ATD-2
Integrated Arrival/Departure/Surface

NASA

Turning SWIM Data into Consistent Reports for Analysts and Users

May 22, 2019

Background

- 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 for analysts and users, but is too verbose to use effectively*

- To address this challenge, we have developed a variety of standardized reports to serve analyst and user needs

Analyst challenges in using data

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 is complex
3. *"Noise"*: human inputs, complexities of data mediation, order of processing messages, bugs in earlier versions of ATD-2 software, etc.
4. *Business rules*: so many conventions for measurement

Create standardized reports to support analyst and user needs

Sample of reporting artifacts

- *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

flightSummary report introduction

- Fully compatible for all ATD-2 airports
- Report generated on data warehouses each morning for prior “day” (0400-0400 local), requiring ~15 minutes to complete
- Application written in Python, runs ~50 SQL queries, joins results, and adds additional columns leveraging data between queries
  - Approach is generic: could be implemented in other languages, or in pure SQL

High-level sections of flightSummary

- "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

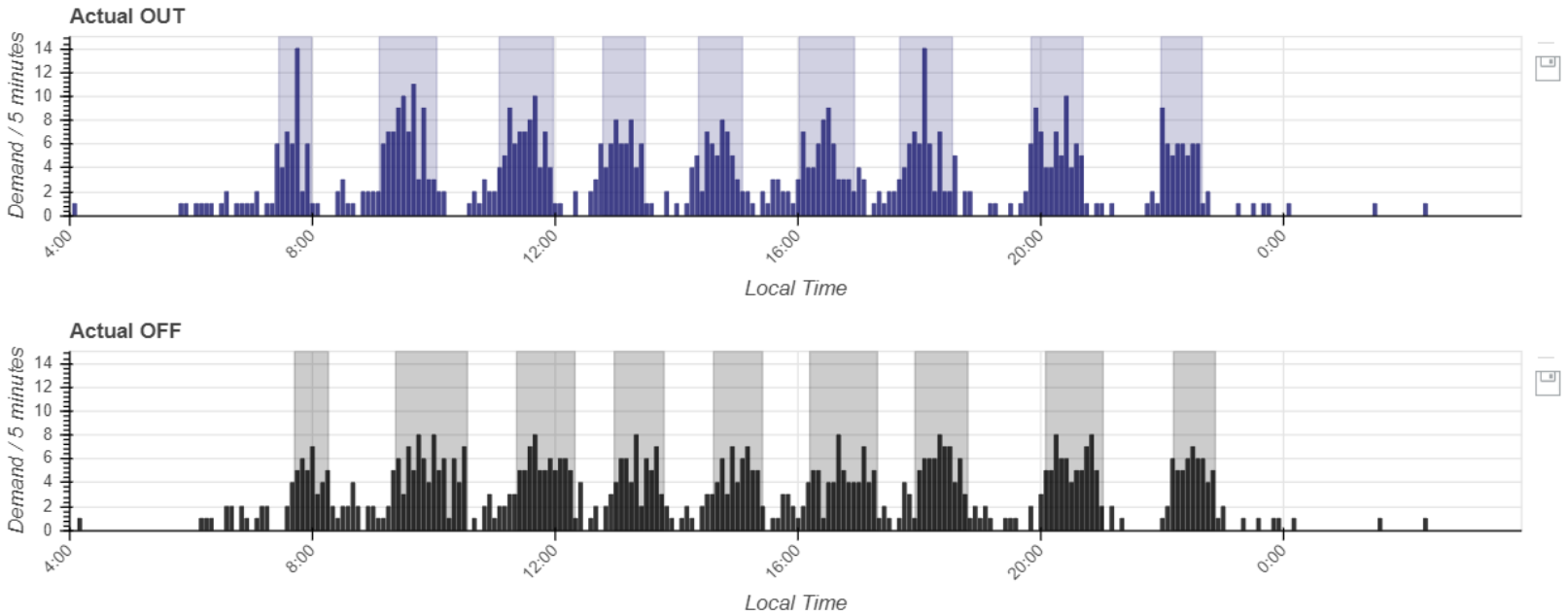
“Basic” descriptive data

From final values for each flight, report:

- ACID, GUFI
- Category, origin/destination
- Aircraft identifying info (type, wake, engine class, etc.)
- SOBT, SIBT
- AOBT, AMAT, 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 opnec indicators
- IOBT, Final PTIME

Bank data

- 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



Clearances

- 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

Flight states

- 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)

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

- For arrivals, immediately before:
  - Fix crossing, landing, spot crossing, in
- Predict:
  - Fix, runway, spot, gate (for all “future” resources)

- Include data source for each resource prediction, e.g., STBO prediction, TBFM data

Time values & predictions at events

- 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

EOBT / LTIME data

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

TMI impacts

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*

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
- 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

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

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

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

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)

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

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
- Development has also helped highlight some bugs in the system that were not otherwise apparent
- Approach is generic, but can be adapted as appropriate

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