



Airspace Technology Demonstration 2 (ATD-2)

Turning SWIM Data into Consistent Reports for Analysts and Users

May 22, 2019



- ATD-2 systems **ingest huge** amounts of SWIM data
- They also **output huge** amounts of data, recording every aspect of the operation
- *This output data is very valuable, but is too verbose to be used effectively for some analysis use cases*
- To address this challenge, we have developed a variety of standardized reports to serve analyst and user needs



This output data presents several problems:

1. ***Scale***: this is big data for most analysts, and Postgres query engine not forgiving for inexpert query design, particularly when trying to conduct longitudinal analysis
2. ***Complexity***: DB design may seem complex to some analysts
3. ***“Noise”***: human inputs, complexities of data mediation, order of processing messages, changes from earlier versions of ATD-2 software, etc.
4. ***Business rules***: so many conventions for measurement

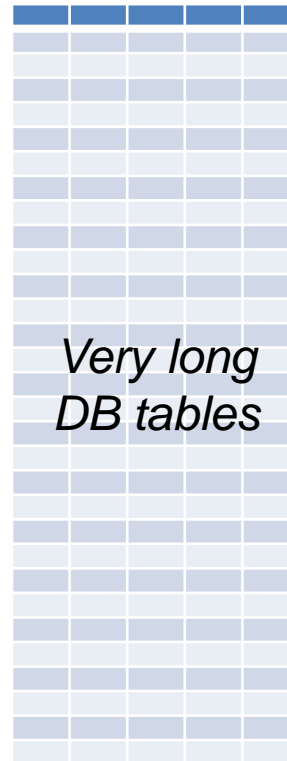
Create standardized reports to support analyst and user needs



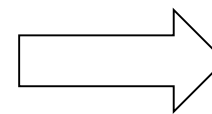
All reports possible because of consolidated view provided by fuser

- *flightSummary report*
 - Tabular report generated each day, one row per flight, *many* computed metrics
- *APREQ compliance report*
 - Subset of flightSummary, covering APREQ negotiation and compliance pushed to users each morning
- *Post-Metering report*
 - Subset of flightSummary, covering metering performance immediately after each bank at Charlotte
- *Daily Data Digest*
 - Summary of prior day's operation pushed to users and researchers each morning

- Fully compatible for all ATD-2 airports
- 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



*Very long
DB tables*



ABC123			
ABC456			
DEF789			
DEF567			

*One row
per flight*

...



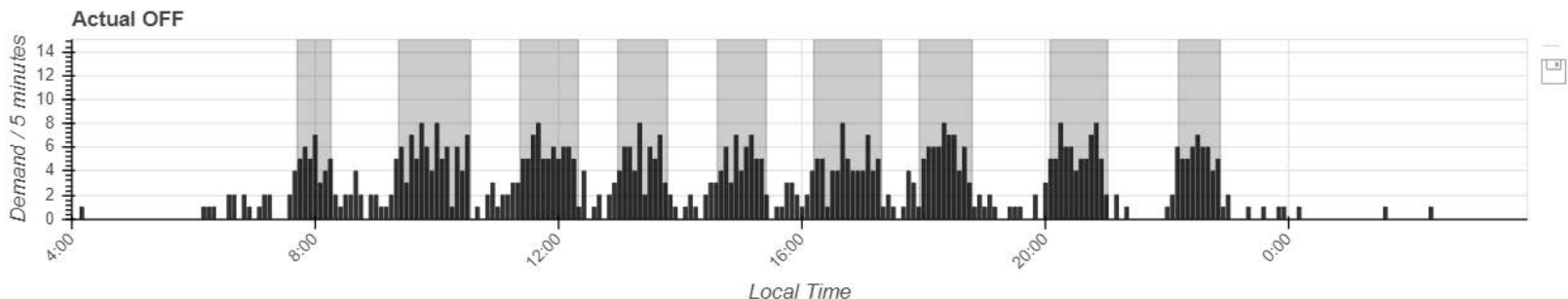
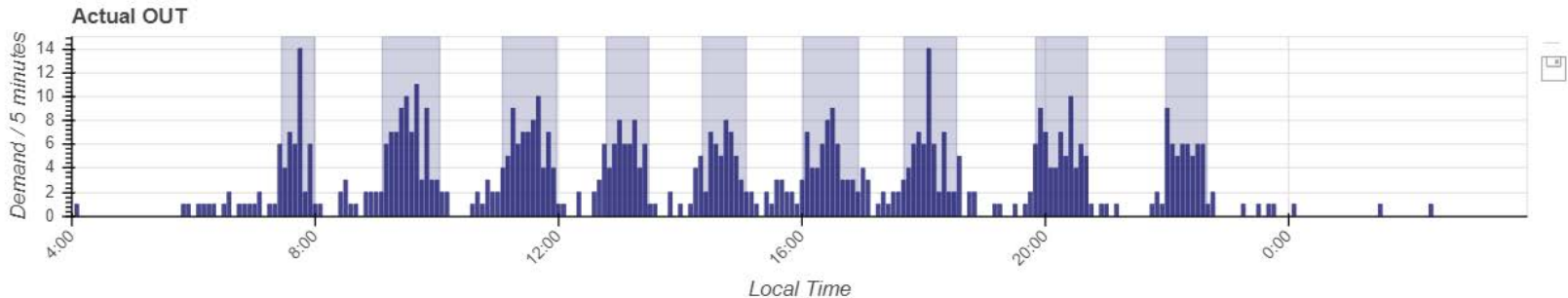
- “Basic” data
- Banks
- Clearances
- Flight “states”
- Surface metering
- Time/resource predictions at events
- EOBT, LTIME & associated accuracy
- EDCT, MIT, GS & Fix closures
- APREQ
- Undelayed/actual/excess taxi times
- AOBT by source
- Gate conflicts
- Airport configuration
- Predicted in times for departures
- AEFS
- First surveillance
- On-time performance



From final values for each flight, report:

- ACID, GUF1
- 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
- Mainline/regional indicator
- Last system providing data, last timestamp of data received
- Long on board, priority status, runway open indicators
- IOBT, Final PTIME

- Use clustering algorithm to infer banks from schedule and actual operations
 - Calculated for: scheduled in/out, actual on/off, actual out
 - Density-based clustering used, so some flights fall into no bank, representing lulls in traffic
- Also report operator-defined bank numbers, when available



- RTC records all ramp controller actions, report gets last time each clearance issued
 - Gate pushback hold, gate pushback approved, proceed to spot, hold, return to gate, “not set”, cleared to gate
- Indicator for “true” return to gate status
 - 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



- ATD-2 internal model maintains state of flight, based on available data and rules
 - 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*



- For departures, immediately before:
 - Pushback, spot crossing, queue entry, off, fix crossing
- Predict:
 - Gate, spot, runway, fix (for all “future” resources)
- Include data source for each resource prediction, e.g., STBO prediction, TBFM data
- For arrivals, immediately before:
 - Fix crossing, landing, spot crossing, in
- Predict:
 - Fix, runway, spot, gate (for all “future” resources)



- At same events that resource predictions are sampled, get many times (set 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, at pushback clearance
- 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

MIT & Fix closures:

- First/last time received
- Count of distinct restrictions

Ground stop:

- Indicator for data received

➤ *Area of active development to improve metrics*

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
- Time & fuel savings from rescheduling
- Actual & truncated compliance
- Prescheduling indicator, EOBT at prescheduling
- 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



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

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)



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

Downstream 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

- 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 future work, we believe that maintaining a common 360° view of each flight is extremely valuable.*