Airspace Technology Demonstration 2 (ATD-2)

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

ATD-2 reporting agenda

- **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 reporting background

- 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*

Core ATD-2 data files

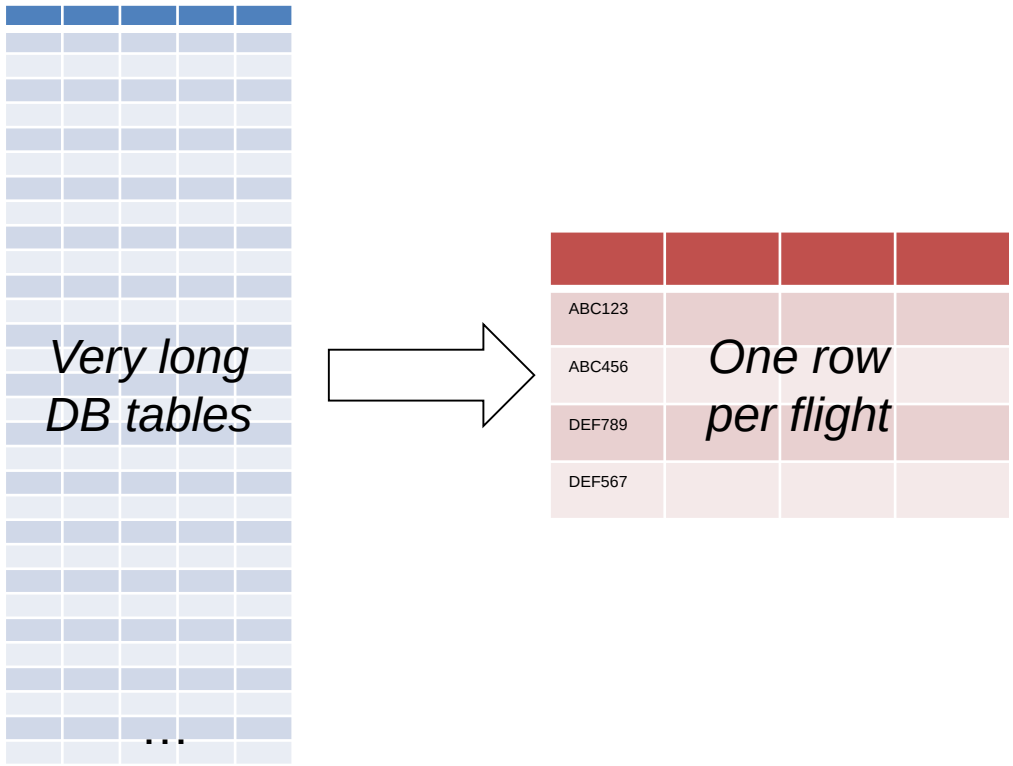
Three basic reports used for analysis and reporting:

- *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

Data available in flightSummary file

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

Bank data

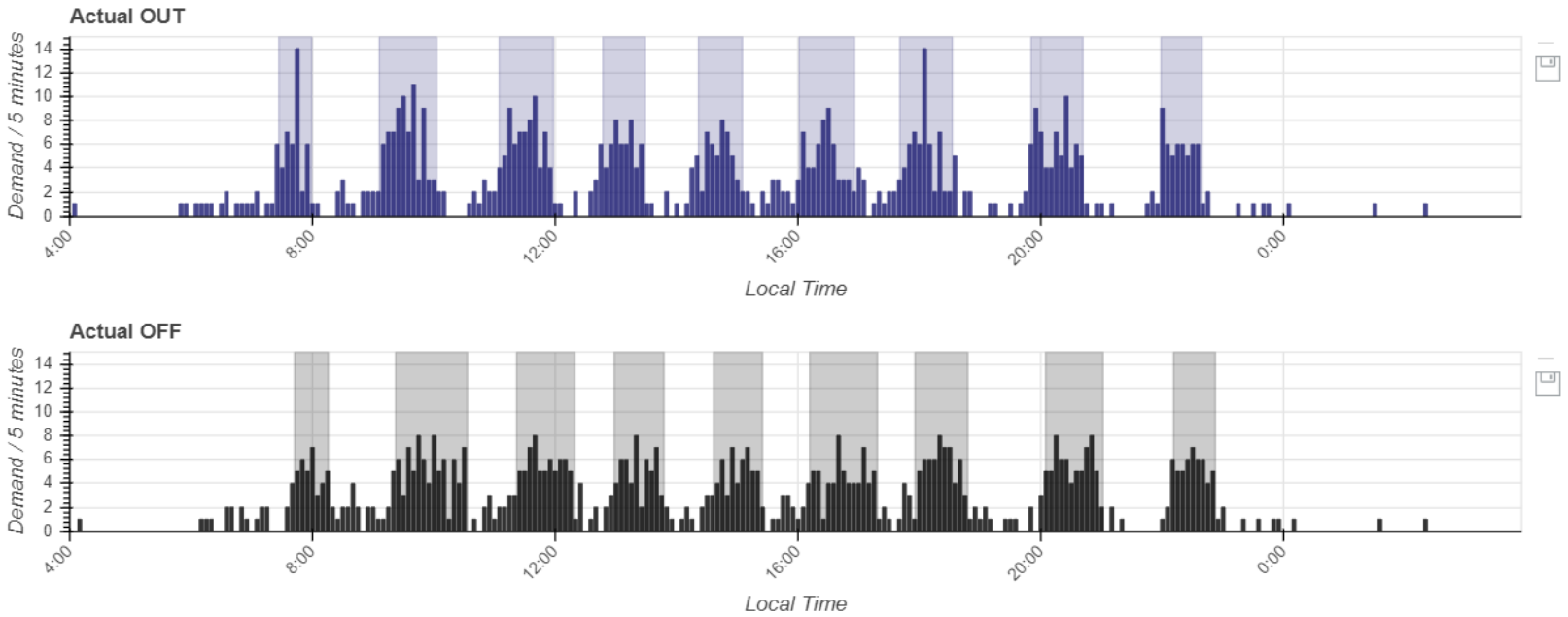
Many ways to define "banks"

- 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

Bank data

- 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)

Surface metering analysis

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

Time values & predictions at events

- 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

EOBT / LTIME data

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

TMI impacts

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

APREQ data

***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

Taxi times

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)

Other data

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

Other data

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)

Other data

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

TOS-related data

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…

List of ATD-2 reports

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*.