Fuel Conservation
Operational Procedures for Environmental Performance

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September 2006
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

- CO₂ emissions are directly proportional to fuel burn
- Practicing fuel conservation will also reduce CO₂
- Reduction in other emissions depends on the specific procedure
<table>
<thead>
<tr>
<th>Airplane type</th>
<th>Fuel savings gal/year/airplane</th>
</tr>
</thead>
<tbody>
<tr>
<td>777</td>
<td>70,000 → 90,000</td>
</tr>
<tr>
<td>767</td>
<td>30,000 → 40,000</td>
</tr>
<tr>
<td>757</td>
<td>25,000 → 35,000</td>
</tr>
<tr>
<td>747</td>
<td>100,000 → 135,000</td>
</tr>
<tr>
<td>737</td>
<td>15,000 → 25,000</td>
</tr>
<tr>
<td>727</td>
<td>30,000 → 40,000</td>
</tr>
</tbody>
</table>

(Assumes typical airplane utilization rates)
Reducing Fuel Used Requires Everyone’s Help

• Flight Operations
• Dispatchers
• Flight Crews
• Maintenance
• Management
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
1% reduction in landing weight produces:

$\approx 0.75\%$ reduction in trip fuel (high BPR engines)

$\approx 1\%$ reduction in trip fuel (low BPR engines)
Components Of Landing Weight

\[ W_{LDG} = \text{OEW} + \text{Payload} + \text{Zero fuel weight} \]

- **Fuel on board at landing**
  - Required reserve fuel
  - Additional fuel loaded but not used
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 $L_{\text{wing}}$ and WT
- Less angle of attack, $\alpha$, is required to create the lower $L_{\text{wing}}$ required to offset the WT plus the less negative $L_{\text{tail}}$
- Same $L_{\text{total}}$, but lower $L_{\text{wing}}$ and therefore lower $\alpha$ 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

<table>
<thead>
<tr>
<th>Aircraft type 1</th>
<th>Δ trim drag at cruise Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG range</td>
<td>ΔC_D trim</td>
</tr>
<tr>
<td>8% to 12%</td>
<td>+2%</td>
</tr>
<tr>
<td>13% to 18%</td>
<td>+1%</td>
</tr>
<tr>
<td>19% to 25%</td>
<td>0</td>
</tr>
<tr>
<td>26% to 33%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aircraft type 2</th>
<th>Δ trim drag at cruise Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG range</td>
<td>ΔC_D trim</td>
</tr>
<tr>
<td>14% to 19%</td>
<td>+2%</td>
</tr>
<tr>
<td>19% to 26%</td>
<td>+1%</td>
</tr>
<tr>
<td>26% to 37%</td>
<td>0</td>
</tr>
<tr>
<td>37% to 44%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

- 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

Optimum Altitude

4000 ft

2000 ft

= Off optimum operations
Off-Optimum Fuel Burn Penalty

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

1000 ft

4-hour Average = + 0.6%

4-hour Average = + 4.8%
Speed Selection

LRC Versus MRC

MRC = Maximum range cruise
LRC = Long Range cruise

Increasing weight

MACH number

NAM/kg fuel

M_Mo

1%
Flying Faster Than LRC?

5000 NM cruise

Δ Fuel For Flying Faster Than MRC

Δ Time For Flying Faster Than MRC

Aircraft Type 1

LRC (a/c 1)

Δ Mach from MRC

Δ Mach from MRC

Aircraft Type 2

LRC (a/c 2)
Speed Selection - Other Options

• Cost Index = 0 (maximize ngm/kg = wind-adjusted MRC)

• Selected Cost Index (minimize costs)

\[
CI = \frac{\text{Time cost} \sim \$/hr}{\text{Fuel cost} \sim \text{cents}/\text{lb}}
\]

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
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
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
Winds

- Wind may be a reason to choose an “off optimum” altitude
- Want to maximize ground 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)
Distance Final cruise altitude

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

Altitude

Cost index increasing

Min time from point A to B

A

B

Final cruise altitude

Distance
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!
End of Fuel Conservation
Operational Procedures for Environmental Performance

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