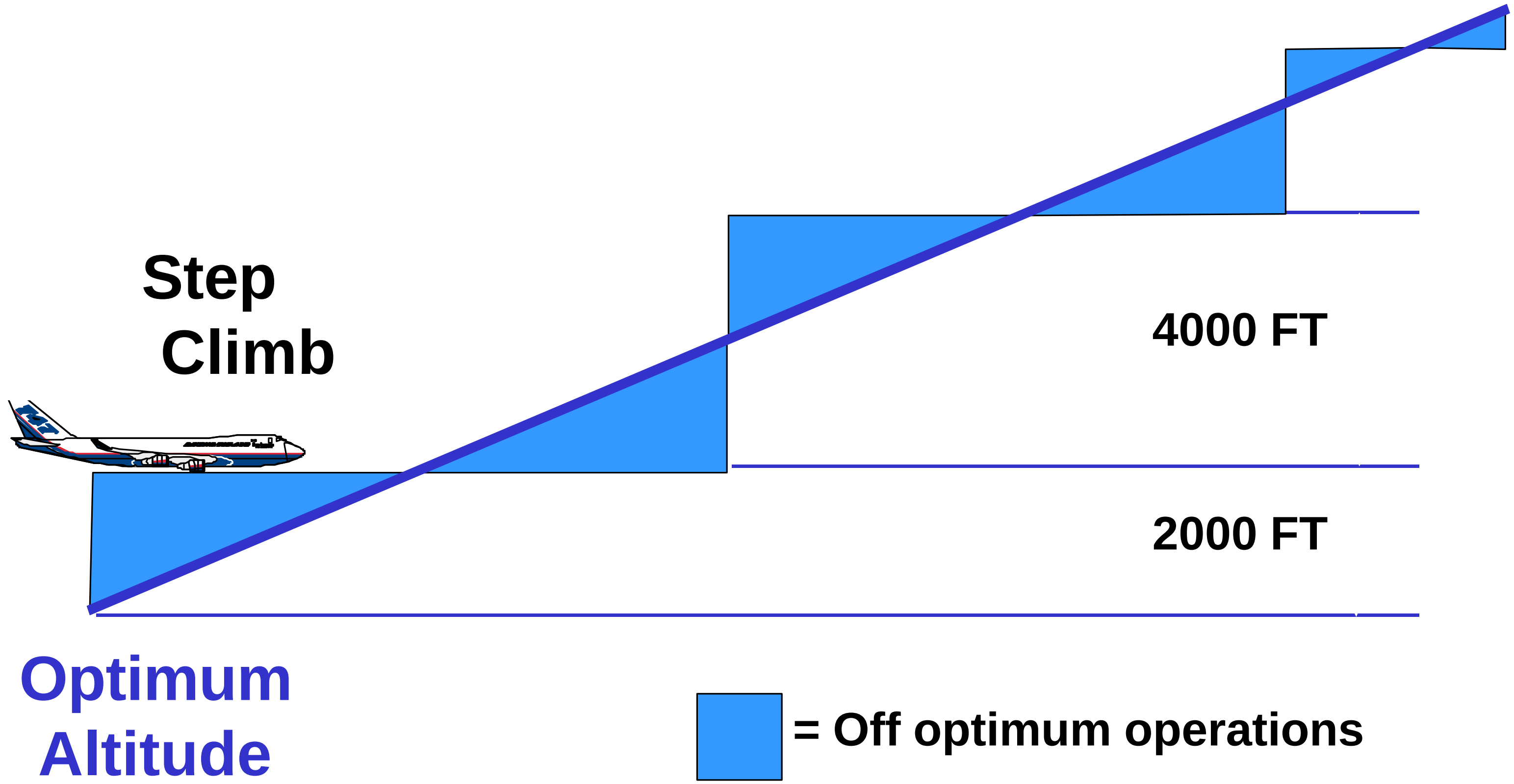
- **Less drag**
- **Better climb performance**
- **Spend less time at low altitudes, burn less fuel**

Altitude Selection

Optimum altitude:

Pressure altitude for a given weight and speed schedule that gives the maximum mileage per unit of fuel

Step Climb


Step
Climb
4000 FT
2000 FT
Optimum
Altitude
= Off optimum operations

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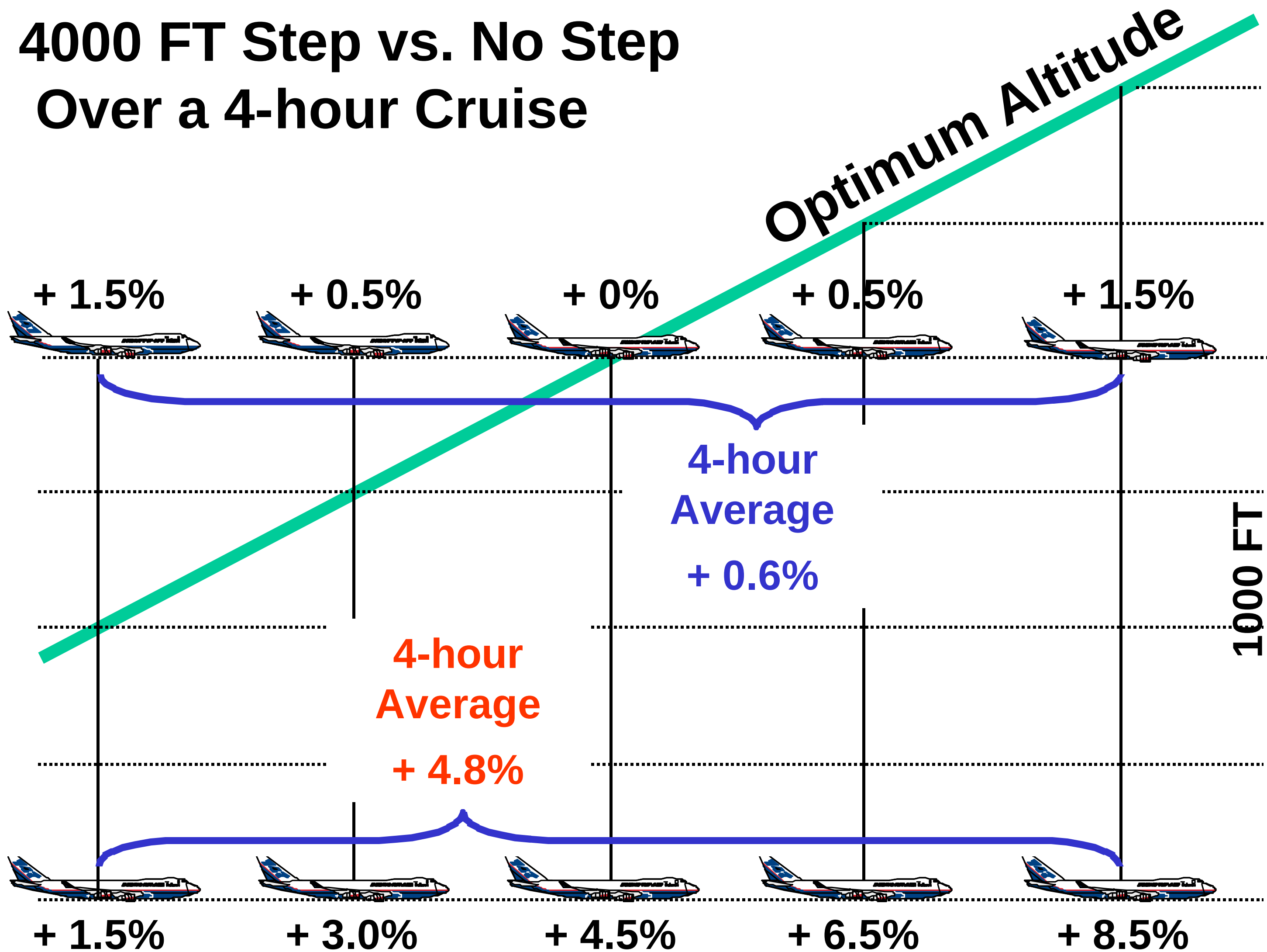
Off-Optimum Fuel Burn Penalty

4000 FT Step vs. No Step Over a 4-hour Cruise



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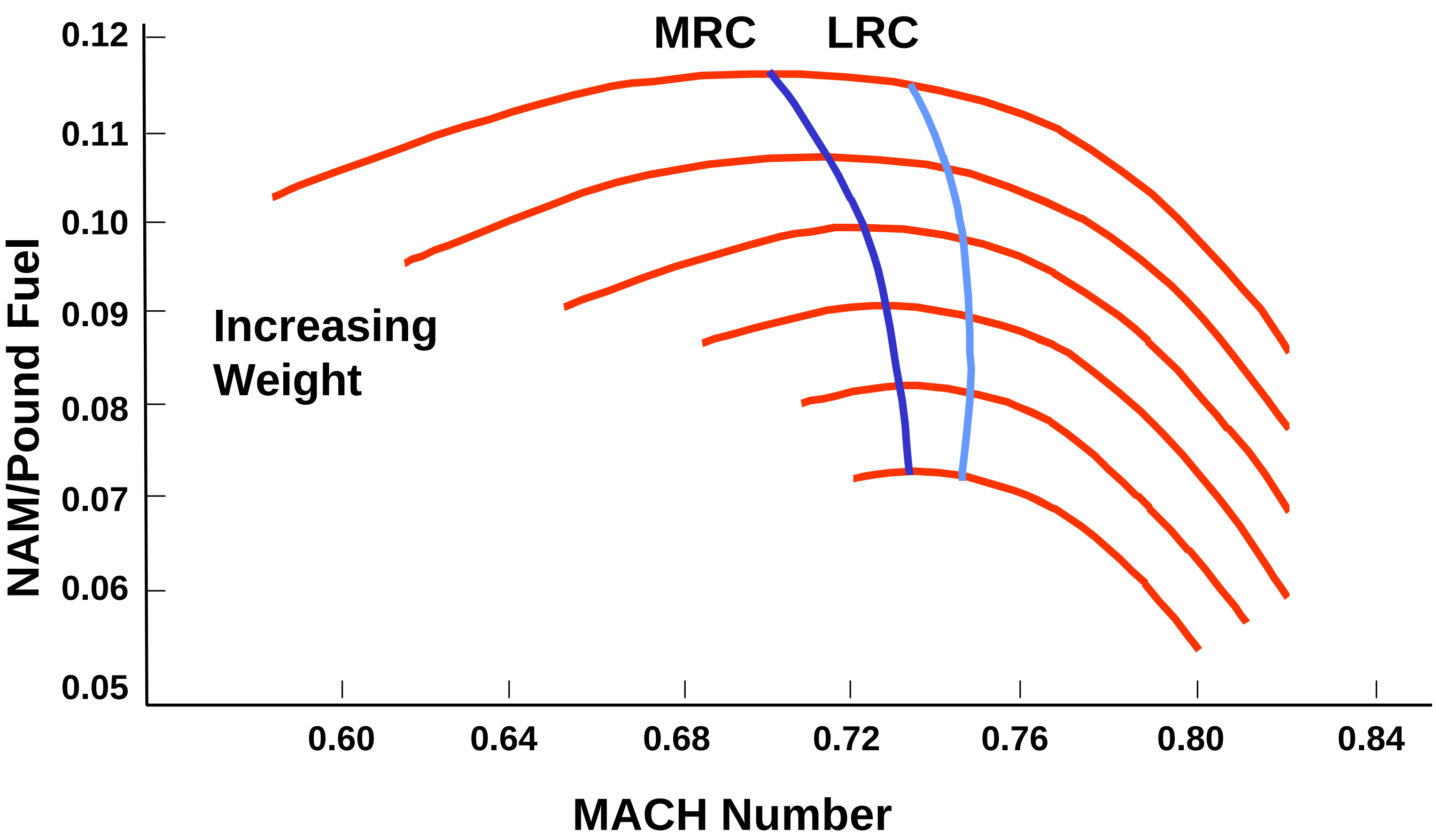
Speed Selection - LRC vs MRC

MRC = Maximum Range Cruise

LRC = Long Range Cruise



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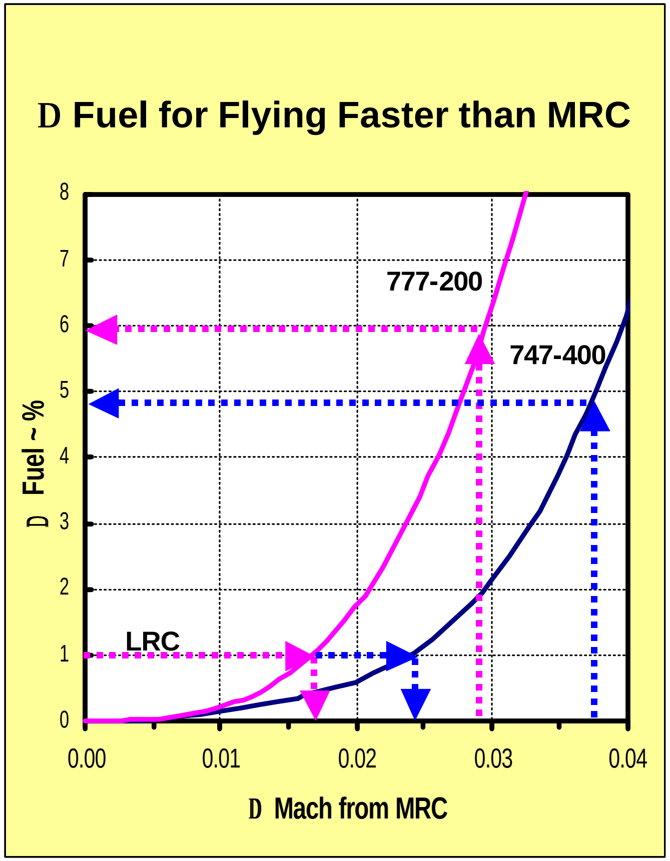
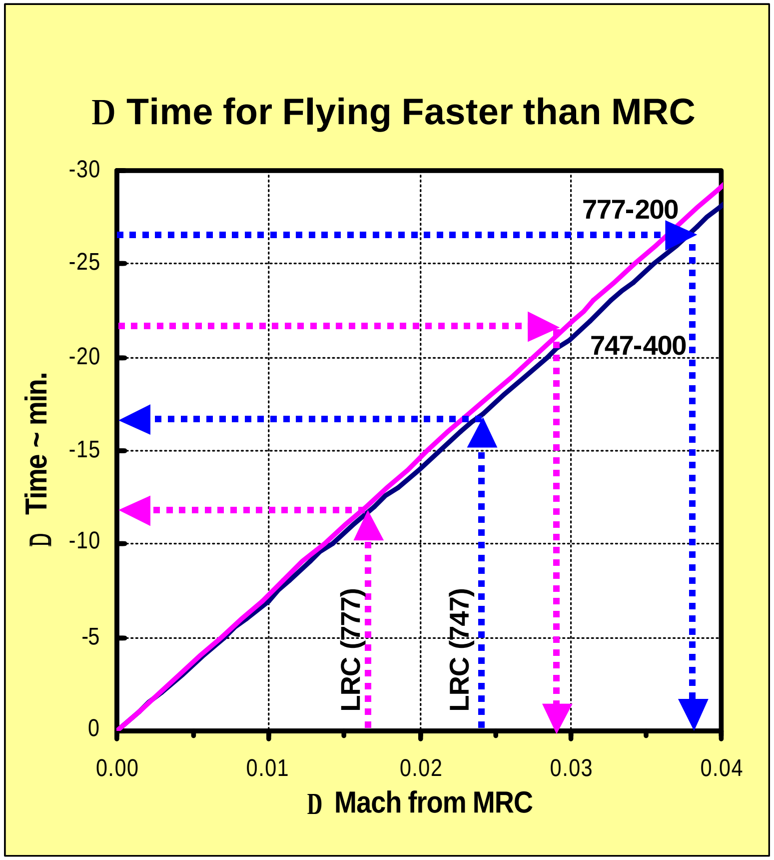
Flying Faster Than MRC?

- **5000 NM cruise**





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Speed Selection - Other Options

- Cost Index = 0 (maximize ngm/lb; = MRC)
- Selected Cost Index (minimize costs)

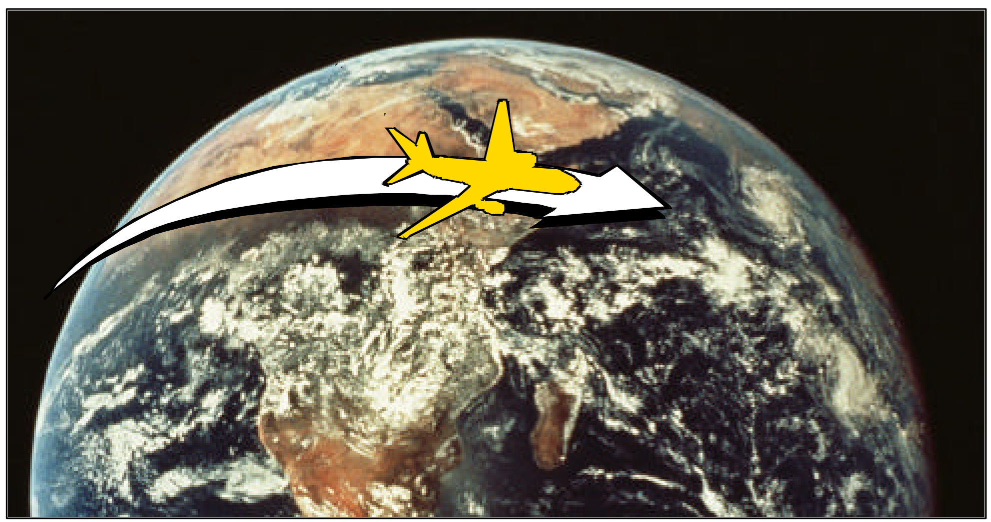
$$CI = \frac{\text{Time Cost} \sim \$/\text{hr}}{\text{Fuel Cost} \sim \text{cents/lb}}$$

- Maximum Endurance (maximize time/lb)

Route Selection

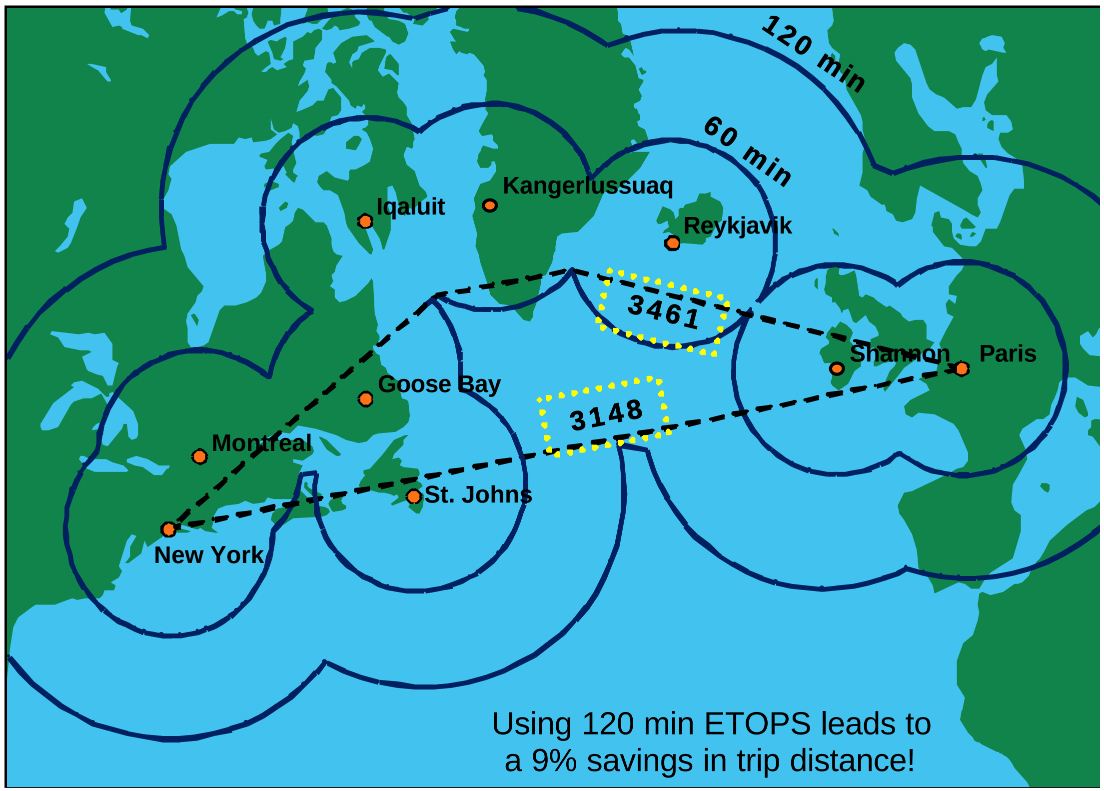
- Choose the most direct route possible
-

  between 2 points on the earth's surface
- Great circle may not be the shortest <u>air</u> distance when winds are included



ETOPS

- ETOPS allows for more direct routes
- Shorter routes = less fuel required



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
- 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 & before-takeoff checklists delayed
- Reduced fire protection from ground personnel
- High weights, soft asphalt, taxi-way slope
- Engine thermal stabilization - warm up & 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

Sample Taxi and APU Fuel Burns

Condition	727	737	747	757	767	777
Taxi (lb/min)	60	25	100	40	50	60
APU (lb/min)	5	4	11	4	4	9

Takeoff

- Retract flaps as early as possible
- Using full rated thrust will save fuel relative to derated thrust (but will increase overall engine maintenance costs)

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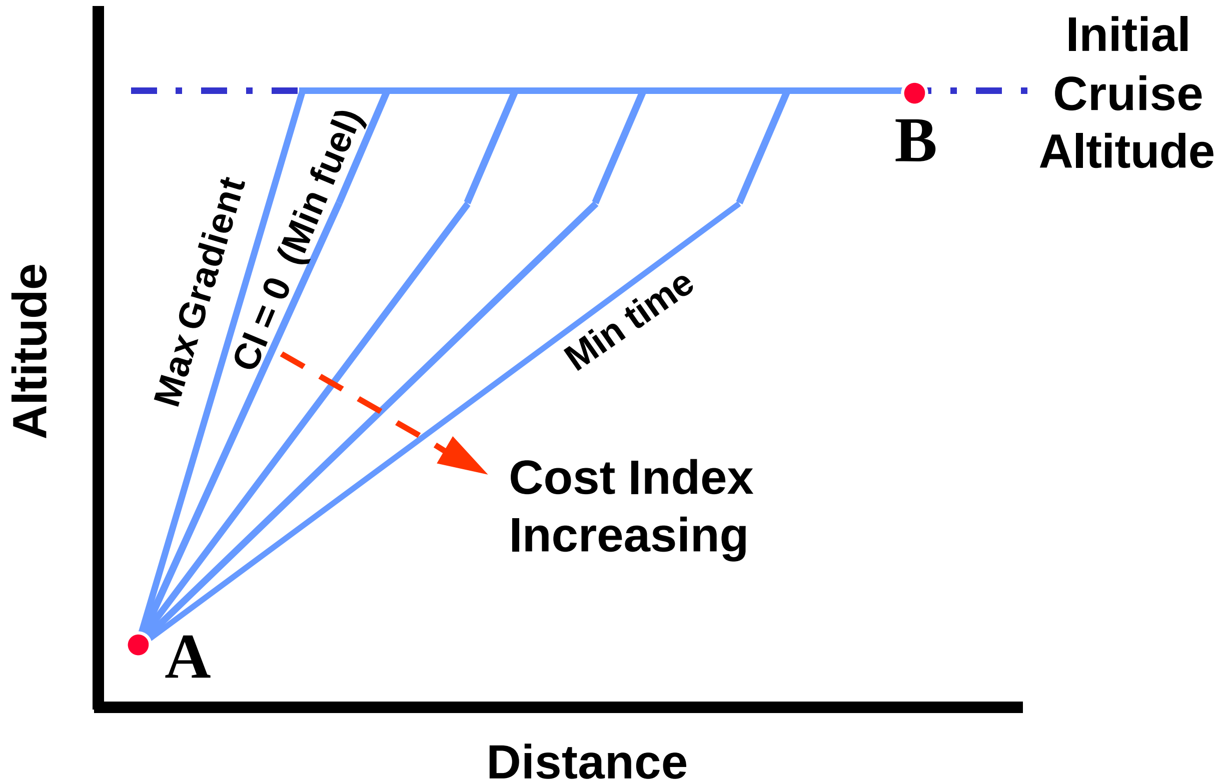
Climb

- **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

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:

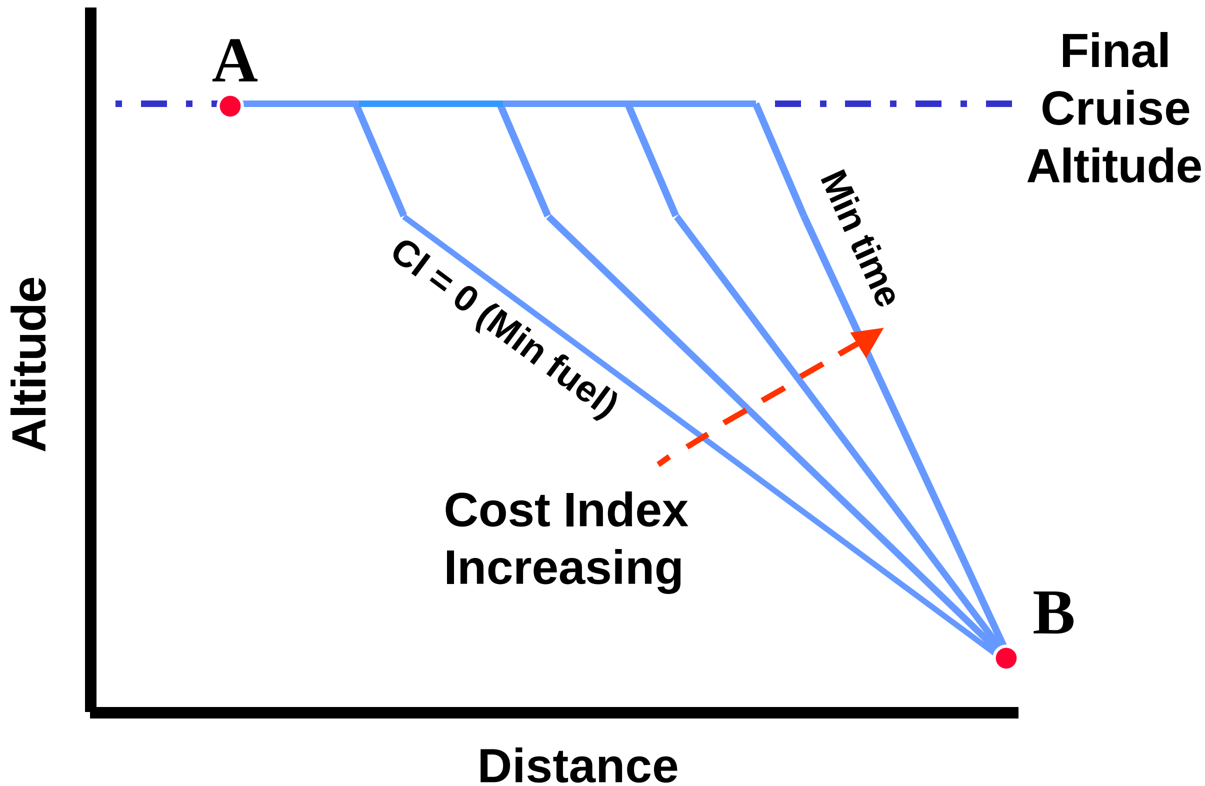
- **Wind may be a reason to choose an “off optimum” altitude**
- **Want to maximize ground miles per gallon of fuel**
- **Wind-Altitude trade tables are provided in Operations Manual**

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 lowest flap setting required
- Target optimum altitude (wind-corrected)
- Target LRC (or cost index)
- Choose most direct routing

Summary of Operational Practices

Flight Crews:

- Minimize engine/APU use on ground
- Fly the chosen Cost Index speeds
- Use proper trim procedures
- Understand the airplane's systems
- Don't descend too early
- Don't transition to landing config too early

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Summary of Operational Practices

Questions?

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