A Look at the State of Airline Fuel Conservation

LIFECYCLE SOLUTIONS

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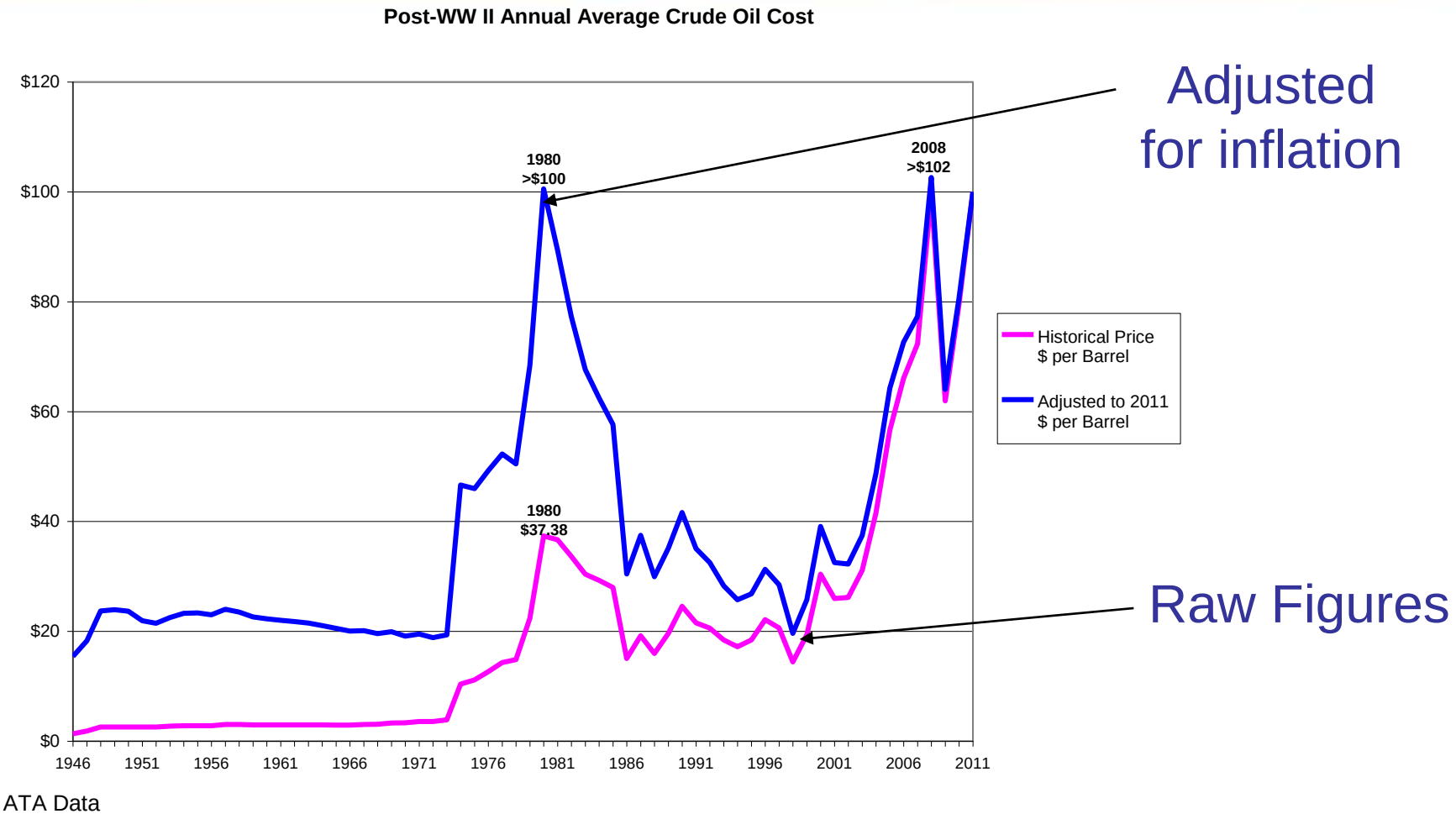
Boeing Commercial Airplanes

AGIFORS Operations Control – May 2011

Once Again – Fuel Cost – A Drag on Airlines



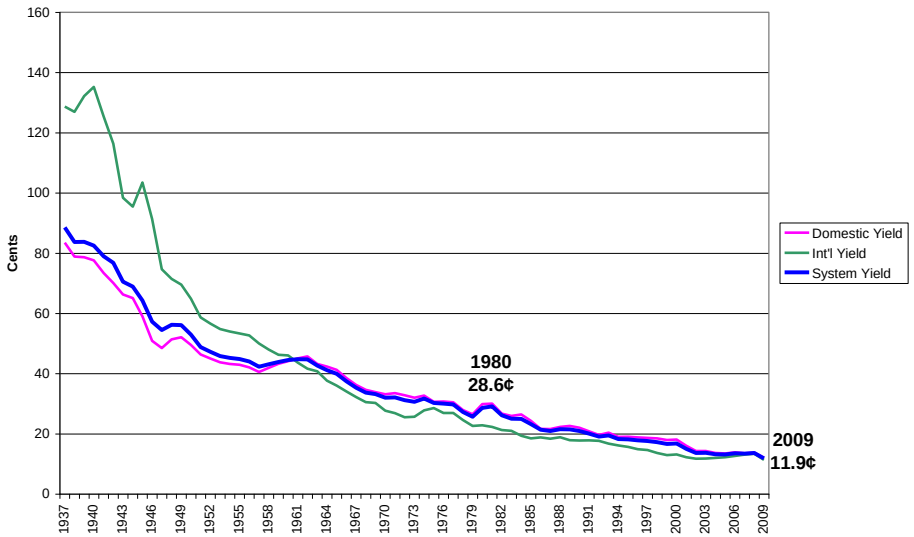
* ATA Data

- **Not only are fuel costs near all-time highs, their impact is worse than in the past …**
- **The world's airlines spent over $130B in fuel in 2009**

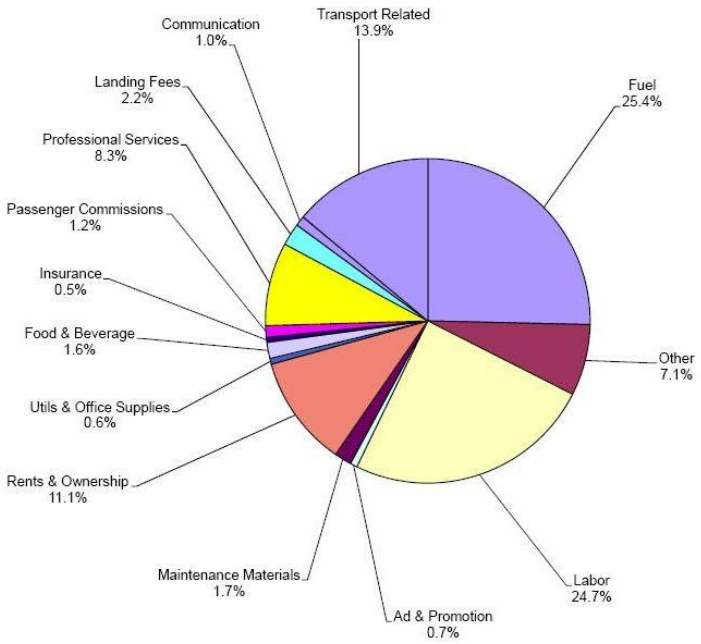
What is Different About the Current Fuel Price Crunch?

- **Adjusting for inflation, the current price peak isn't THAT much different from previous peaks over the last 30 years**
- **But what really makes each price surge more critical is ever-declining yields. This creates a cost crunch, where the share of fuel cost is growing**
- **Fuel costs represent up to 25-30% of an airline's annual operating budget**

Annual Historical Yield - U.S. Carriers



Operating Costs by Objective Grouping



* ATA Data for U.S. Airlines

How Can One Save Fuel, Money, Carbon?

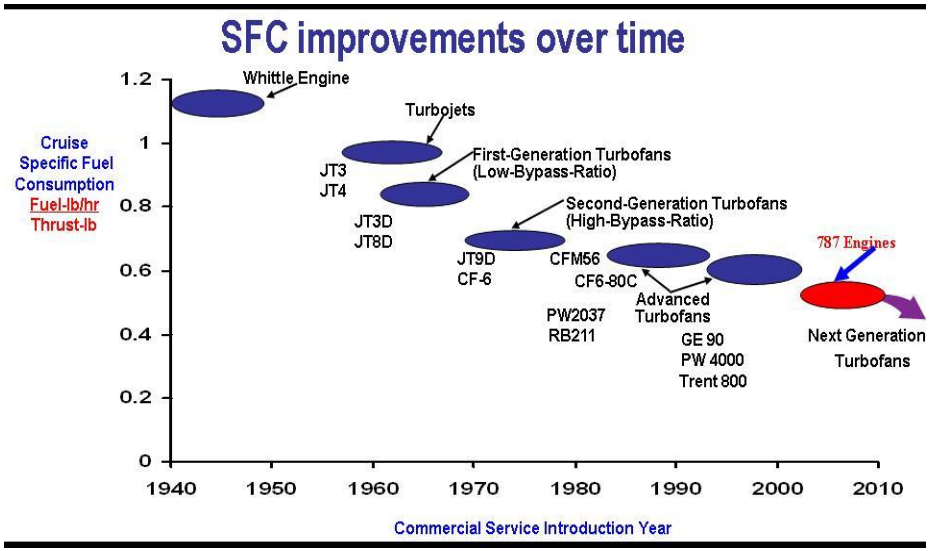
- **Not necessarily the same thing**
- **Saving fuel requires efficiencies**
- **Saving carbon can also be accomplished by alternates to petroleum**
- **Saving money may or may not always involve saving fuel!**

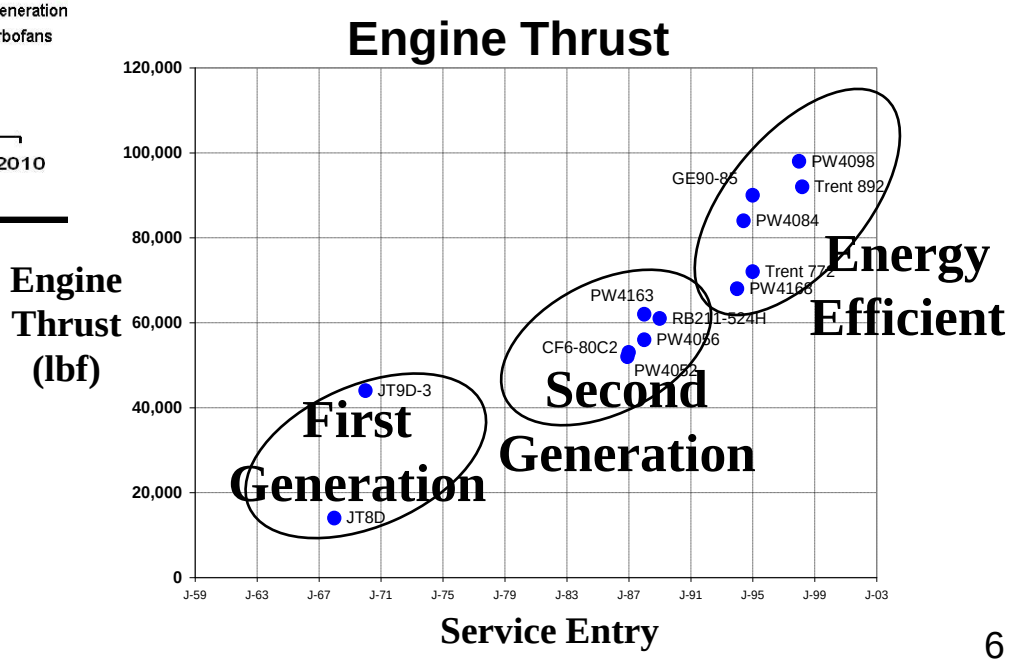
Some Detail On Fuel vs. Carbon vs. Money

- **Fuel can be saved by burning less via:**
  - **Aircraft & engine design**
  - **Carrying less weight**
  - **Eliminating wasteful practices**
- **Carbon can be saved by:**
  - **Saving fuel**
  - **Biofuel – same amount of fuel & carbon, but partially offset from a renewable source**
- **Money can be saved by:**
  - **Saving fuel**
  - **Tankering: burns more, cheaper fuel to keep from buying less fuel for a much higher price**
  - **Cost index: trading off the cost of time vs. cost of fuel**
  - **Hedging: an investment strategy – nothing to do with the fuel purchase or consumption – involves a financial contract that makes as much money as equivalent fuel price change loses**

Most Fuel Savings Have Come From Aircraft & Engine Improvements

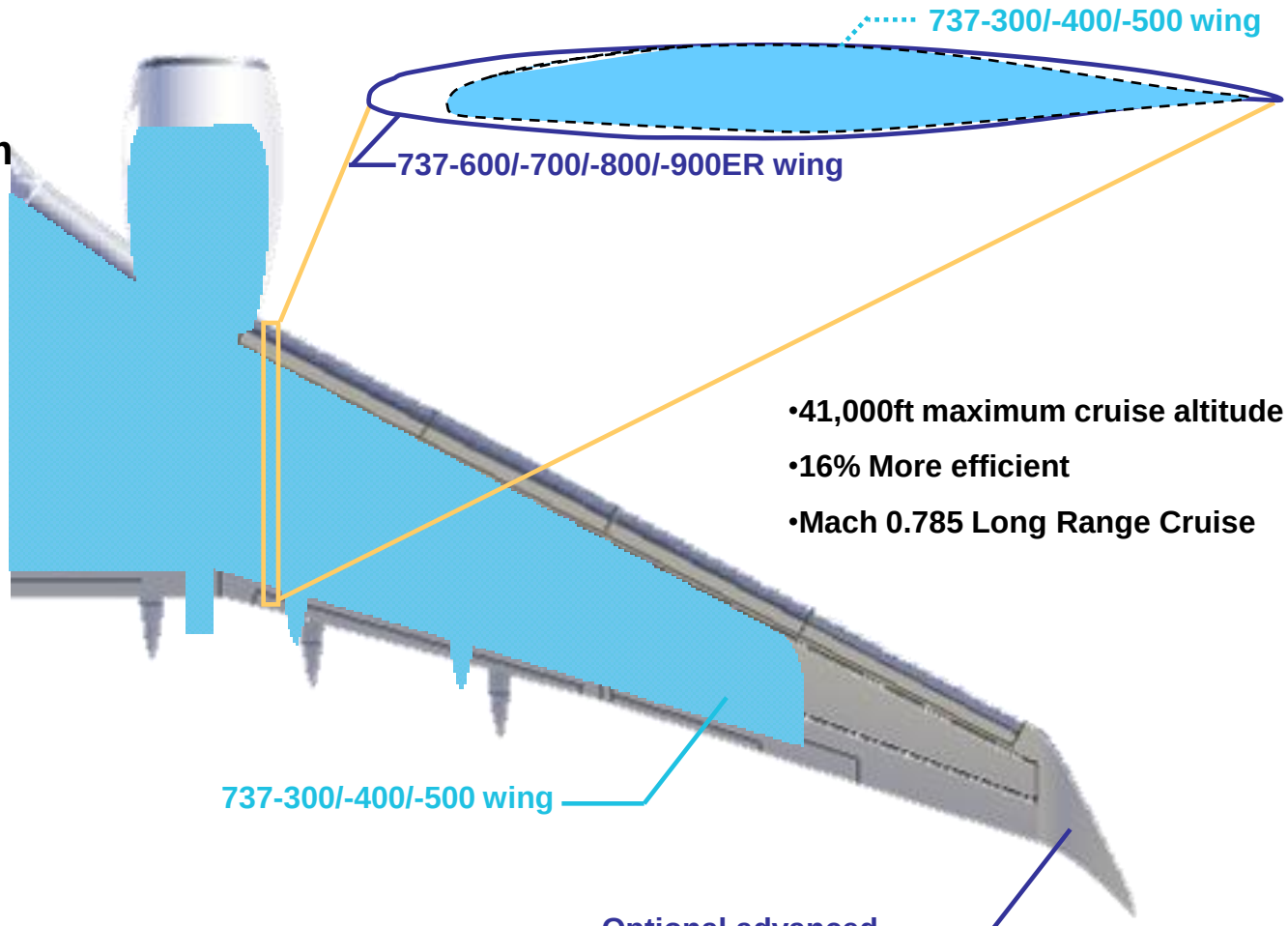
- **Engine improvements through technology, higher temperature and more bypass**





Aerodynamics: Example of Wing Evolution in 737

- **25% more wing area**
- **Simplified flap system**
- **New supercritical airfoil**
- **Performance enhancing blended winglets**

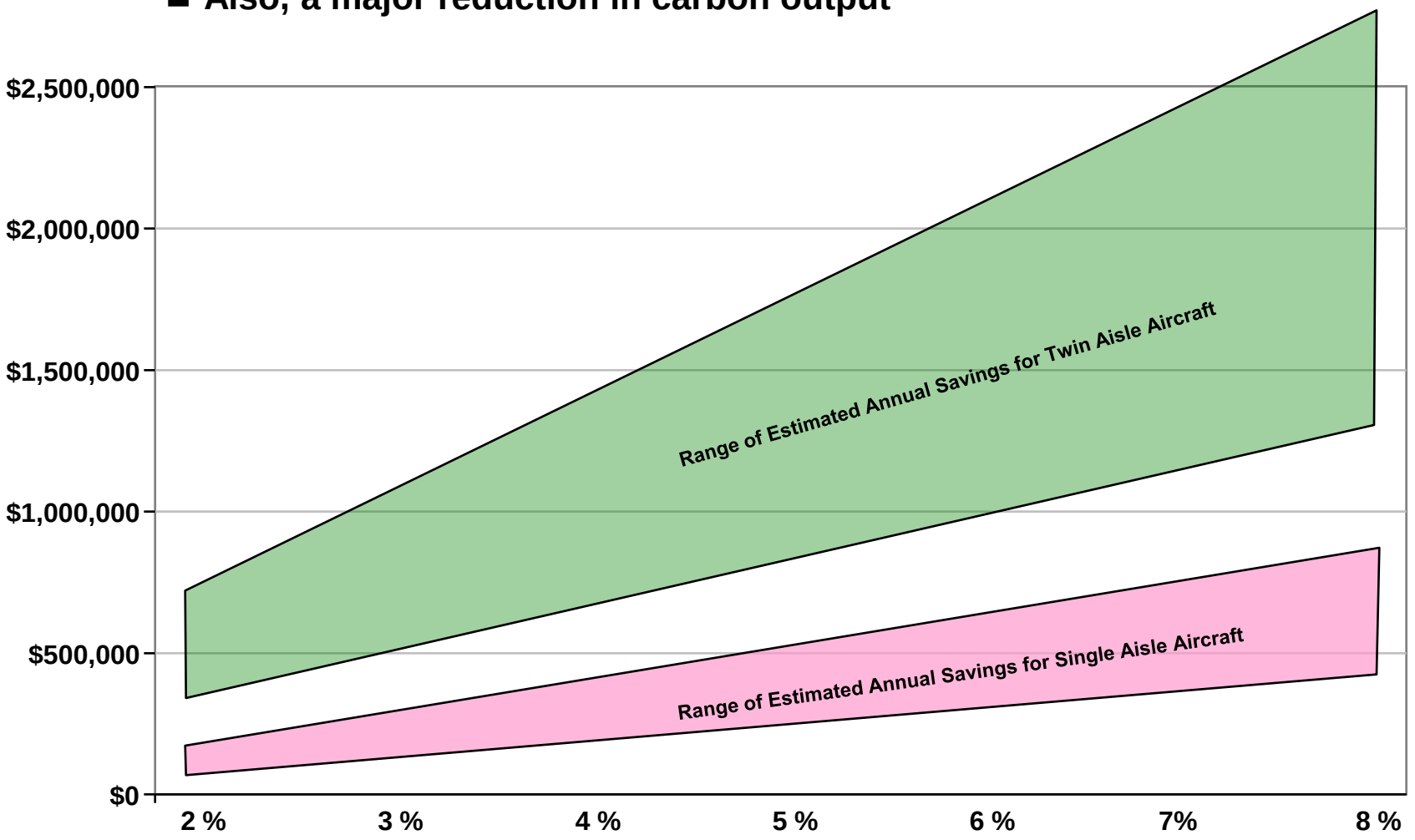


Another Key Aerodynamic Improvement – Winglets

- **Increases range, payload, and takeoff performance**
- **Decreases fuel burn 2.5% - 5% (aircraft / range dependent)**
- **Blended winglets now available on Boeing 737, 757, 767**
- **Sharklets on A320**
- **Raked wingtips:**

Fuel Conservation – the Savings Opportunity

- Many airlines have found that they can save 2-8% of fuel expenditure via weight reductions & improved processes
- Also, a major reduction in carbon output



Savings per aircraft @ $3 per gallon

So What Are Basic Issues in Fuel Conservation?

- There is too much weight on an aircraft
- The airline does not accurately calculate the weight of the aircraft
- Fuel is wasted by inappropriate procedures on the ground
- Pilots fly inefficient or inappropriate procedures
- The airplane is flown too fast
- The airplane generally lands with too much fuel
  - A special case of the airplane being too heavy
  - Only OK if caused by tankering (flying cheap fuel)
- There is something wrong with the aircraft that leads to excess fuel consumption
- Enough information regarding fuel is not being tracked by the airline
  - Knowledge is control
  - Proper data modeling identifies and often leads to the correction of ALL of these problems!

Fuel Conservation Is Everybody's Business!

- **Fuel conservation usually is viewed as an issue primarily for Flight Operations**
- **But, every organization in the airline affects fuel conservation in some way…**
- **Anybody who has an impact on the type of airplane that will fly a route, how often it will be flown, and any weight that may be carried on the aircraft is impacting fuel consumption. Some of the ancillary issues are:**
  - **Match capacity to demand**
  - **Reduce delays in spare parts purchasing**
  - **Reduce excess flying**
  - **Right size airplane for flight**
  - **Efficient procedures everywhere in the airline**
  - **Efficient scheduling**
  - **Control, weigh and charge for excess baggage**
  - **Control carry-on baggage, and carry it in the hold where possible**
  - **Coordinate definition of airline brand & customer product with true costs associated with carriage of weight**
  - **Coordinate definition of on-board catering with cost of weight**
  - **Etc.**

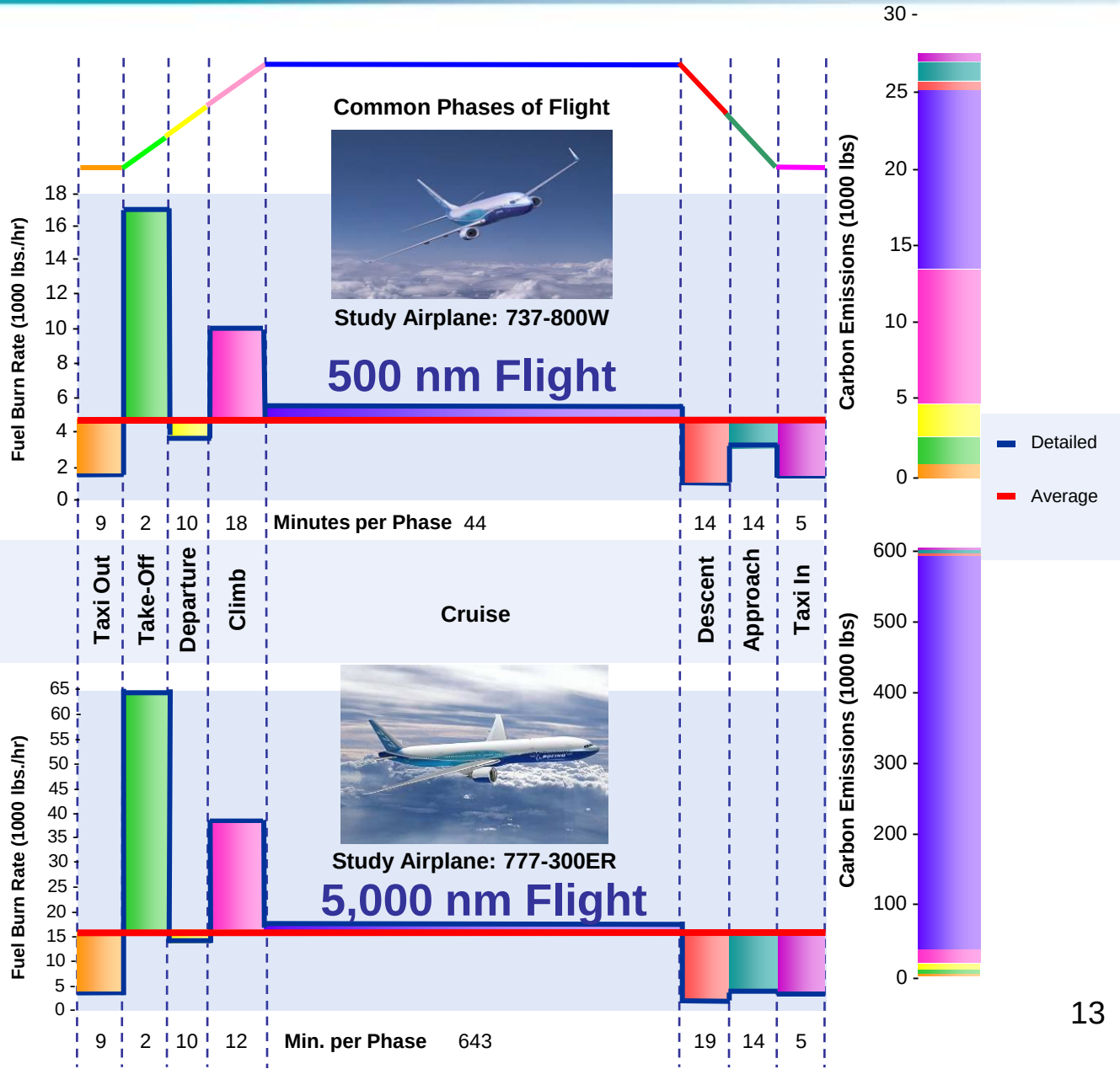
- **It is best if an airline's <u>entire staff</u> has exposure to the issues involved in effective fuel management**

Where Do You Go To Find Solutions?

- **Boeing's MyBoeingFleet for all Boeing customers has hundreds of fuel savings articles**
  - **https://www.myboeingfleet.com/flightops/**
- **International Air Transportation Association website:**
  - **http://www.iata.org/whatwedo/aircraft_operations/fuel/Pages/fuel_conservation.aspx**
  - **Large amount of info here, including document "Guidance Material and Best Practices for Fuel and Environmental Management", which can be requested from IATA via e-mail**
- **ICAO Circular 303 "Operational opportunities to Minimize Fuel Use and Reduce Emissions",**
  - **Can be ordered from ICAO website http://www.icao.int for US$55**
- **Air Transport Association website Fuel information page**
  - **http://www.airlines.org/Energy/Fuels101/Pages_Admin/Fuels101.aspx**
- **Or, you can come to Boeing for products, services & consulting to help you save fuel!**

Where Is Fuel Burned In Flight?

- A Boeing 737 on a short flight & a Boeing 777 on a long flight
- Highest burn rate is in climb to cruise level, after executing the SID
  - By a factor of >3!
- But, the highest percentage of total burn is in cruise



Where Do You Save Fuel On the Ground?

- **Many opportunities to save fuel in ground handling. Some key areas include:**
  - **APU usage**
    - **Analyze trade-off during turns between using APU and GPU/PCA units. Factors involved also include third party handling contracts**
    - **Many airlines have found that the worst issue for the APU is during overnight maintenance**
  - **Potable water uplift policy**
    - **Tanks on aircraft designed for worst case scenarios**
  - **Fueling procedures & over-fueling**
  - **Control of carry-on baggage**
  - **Center of Gravity (CG) control**
    - **Maintain CG in the mid to aft range**
- **Pilot procedures on the ground affect fuel savings**
  - **Take delays at the gate if possible**
  - **Start engines as late as possible, coordinate with ATC departure schedule**
  - **Single engine (or engine out) taxi –in and –out**
    - **Need appropriate safety procedures & engine warm-up/shutdown**

How Do You Maintain Aircraft for Fuel Efficiency?

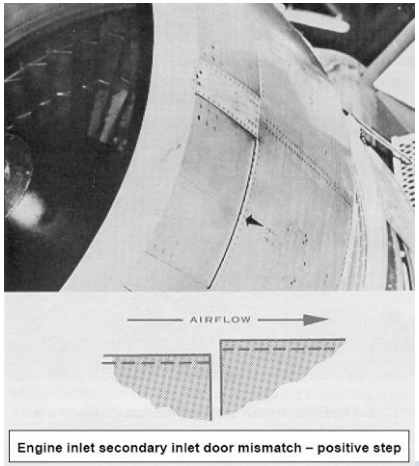
- As airplanes age, fuel consumption grows
  - Drag due to surface issues
  - Trim and rigging
  - OEW control
- Maintenance programs impact consumption
  - Minimize duration of MELs & CDLs
  - Rapid replacement of pressurization and air conditioning units and engine bleed valves
  - Rapid repair of anti-ice, brakes & weather radar
- Manufacturer-recommended efficiency modifications
  - Carbon Brakes
  - Anti-skid auto brakes
  - Brake temperature monitoring system
  - FMC software revisions

What Are Engine Maintenance Issues?

- **Performing maintenance will help keep fuel consumption from deteriorating**
  - **Erosion/wear/contamination**
  - **Seals/valves/cooling**
- **On-wing engine bleed rigging addresses leakage caused by bleed system wear**
  - **Problem identified from in-flight performance trends**
- **Engine manufacturer**
  - **Enhanced performance kits**
- **Engine washing**
  - **Up to 1.5% improvement for engine washing**

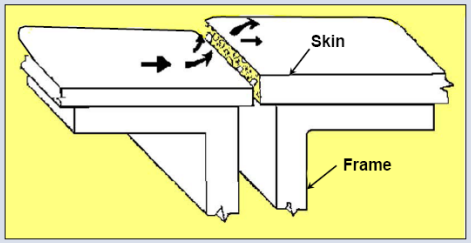
Another Maintenance Issue – Drag Wastes Fuel!

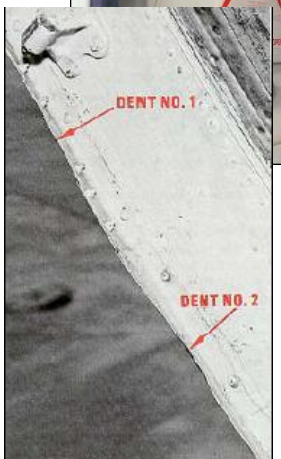
- Engine surface mismatch
- Misrigged ailerons
- Door seals
- Dents
- Maintain a clean airplane (washing)
- Periodic washing of exterior is beneficial
- Fluid leaks contribute to drag
- Use flush patches or doublers with flat head rivets
- Drag extra important on all leading edges and on fuselage ahead of wing



Engine inlet secondary inlet door mismatch – positive step

Steps at skin joints, around windows, doors, control surfaces, and access panels





1% drag (gallons / year)

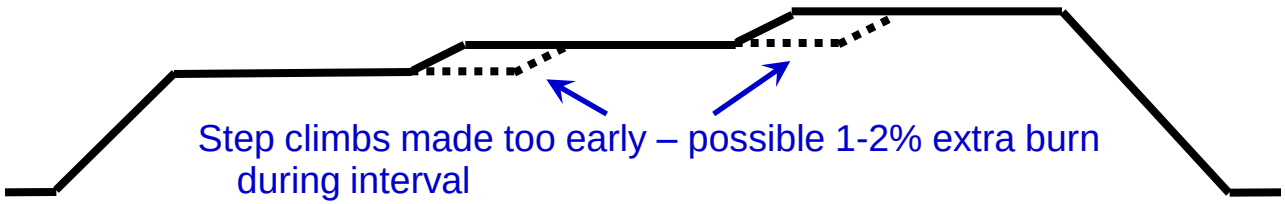
747 ~ 100,000 = $300 K

What Are Common Aircraft Weight Issues?

- **It costs fuel to carry fuel**
  - **3% of additional weight in additional fuel per hour of flight**
- **Dry Operating Weight (DOW) grows average + 0.1% to 0.2% per year, up to about 1% total**
  - **Most unaccounted for DOW growth is mainly due to moisture or dirt**
- **Check all weights – from the weight of the aircraft to the weight of everything carried on board**
- **Evaluate aircraft seats and configuration for tradeoffs between cost, revenue & reduced weight**
- **Remove excess magazines & materials from seatback cushions & overhead bins**
- **Review catering policies**
  - **Review all galley equipment for cost/benefit**
  - **Standardize & minimize supplies**
  - **Manage beverages (which add considerable weight)**
  - **Adjust catering by time of day**
  - **Review double catering (for return flights)**
  - **Review Duty Free**
  - **Trolley management – carriage of empty trolleys**
- **Switch to electronic manuals (EFB/ELB) – paper manuals can weigh ~20 kgs.**
- **Optimize potable water carried**
- **Empty Cargo and baggage containers (unless needed for network balance)**
- **The biggest source of excess weight is excess fuel! And much of it can be safely eliminated**

Errors In Weight: the Passenger Weight Issue

- **Airline passenger weights often set 10 kg. too low. On a flight with 200 passengers, calculated weight will be two tonnes too low**
  - **This increases block fuel burn significantly**
- **Boeing recommends flying with real passenger weights, as measured thru testing (also periodically recommended by the FAA)**
- **Flying with false low vs. "real" weights does not overall result in an actual increase in fuel burn**
  - **The true weight of the loaded airplane stays the same**
  - **The degradation factor will increase the flight plan fuel, but the low weight calculation will decrease the flight plan fuel. The net result is no change to the amount of fuel loaded and burned**
- **Nevertheless using false weights affects fuel management in the airline**
  - **Low load factor flights will appear to have more reliable fuel burn**
  - **Unreliable flight plans cause pilots to request extra fuel more often, thereby increasing true fuel burn**
- **There is a further effect that may cause increased fuel burn – the FMC will recommend an optimum altitude that is slightly higher than optimum, so the potential exists to burn extra fuel by flying too high**

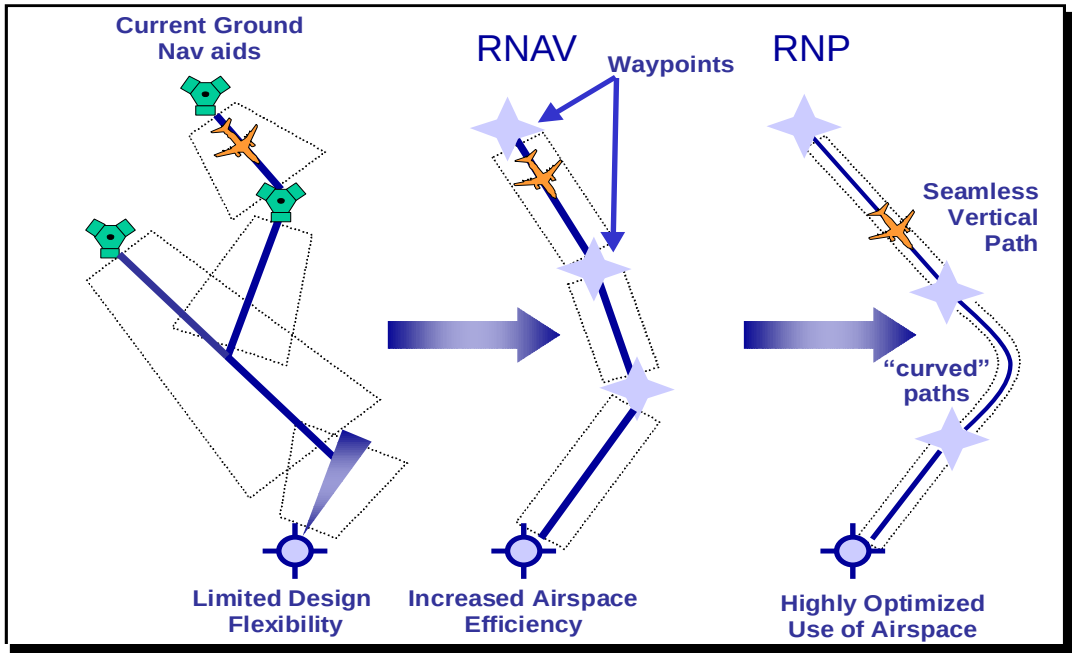


How Do You Gain Efficiency in Flight Operations?

- Use lowest flap setting that will meet takeoff performance requirements
- Retract flaps as early as possible
- Reduce steps in climb to initial cruise
- Fly the flight-planned speeds for all phases of flight
- Use proper trim procedures
- Understand the airplane's systems
- Understand wind/altitude trades
  - Wind may be a reason to choose an "off optimum" altitude
  - Want to maximize ground miles per unit of fuel burned
  - Important to update winds during flight
- Speed Selection: target Long Range Cruise (LRC) or use Cost Index (CI)
  - LRC = MRC + 1% fuel burn
  - Significant speed increase for only a 1% decrease in fuel mileage

Required Navigation Performance & CDA

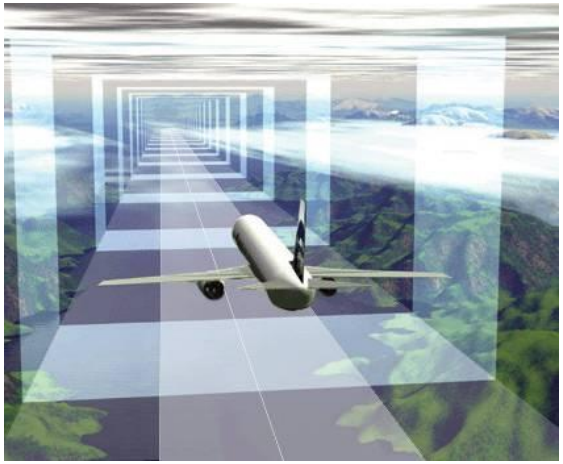
- **Required Navigation Performance (RNP) — a new air traffic paradigm and 21st century flight operation concept**
- **Continuous Descent Approaches (CDA)**



- **Ground-based**
- **Fixed routes**

- **Waypoint-to-waypoint**
- **95% accuracy**

- **Repeatable track**
- **Curved path**
- **Containment certified**
- **Crew alerting**



Alaska Airlines is saving more than $15 million / yr. on fuel with its current RNP approaches

A Major Savings Opportunity: Common Descent, Approach & Landing Issues

- Descent is one of the best areas to save fuel – often as much as 250 kgs. per flight
- Common issue – overflying optimum Top of Descent point (TOD) for greater stability
- Alternatively, the penalty for early descent is to spend more time at low altitudes, higher fuel burn
- Important to update winds during flight
- Don't transition to landing configuration too early
  - Fuel flow in the landing configuration is approximately 150% of the fuel flow in the clean configuration
  - In good weather, lower flaps and gear as late as possible
- Idle reverse on landing
  - Significant savings
  - Pilots usually want to take first high-speed exit
  - Idle reverse landing feasible on most long runways
    - An A320 or Boeing 737 needs less than 6,000 feet under most common conditions
- Cheaper to wear on brakes rather than waste fuel

What Are Common Issues In Flight Dispatch?

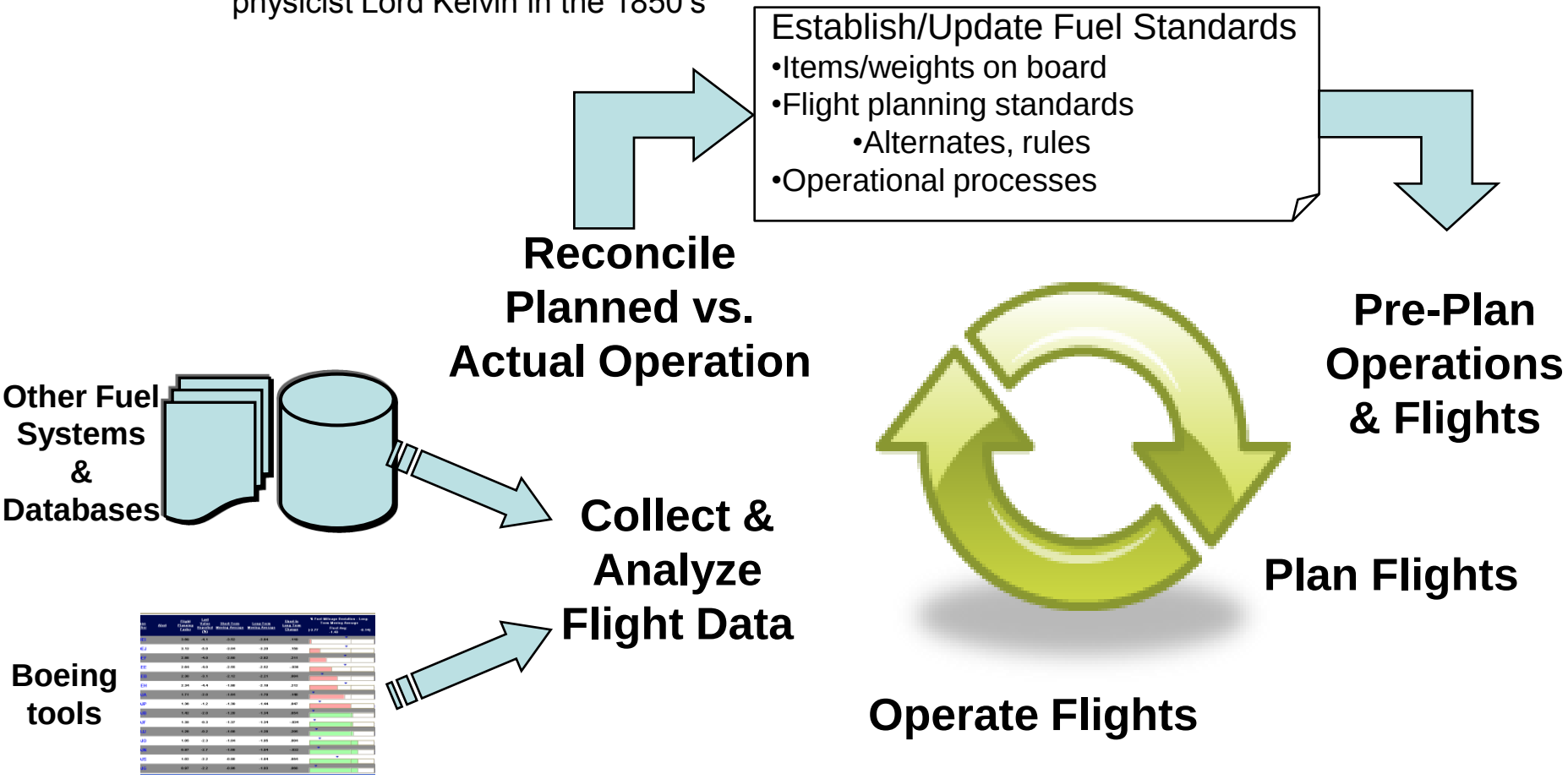
- Select shortest route, incorporating wind distance routing
- Use closest legal alternate with suitable weather
- Track & manage all extra fuel requests
  - Record extra fuel and reason
- Use fuel tankering where appropriate and cost effective
- Load proper fuel reserves
  - Minimum for current weather, route and destination conditions
- Plan and fly efficient speeds
- Take advantage of re-dispatch to reduce percentage-based fuel reserves
- Use either LRC or Cost Index for flight planning, whichever most appropriate
  - Cost Index trades off time vs. fuel costs
  - Include cost of potential delays & mis-connecting passengers in CI analysis
- Minimize and control planned vs. actual variances
  - Planned vs. actual weight and fuel load
  - Scheduled vs. planned vs. actual times

Planned vs. Actual: Why Is It So Important?

- **Most airlines monitor consumption, but not how it compares to the original plans**
- **Without comparing actual consumption to plans, it is much more difficult to isolate & monitor these issues:**
  - **Excess loading of fuel by fueler**
  - **Excess APU fuel usage**
  - **Trends in excess arrival fuel**
  - **Non-weather-related excess fuel burn**
  - **Altitude issues**
  - **Aircraft performance issues**
  - **Incorrect block, taxi & air times**
  - **Weight issues**
  - **Excess Maintenance taxi (vs. tow)**
  - **Any type of variance & trends**
- **Not having detailed trend analysis will cause assumptions that add to arrival fuel & inability to identify underlying problems**

Fuel Optimization – The Knowledge Loop

- **It's all about better monitoring, analysis, management & planning data**
  - Fuel, time, weight & variance
  - Real-time & post-operation
  - "To measure is to know. If you cannot measure it, you can not improve it." – legendary physicist Lord Kelvin in the 1850's



What Is the Biggest Problem Left To Solve?
Arrival Fuel!

- A different approach to reducing the biggest weight problem: destination-specific arrival fuel
- Ultimate Goal
  - Reduce the amount of fuel needlessly carried, thereby saving money and increasing payload capability
- Long-Term Objective
  - Accurately define the amount of fuel necessary for a given flight, ultimately with a computer system that can treat each flight independently, and monitor progress
- Near-Term Objective
  - Implement as a first step an analytical, destination-specific arrival fuel for all domestic destinations, using manual methods.
- Highlights
  - A methodology has been developed to tie hold fuel to an analysis of delay history, weather conditions, and emergency requirements. The initial implementation of the preliminary approach will lead to a natural progression to the long-term objective.

What Are Today's Roadblocks to Saving More Fuel?

- **Bad habits and psychology**
  - **Often requires outside facilitators to enable change**
- **Every airline knows what to do to save fuel**
  - **So concentrate on gathering data & performing analysis**
  - **Use the analysis to correct and monitor bad habits**
- **Effect of errors on pilot behavior**
  - **Major variances & overburns create pilot mistrust in flight plans causing pilots to order excess fuel for ALL flights**
  - **Variances need to be minimized where possible**
  - **Predictable variances (aircraft deterioration, predictable destination air traffic) need to be documented & explained to pilots**
  - **Major unexplained or unjustified errors may cause pilots to order extra fuel in increments of 1,000 lbs. (US) or 500 kg. (rest of world) per flight**
- **Improve pilot/dispatcher interaction & psychology through better data management, analysis & communication**

Thank You …

Onward and upward with fuel savings!