Airspace Technology Demonstration 2 (ATD-2)

SWIM-Fused data products used by ATD-2 analysts for quantifying NAS performance and benefits

September 4, 2019
• **Session 1:**
  – Detailed description of approach and scope for `flightSummary` report, the core file used for analysis and reporting on ATD-2 project
  – Lots of questions and answers!

• **Session 2:**
  – Description of other ATD-2 core data files (`tmiSummary` and `tosSummary`)
  – Discussion of reports built on top of core data files
  – Lots of questions and answers!
ATD-2 systems ingest huge amounts of SWIM data
• They also output huge amounts of data, recording every aspect of the operation
• Besides scale, data contains “noise”
  – e.g., human inputs, complexities of data mediation, order of processing messages, changes from earlier versions of ATD-2 software
• Project has developed standard conventions for measurement that need to be implemented
• To address these challenges, we have developed a variety of standardized summary files and reports to serve analyst and user needs
Three basic reports used for analysis and reporting:

• *flightSummary report*
  – Tabular report generated each day, one row per flight, with *many* computed metrics

• *tmiSummary report*
  – Tabular report generated each day, one row per distinct TMI, with data about program characteristics

• *tosSummary report*
  – Tabular report generated each day, one row per flight & TOS route, with many metrics about route stats at different flight milestones

*Focus of this session*
flightSummary technical approach

- Report generated on data warehouses each morning for prior “day” (0400-0400 local), requiring ~15 minutes
  - Application written in Python, runs ~50 SQL queries, joins results, adds additional columns leveraging data between queries
  - Approach is generic: could be implemented in other languages, or in pure SQL

- Fully compatible with all ATD-2 airports
Wide variety of “modules,” some of which only apply to specific airports:

- “Basic” data
- Banks
- Ramp controller clearances
- Flight “states”
- Surface metering stats
- Times & locations predicted at events
- EOBT, LTIME & associated accuracy
- TMI impacts (GDP, GS, MIT, fix closure, APREQ)
- Taxi times (undelayed & actual)
- Gate conflicts
- Various estimates of AOBT
- Airport configuration
- Predicted downline times for departures
- On-time performance
- AEFS activity
- First surveillance
- TOS-related data
“Basic” descriptive data

From final values for each flight, report:

• ACID, GUFI
• Category, origin/destination
• Aircraft identifying info (type, wake, engine class, etc.)
• SOBT, SIBT
• AOBT, AMAT, ATOT, ALDT, AIBT (+ queue entry time)
• Actual terminal/ramp/gate/spot/runway/fix
• Cancellation indicator/time
• Final position
• Final route, assigned altitude
• Operating and marketing carriers
• Last system providing data, last timestamp of data received
• Long on board, priority status, runway opnec indicators
• IOBT, Final PTIME
Many ways to define “banks”

• Want to recognize partner definitions, e.g., a bank might be defined from 12:15 – 13:40
  – We report operator-defined bank numbers when available

• But for analysis purposes, also want to be adaptable to how conditions evolve each day
  – Allows analysts to track holistic changes in schedule & operations

• So, use a clustering algorithm to infer bank structure, and assign sensible numbering, from the data
  – Density-based clustering used, so some flights fall into no bank, representing lulls in traffic
  – Calculated for: scheduled in/out, actual on/off, actual out, as different audiences have different interests & objectives
• Example of learned banks using pushback and takeoff events

This is machine learning in action

• Simple application, but able to bring considerable value to analysis efforts on project
Ramp controller clearances

- RTC, *when used*, records all ramp controller actions, report gets last time each clearance issued
  - *Typical departure sequence:*
    - Gate pushback hold: 12:15:40
    - Gate pushback approved: 12:19:45
    - Proceed to spot: 12:23:00
  - *Other clearances:*
    - Hold
    - Return to gate
    - Not set
    - Cleared to gate

- Indicator for “true” gate returns
  - Often observe controllers quickly undo clearance, pushing flight into unset state
  - Logic requires >5 minutes between clearance going return to gate or unset, and next good clearance, to count

- Indicator for pushback approved clearance being undone
- Last clearance type issued
- Infer pushback duration by difference between pushback approved and proceed to spot
  - Only captures flights cleared using RTC, as surveillance does not give reliable pushback duration
Flight states

• ATD-2 internal model maintains state of flight, based on available data and rules, to make predictions
  – Scheduled, pushback, ramp taxi out, taxi out, in queue, off, in terminal airport, en route
  – On final, taxi in, ramp taxi in, in gate
  – Return to gate, cancelled, suspended, unknown
• Query gets first time flight enters each state
• Report final state reached (helps with finding “stuck” flights)
Developed suite of metrics around surface metering:

- Some values computed here apply to all flights, while others are specific to metered flights
- Infer flight ready time: capture clearance sequence, observation of surveillance, account for return to gate:
  - Report predictions at ready: controlled times, UOBT, UTOT, TOBT, TMAT, TTOT
- Infer metering “status”
- Standardized TOBT/TMAT compliance: using metering status and standard windows (TOBT +/- 2 mins, TMAT +/- 5 mins)
- Gate holds: advised and actual
- Held beyond SOBT or LTIME
- Fuel/emissions savings associated with actual gate hold
- Bulk of this data distributed after each bank for common situational awareness as the *Post-Metering Report*
Resource predictions at events

- For departures, immediately before:
  - Pushback, spot crossing, departure queue entry, takeoff, fix crossing

- Predict:
  - Gate, spot, runway, fix (for all “future” resources)

- For arrivals, immediately before:
  - Fix crossing, landing, spot crossing, gate in

- Predict:
  - Fix, runway, spot, gate (for all “future” resources)

- Include data source used for each resource prediction in internal model, e.g., STBO prediction, TBFM system
At same events that resource predictions are sampled, get many times (set of times tailored to event):

- **Departures:**
  - At pushback: suite of gate (UOBT, LTIME, etc.), spot, runway (controlled, undelayed, etc.), fix times (targeted, undelayed, etc.)
  - At spot crossing: suite of spot, runway, fix times
  - At queue entry: suite of runway, fix times
  - At takeoff: suite of runway, fix times
  - At fix crossing: suite of fix times

- **Arrivals:**
  - Undelayed times for all future resources
For each of EOBT and LTIME, report:

• Value at pilot ready time (this is what EOBT trying to predict!)
• Final value received
• Difference versus ready time, pushback clearance, AOBT (using value in effect at that instant)
• EOBT at prescheduling
• Time first/last value received
• Number of times value updated
• Accuracy versus ready and AOBT at 0, 5, 10, 15, 20, 30 minutes prior to event
**EDCT:**
- Values at pilot ready time, final
- When first/last EDCT received
- Number of updates
- Actual & truncated compliance

**Ground stop:**
- Indicator for data received

**MIT & Fix closures:**
- First/last time received
- Count of distinct restrictions
- Actual MIT value, actual alternate for closure
Significant undertaking to include everything:

- First/actual release type (original, IDAC, free), coordinating center, time requested (if known)
- First/last scheduled times, TBFM-assigned delay
- First/last times flight scheduled, flight states at those
- Point in flight lifecycle when scheduled (e.g., pre pushback)
- Number of times rescheduled
- Prescheduling indicator, EOBT at prescheduling
- APREQ release mode at first/last scheduling event (e.g., automatic)
- Estimated time & fuel savings from rescheduling
- Actual & truncated compliance

- Bulk of this data distributed each morning to support analyst and user needs, common situational awareness
**Undelayed:**

- Record prediction used in system for undelayed taxi times, immediately before:
  - Pushback → ramp taxi time
  - Departure spot crossing → AMA taxi time
  - Landing → AMA taxi time
  - Arrival spot crossing → ramp taxi time
- Filter out “bad” values, include logic to account for bugs in historical data

**Actual:**

- Actual AMA & ramp taxi times for arrivals and departures
- Report excess (difference between actual and undelayed) taxi times for each phase
Gate conflicts

• System models/predicts gate conflicts, so capture data for both arrivals and departures
  – Associated other flight
  – Value present at landing (for arrivals)
  – Start/end/duration of conflict period (as of landing time)
AOBT by source:

• Get AOBTs from:
  – Controller inputs (gate pushback approved)
  – Airline (CLT does not currently use these in operation)
  – Surveillance (occasionally, although coverage quality is low near terminal buildings)

• Often capture multiple airline-provided AOBTs because of different automation systems

Airport configuration:

• At out, off, on, in events for flights, record:
  – flow: direction airport operating in (small set of values for subject airports)
  – scenario: summary of departure procedures in effect
**Downline times for departures**

- For departures from subject airports, report in time as predicted by airline systems, sample at out and takeoff events.
- Useful for analysts to model downstream A04/A14 performance impacts.

**On-time performance:**

- Report indicators for flights meeting D0/D15/A0/A14 milestones.
- Use actual times truncated to minutes to match logic employed by DOT (as airline-provided times typically truncated).
AEFS actions:
• Cleared for takeoff
• Line-up and wait
• Enter runway
• Taxi clearance

First surveillance data:
• Time of first surveillance data
• System providing first surveillance
• Flight state at first surveillance
  – Useful for understanding if flights pop into system before expected
To support analysis for phase 3 activities, report:

• TOS-related flight event times
  – Flight becoming eligible
  – Submission by operator
  – Approval by ATC

• Predictions / plans from terminal scheduling engine at different flight events

• Best TOS route at different flight events

• Terminal transit times used by scheduling engine

All this at a flight level, but have different file that provides stats on each flight’s TOS routes…
On top of the flightSummary file, a variety of reports have been developed to support analyst and user needs:

- **APREQ compliance report**
  - Subset of flightSummary rows and columns, covering APREQ negotiation and compliance pushed to users each morning

- **Post-Bank Gate Hold report**
  - Subset of flightSummary rows and columns, covering metering performance, pushed immediately after each bank at Charlotte

- **Daily Data Digest**
  - Summary of prior day’s flight and airport operations pushed to users and researchers each morning for Charlotte, DFW, and Love Field

- **System Prediction Quality report**
  - Internal report quantifying system prediction accuracy to monitor performance and rapidly address issues

- **And more!!**
Wrap-up

- These reports widely used within project as starting point for analysis, saving considerable redundant work
- Versions shared with project partners regularly for their analysis and feedback
- Development of these reports highly collaborative, adding new features regularly
- Approach is generic, but can be adapted as appropriate
- Infinitely simpler by starting with fuser data

- This is current ATD-2 approach, but for any future work, we believe that maintaining a common 360° view of each flight is extremely valuable.