Flight Planning: Today and Tomorrow

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Agenda

- **Introduction**
- Minimum cost system-wide
- Pre-flight
  - Leveraging airspace liberalization
  - Probabilistic Weather Forecasts
  - How fast should you fly
- Post-departure updates
- Post-arrival analysis
- Status updates
  - Next Generation Flight Planning
  - JetPlanner 2014
- Conclusion
Flight planning is regulatory...

ICAO Annex 6 – Operation of Aircraft

4.3.3 Operational Flight Planning

4.3.3.1 An operational flight plan shall be completed for every intended flight...

(Leading to, e.g., FAR 121.663, “... shall prepare a dispatch release for each flight between specified points...”)
Minimize:  \[ Cost = C_{\text{fuel}} + C_{\text{time}} + C_{\text{overflight}} + C_{\text{payload limitation}} \]

Subject to:  
Equations of motion (including mass variation)  
Temperature = T(x, y, h, t)  
Wind = (u(x,y,h,t),v(x,y,h,t))  
Regulatory constraints (FAR, EU-OPS, AIP, RAD, etc.)  
Operational constraints (company fuel policy, etc.)

By varying:  
Route  
Altitudes  
Speed (Cost Index)  
Departure fuel  
Payload

... but it is also an opportunity to optimize operations and minimize cost
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Expanding the scope of "flight planning"
Expanding the scope of "flight planning"
Expanding the scope of "flight planning"
Expanding the scope of "flight planning"
Flight planning as a sub-problem

Minimize fuel for each flight?
-or-
Minimize fuel to transport payloads to destinations?

Mx schedule
Payload demand
Individual tail fuel burn variation
Tankering opportunities
Aircraft equipage
MEL/CDL
Forecast wind/temp

Assign Tails

Total fuel for specific routings
Other costs and constraints

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Tail assignment integrated with flight planning

Example: Part of your fleet is overwater equipped

- Three Choices:
  - Ignore the difference in routing
  - Force use of overwater-equipped aircraft
  - Optimize using the real difference in cost (integrating flight planning) to correctly weigh extra fuel against Mx schedule and other constraints (depends on wind, temperature, payload – not a static solution!)
### Tail assignments proof-of-concept

#### In Scope
- Fuel burn variation by tail
- Overwater equipage
- Overwater routing

#### Out of Scope
- MEL/CDL
- Tankering opportunities
- Schedule changes, demand-based re-fleeting

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<td>~40</td>
<td>~$35 000</td>
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Total fuel saving: $6.3M / Year
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Cost saving opportunities: Leverage Airspace Liberalizations

ICAO Block 0 airspace liberalizations (now through 2018)

- Implementation: NRS in United Statues (already implemented)
- Benefit: EWR-SFO optimizing on NRS saves $300 per flight
Cost saving opportunities: Leverage Airspace Liberalizations

ICAO Block 0 airspace liberalizations (now through 2018)

- Implementation: night directs in Europe (already implemented)
- Benefit: EFHK-LPMA using night direct routing in Germany, France, and Portugal saves 3 minutes, 100kg fuel
Weather forecasting

- Massive systems of PDE’s
- Heuristics for other effects
- Quite a bit of computing power…
Weather Forecast Uncertainty

The concept of “Chaos” was introduced to describe this effect in weather forecasting.
Assessing Uncertainty

ENSEMBLE PREDICTION SYSTEM – EPS
Provides quantitative information about predictability, i.e. forecast uncertainty.
From Ensemble Results, we calculate RISK

Probability distributions for different weather parameters + operator-defined thresholds = risk indicators
Dashboards show risk based on Ensemble forecast

Hierarchical views for drill-down: start with airport list
Dashboards show risk based on Ensemble forecast

Hierarchical views for drill-down: source of risk at airport
Dashboards show risk based on Ensemble forecast

Hierarchical views for drill-down: decompose by aircraft type

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Flight Plan Optimization

Minimize: \[ Cost = C_{\text{fuel}} + C_{\text{time}} + C_{\text{overflight}} + C_{\text{payload limitation}} \]

Subject to: Equations of motion (including mass variation)
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Regulatory constraints (FAR, EU-OPS, AIP, RAD, etc.)
Operational constraints (company fuel policy, etc.)

By varying: Route
Altitudes
Speed (Cost Index)
Departure fuel
Payload

How fast should we fly?
How fast should we fly?

The FMC literature says to simply pick the CI to minimize the sum of fuel costs and linear, continuous time costs. Is this realistic?
We want to minimize total cost, which includes the cost of time

Minimize: \[ \text{Cost} = C_{\text{fuel}} + C_{\text{time}} + C_{\text{overflight}} + C_{\text{payload limitation}} \]

Subject to:
- Equations of motion (including mass variation)
- Temperature = \( T(x, y, h, t) \)
- Wind = \((u(x,y,h,t), v(x,y,h,t))\)
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By varying: Route, Altitudes, Speed (Cost Index), Departure fuel, Payload

What are the sources and mathematical structure of these costs?
# Source of time-based costs

<table>
<thead>
<tr>
<th>Source</th>
<th>Flight duration dependent</th>
<th>Arrival time dependent</th>
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| Aircraft             | - Maintenance intervals
                      | - Hourly lease rates                                                             | - Subsequent flights
                      |                                                                     | - Operational flexibility                                             |
| Crew                 | - Direct pay (some operators)
                      | - Duty limits – less optimal crew solution later in month/year                   | - Subsequent flights
                      |                                                                     | - Direct pay, if based on schedule times                              |
| Passengers and Cargo |                                                                                          |                                                                          |
|                      |                                                                                          | - Re-accommodation                                                        |
|                      |                                                                                          | - Compensation                                                            |
                      |                                                                                          | - Reputation & loss of future business                                    |
| Airports             |                                                                                          |                                                                          |
|                      |                                                                                          | - Ground staff pay/overtime                                               |
                      |                                                                                          | - Penalties/fees                                                          |
                      |                                                                                          | - Loss of priority for shared resources                                  |
Time-based Costs vary by flight

Flight Delay impact on pax delays at final arrival destination

- PEK
- JFK
- HKG
- BKK
- BOM

Money units

Flight arrival delay minutes
Optimizing the Cost Index during Flight Planning – implementation

- Jeppesen Integrator
- Fuel Cost
- Mx Costs
- Crew Costs
- Lateness Costs
- STA

Departure time

Flight plan at min-cost CI

ACARS

JetPlan

Server

Server

Server

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Airborne Re-planning of Cost Index

Data integration with other systems

Cost Data (Fuel, Mx, Crew, Network, etc.)

“Off” time

ACARS

Flight planning system

New Optimal CI
Adaptable trailing edge technology

Variable area fan nozzle

Flight trajectory optimization for in-flight planning – enables airlines to determine and fly more fuel-efficient routes and provides flight crews the ability to reroute for weather and other constraints.

Regenerative fuel cells for onboard power

Example: re-optimized route saves 150lb of fuel
Many of the data limitations in the first FMC (B757) persist to the most recent ones (A380, B787, B747-8)

These data limitations have limited use of upgraded calculation features (e.g., advanced step climb optimization algorithms)

The FMC has many “tricks” to build wind models from limited data

Intimate knowledge of how the FMC works → optimal selection of winds to uplink → best performance by the FMC, both enroute and descent
How Wind Updates Works

Gather Real-time Data

- Weather grid from approved weather providers
- Real-time weather information from participating aircraft
- Flight plan information and trajectory updates from the aircraft *(accounts for real-time flight path adjustments)*

Continual Evaluation

- Real-time evaluation of predicted aircraft trajectory
- Selects optimal wind/temp data (FMC type, trajectory, predicted/sensed winds)
- Determines best wind bands for optimal FMS calculations

Send Wind Updates

- En route uplinks delivered at pilot request pre and post departure
- Automated descent uplink ~15 minutes before TOD
- Wind Updates autoloaded in FMS after pilot review
Improved cruise altitude management (saves fuel)
- Better step climb locations
- Additional step climb opportunities
- Better evaluation of step descent opportunities

Improved ETA predictions (cost savings)
Enables more optimal Cost Index
Proactive mitigation for off plan situations

Improved descent performance (fuel savings)
- Optimized TOD, more efficient trajectory
- More stable approach
- Enables additional gains from advanced arrivals (e.g. CDA, RNP, RTA)

Reduces fuel consumption by 30-500 pounds of fuel per flight
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Risks in fuel and time accuracy

- Difference between flight planned path (route, altitudes, speeds) and actual operation
- Biases used in flight plan calculations model two effects:
  - Degradation of airframe/engines (match FMC)
  - Differences between flight plan and actual operation

OEM Performance Monitoring Software

- FMC performance factor
- JetPlan fuel flow bias

Closed-loop planned vs. actual analysis

- Adjustment of JetPlan fuel flow bias
- Other JetPlan biases
Monitoring flight plan accuracy

JetPlan

Archived flight plan data

QAR

Actual flight plan data

JetPlan

Data Warehouse

Planned vs. Actual Analyzer

Human-readable report for a specific flight

Excel output for statistical analysis

KML for graphical comparison

Manual flight plan notes / EFF
Flight Plan Benchmarks Example

Airline: XXX  Flight: XXX  Route: XXX-XXX  Date: 8-Jan-13  Type: 737-900ER

Flight Plan Buffers can mask fuel efficiency opportunities.
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Next Generation Flight Planning (NGFP)
Second-generation 4D Route Optimizer

- Conditional airspace availability
- Beta test customer (holiday carrier) received 98% airspace access efficiency rating from EuroControl
- Mainline carrier using high-end European competitor went to visit them to see how they did it!
- Staff hired to extend rules to world wide coverage
- Real-time NOTAM application with admin tool
NGFP Second-generation 4D Route Optimizer 2013-2014 release schedule

NGFP-2 Optimizer deployed to hosted JetPlan

- TATL including NAT tracks
- Local JetPlan deployments
- Some NOTAM consideration
- European supplemental profile
- Domestic US
- More rule-based functionality
- More NOTAM consideration

Worldwide geographical coverage

Stand-alone NGFP

## Next Generation Flight Planning Virtual Appliance

<table>
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<tr>
<th>Item</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hardware / processors</td>
<td>4-8x - X86_64 SSE, AVX (for improved compute times)</td>
</tr>
<tr>
<td>OS</td>
<td>CentOS 6 or RHEL 6</td>
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<tr>
<td>Hypervisor</td>
<td>Vmware, Vbox</td>
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<td>Memory</td>
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<td>Storage</td>
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JetPlanner 5.2
Features/Functions
- EFF Phase 1. - transmit plan
- W&B Integration
- DRA Integration phase 1
- RAIM updates
- Improved architecture with built in database, optional CITRIX
- Rules based automation of planning tasks
- Automated alerting
- Integration with Jeppesen Notam Management tool.

JetPlanner 6.0
Release Q2 2014
Features/Functions
- User interface and dispatch view redesign
- More Configurability
- Work flow optimization improvements
Compare Flight Plan Scenarios

Plot and compare multiple flight plans routes side-by-side
Dispatch View

Manage multiple flight plans in a sort-able, tabular view
Color coded alerts
Flight plan preparation status (ATC summary, transmission, RAIM, etc)

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<td>00h25m</td>
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Default POA Seable Linked POA of Portland
Rules Based Automated Flight Planning

Administrator controlled rules provide controls for flight planning actions.
Conclusion

- Flight planning leads to tangible cost savings
- Minimize cost over the entire system
- Choose the Cost Index with a real-time analysis
- Save more money with post-departure updates
- Analyze flight data to fine-tune planning and enforce compliance
- NGFP is coming in 2014, along with a radically improved JetPlanner