From Takeoff to Machine Learning

On how aircraft flight data is recorded, protected and how to make it actionable for machine learning.

Florian Schwaiger (f.schwaiger@tum.de)

Research Assistant and PhD Candidate

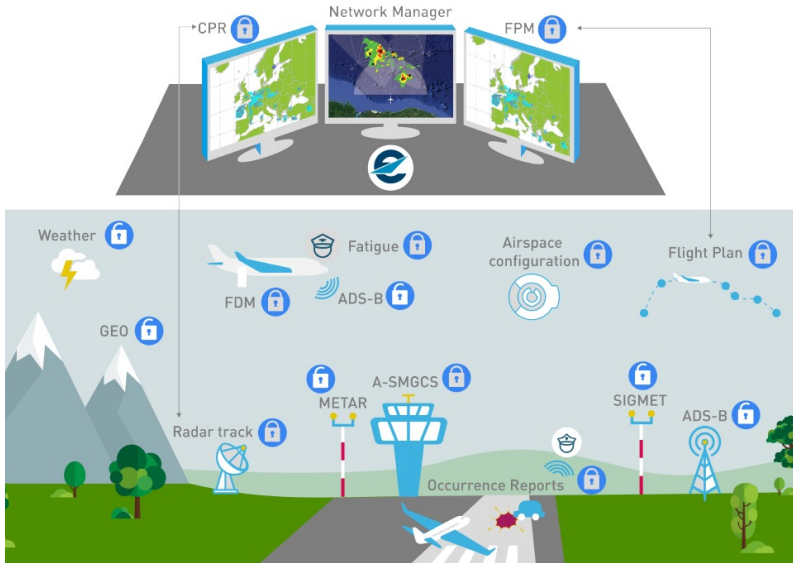
FSD Operational Safety Working Group Involvement

SafeClouds.eu

(until 2019)

Safety Analysis on Merged Data:

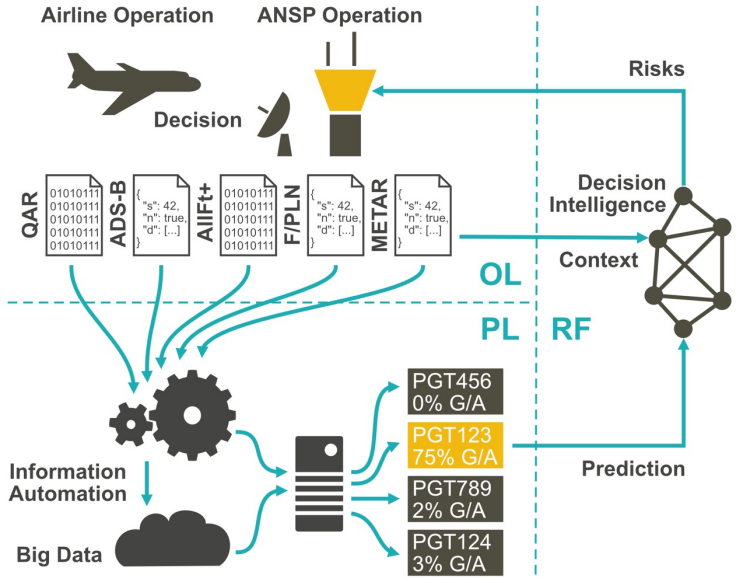
- FDM Dataset Preparation
- Analysis Tools for UA and CFIT



SafeOPS

From Prediction to Decision:

- Unstable Approach Prediction
- Decision Support for ANSP

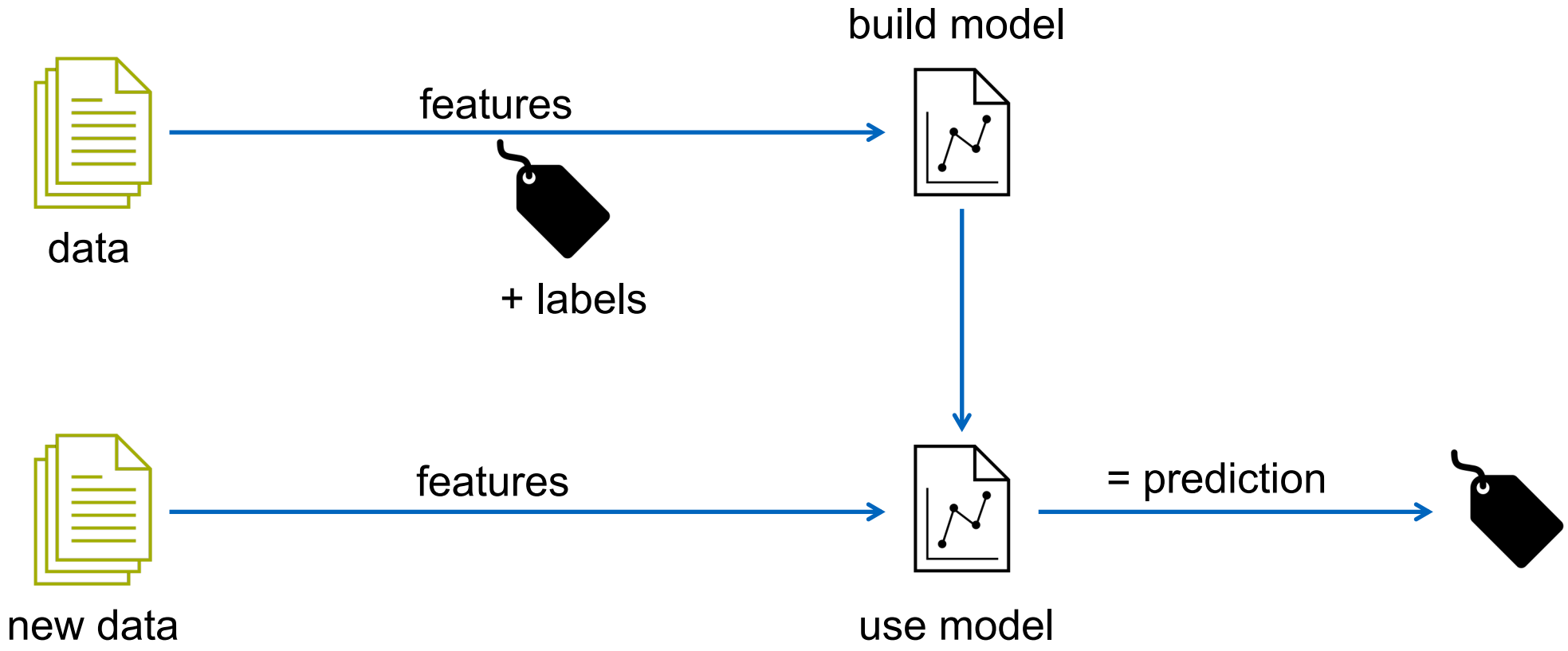


CopFly

Advanced Multivariate Statistics:

- Mathematical Statistics
  - Copula / Vine Copulas
  - Copula State Space Models
- Flight Safety Applications
  - Predictive Analysis
  - Data Reconstruction

Machine Learning needs data, but where does it come from?



Quick Access Recorder

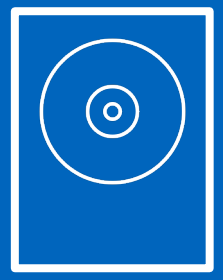
file format: **ARINC717**, ARINC767, SAR

100 – 1000 parameters

avionics, cabin, engines, HMI, FMS, ...

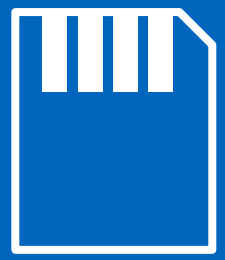
1/64 Hz – 16 Hz varying sampling rates

data about **performance of aircraft and pilots**



on HDD

on optical disc



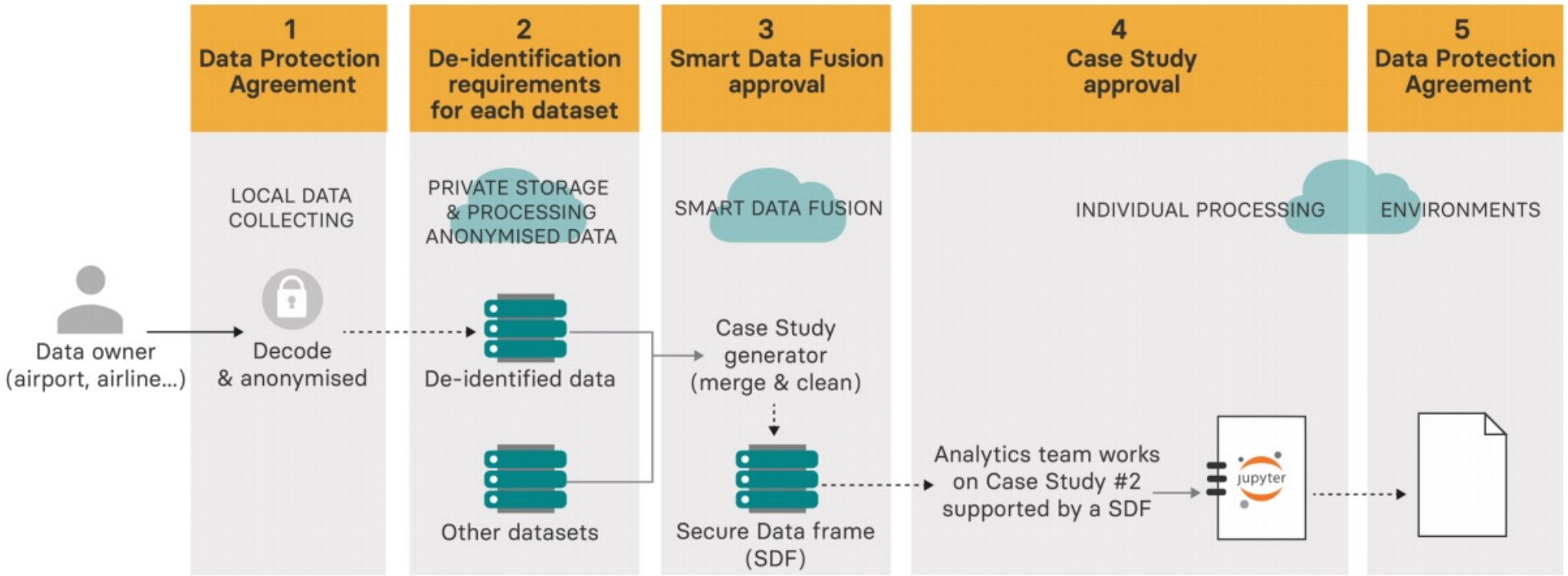
on SD card

wireless upload

Quick insight: the data protection agreements from SafeClouds.eu (2019)

SafeClouds.eu

DataBeacon



source: Innaxis

Decoding ARINC717 binary data needs a dataframe

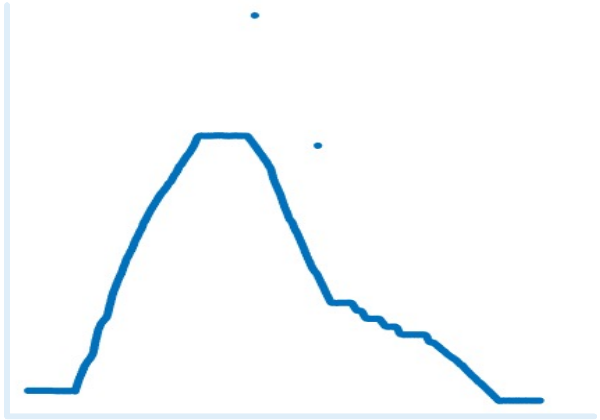
DATAFRAME FOR A/C 1234

F. Schwaiger and F. Holzapfel, "Fast Decoding of ARINC 717 Flight Data Recordings," in *AIAA Scitech 2021 Forum*, 2021.

Iron out the differences between aircraft and recorder vendors

Aircraft 1, Airline A		Aircraft 2, Airline A		Aircraft 2, Airline B	
GPS_POS_LAT	ILS1	GPS_POS_LAT	ILS1	PRES_POS_LAT	VOR1
GPS_POS_LON	ILS2	GPS_POS_LON	ILS2	PRES_POS_LON	VOR2
ALT_STD	GEAR_DL_NS	ALT_STD	GEAR_DL_NS	H_BARO	NS_GEAR_UP
ALT_BARO	SPLR_L	ALT_BARO	SPLR_L	BARO_CPT	SPLR_1
ENG_N11	SPLR_R	ENG_N11	SPLR_R	ENG_N1_L	SPLR_7
ENG_N12	FLAP_LEVER	ENG_N12	FLAPL	ENG_N1_R	FLAP_1
ENG_N13					FLAP_2
ENG_N14					

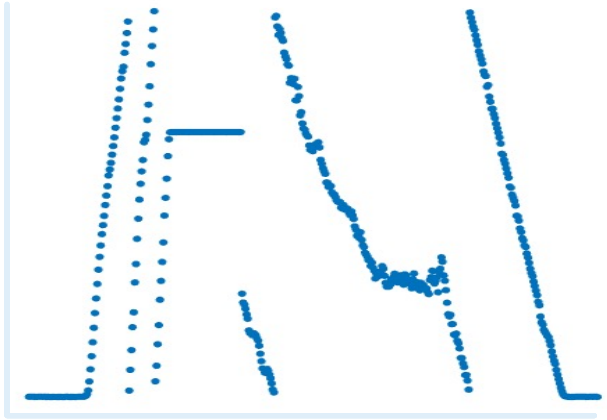
Data has many errors – our goal is to repair as much as possible



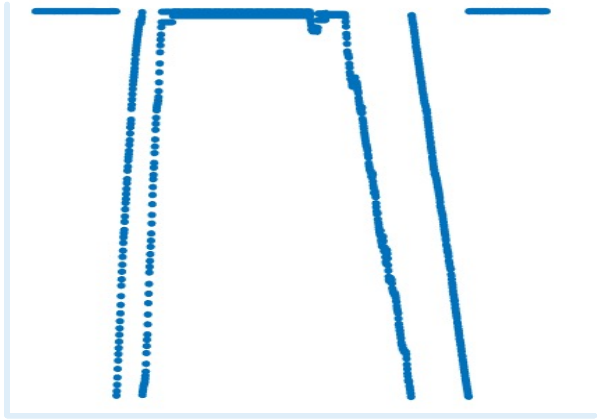
outliers

partially defined

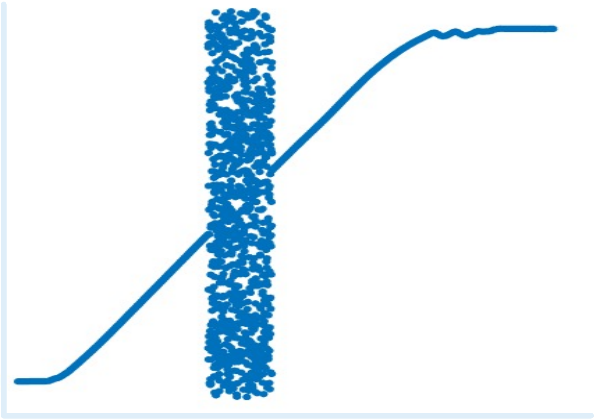
missing



wrapped around



missing sign bit



partially corrupt

Some more examples what to expect from QAR data

- missing letters in destination airport ICAO code from FMS Screen

```
[ _____,                EDDM,                EDD_ ]
```

- air / ground switches wrong

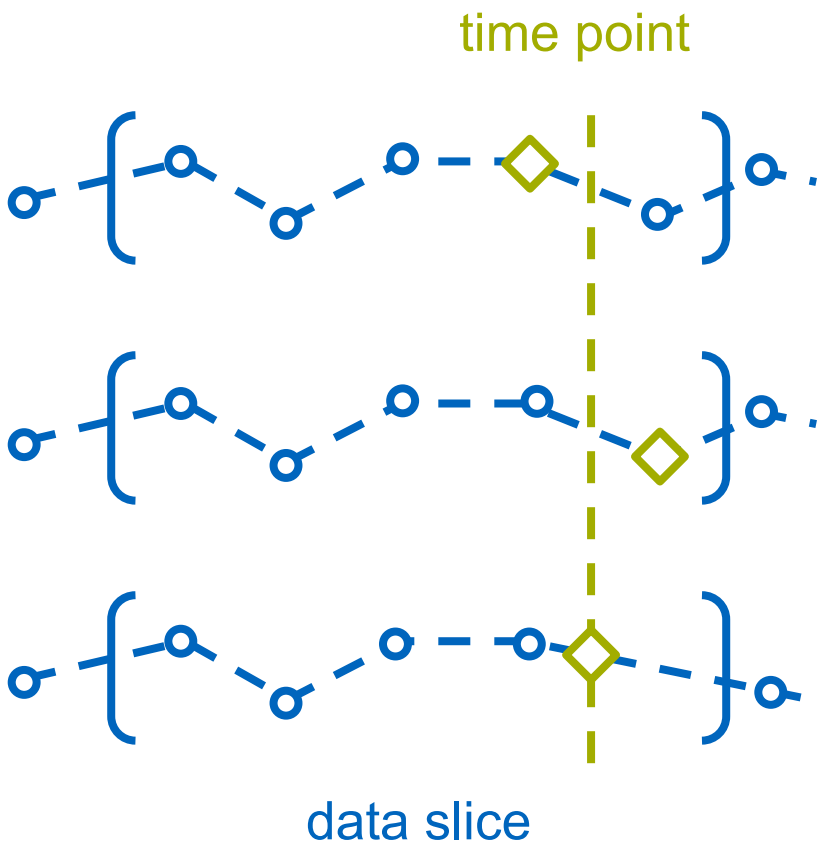
```
[ AIR,          GND,          GND,          GND ]
```

- negative radio altitudes

```
[ -1,  -3,  10,  500,  4096,  700, 400,  10,  -5 ]
```

How to measure signals at time points?

ARINC717: data points can be up to 64 seconds apart, or more if points are missing

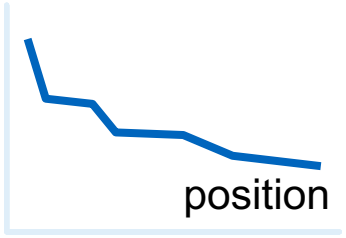


previous — good performance, but might be too early

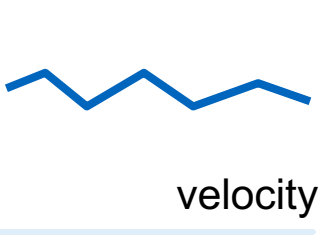
next — same, but might be too late

linear — slower, and what if points are outside the slice?

Full trajectory reconstruction for touchdown / landing measurements



position

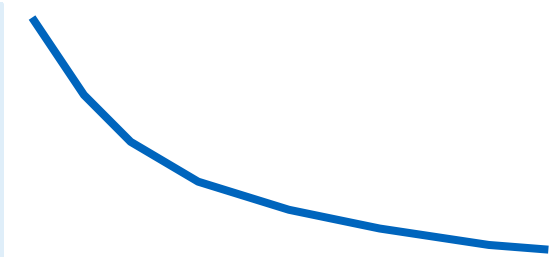


velocity

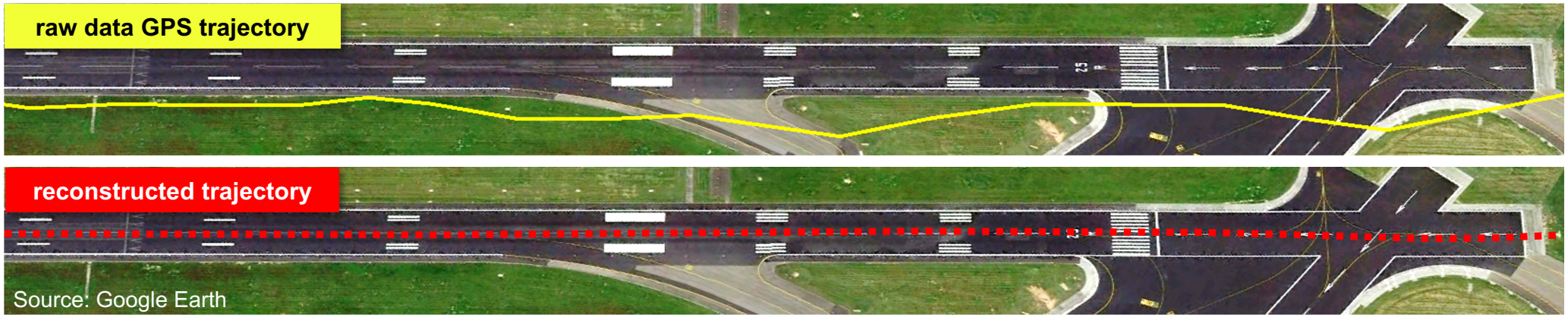
acceleration

ILS deviation

Rauch-Tung-Striebel smoother with 6-DOF aircraft model

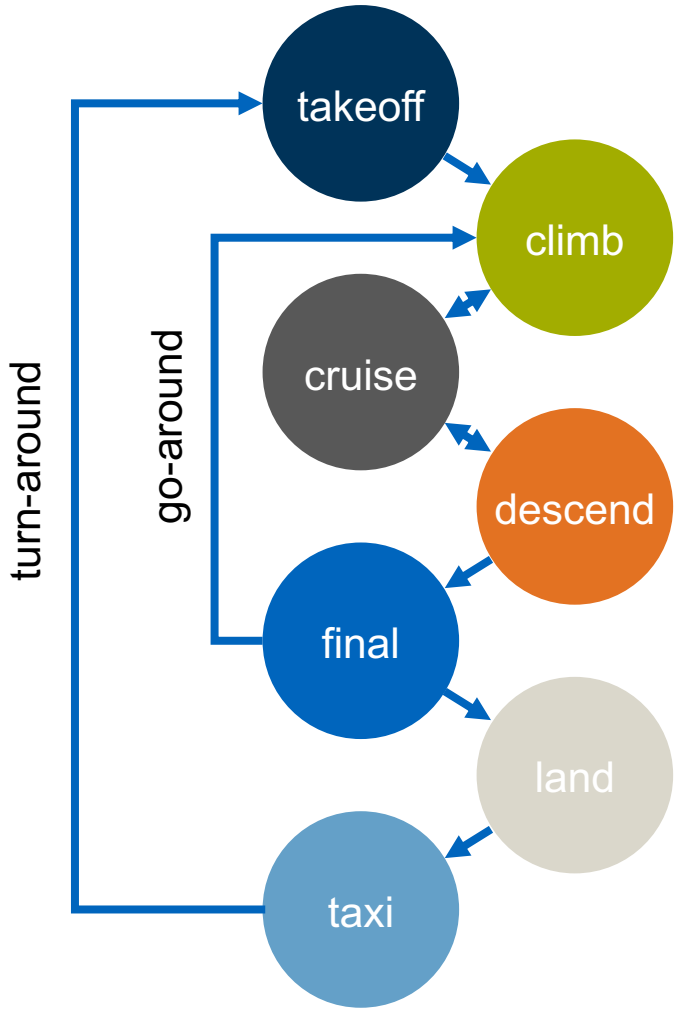


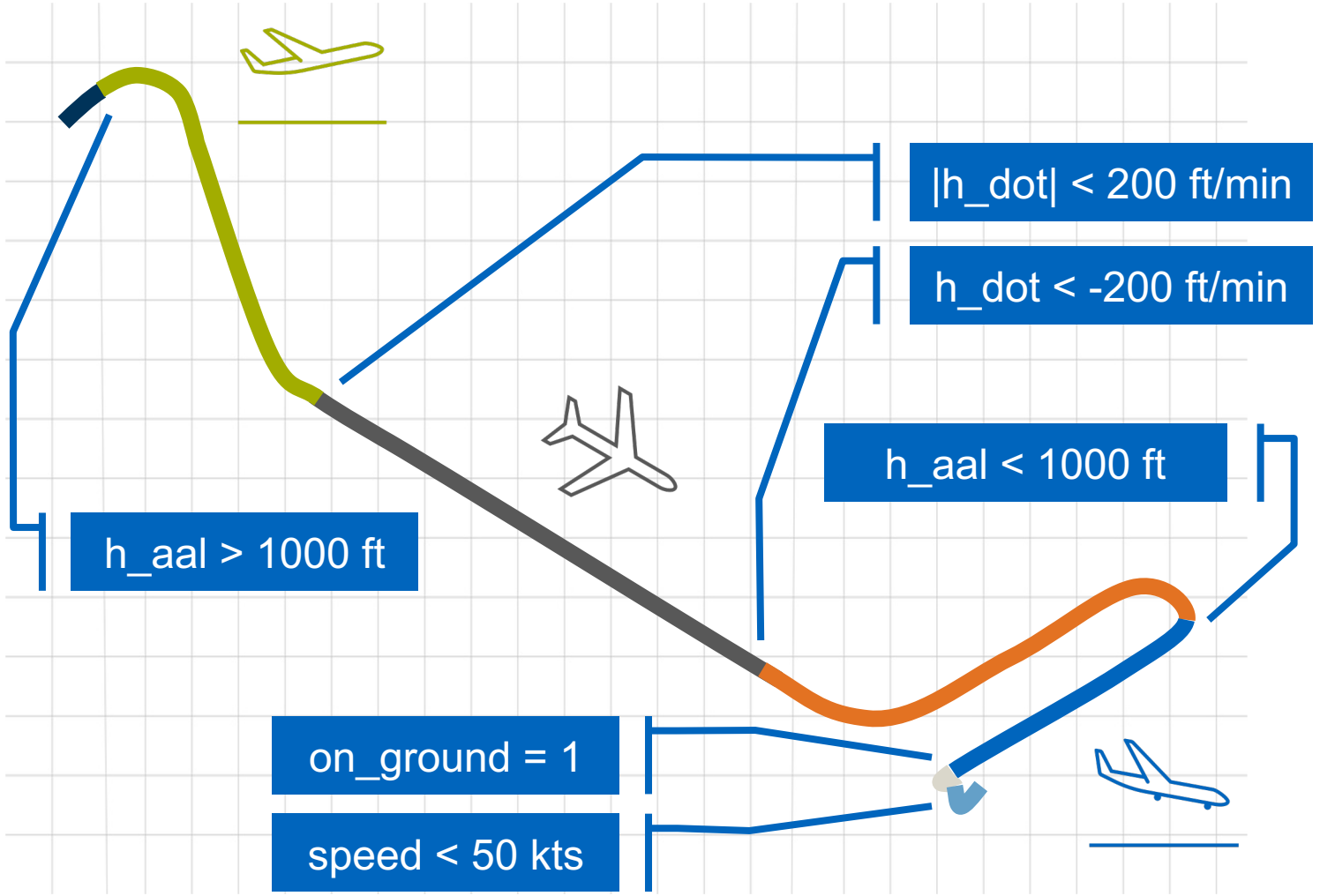
combined state



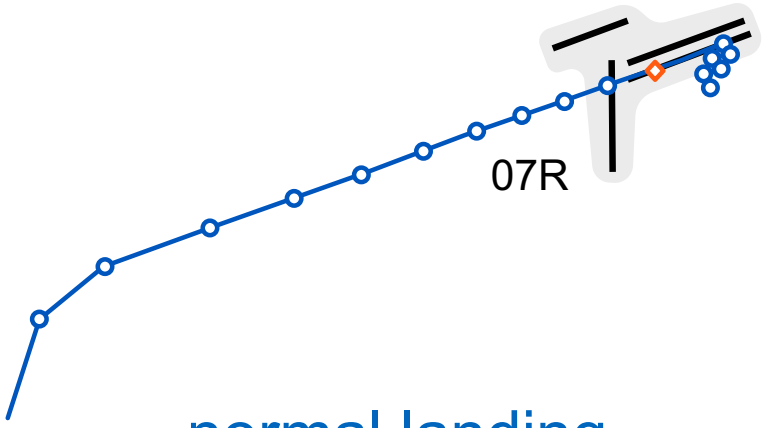
L. Höhndorf, J. Siegel, J. Sembiring, P. Koppitz, and F. Holzapfel, "Reconstruction of Aircraft Trajectories during Landing using a Rauch-Tung-Striebel Smoother, Instrument Landing System Deviation Information, and Taxiway Locations," in *AIAA Atmospheric Flight Mechanics Conference*, Washington, D.C, 2016.

Detect flight phases and events with a state machine

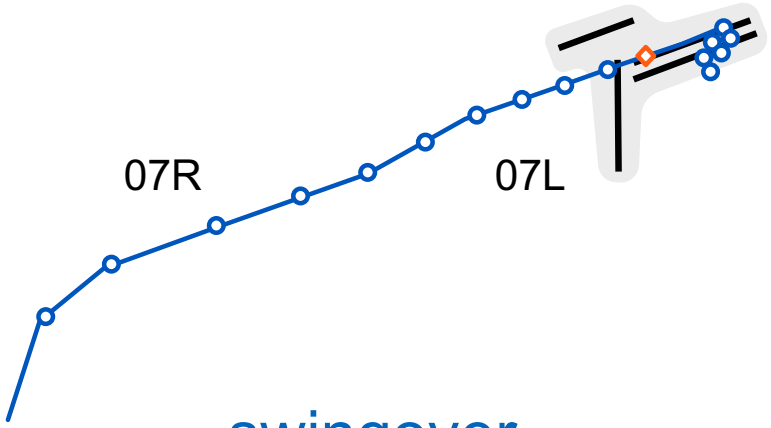




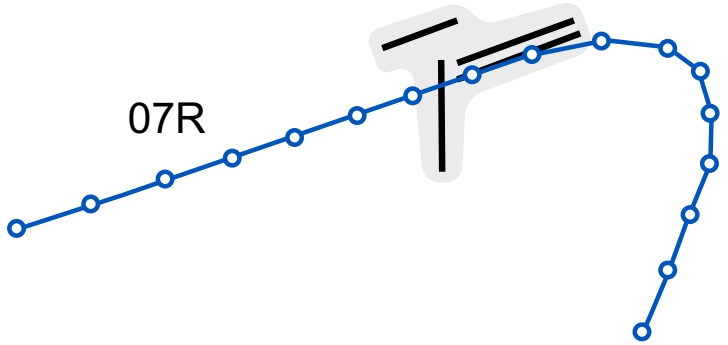
Detect the runway the aircraft lands on – easy in theory only



normal landing

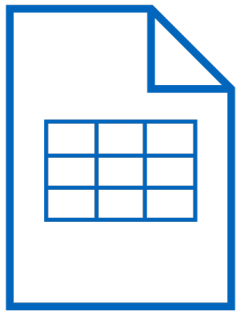


swingover

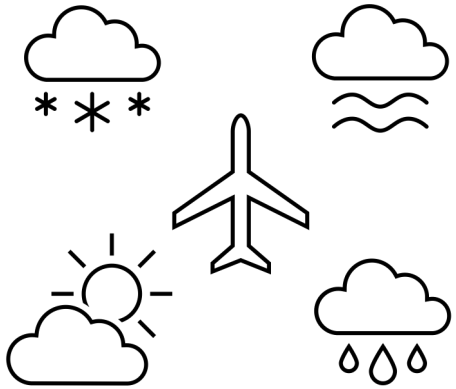


go-around

Merge spatio-temporal weather data with deidentified flights



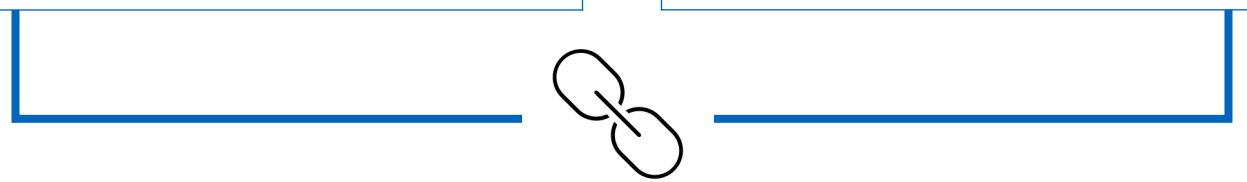
QAR



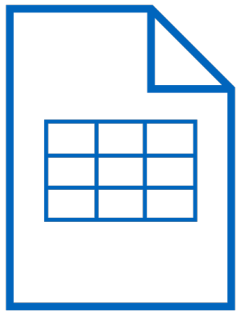
METAR

#	DATE	TIME	AIRPORT	CALLSIGN	…
1000	7s53jw9s	10:20:42	EDDM	a8a5as1g	…
1016	7s53jw9s	10:20:43	EDDM	a8a5as1g	…
1032	7s53jw9s	10:20:44	EDDM	a8a5as1g	…
1048	7s53jw9s	10:20:45	EDDM	a8a5as1g	…
…	…	…	…	…	…

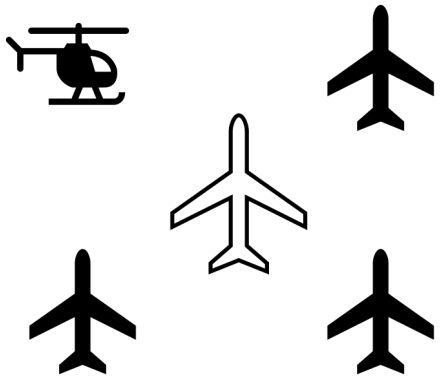
#	DATE	TIME	AIRPORT	REPORT
42	7s53jw9s	10:00	EDDM	11010KT …
43	7s53jw9s	10:15	EDDM	14007KT …
44	w9wc8cs	10:00	EDDM	12008KT …
45	w9wc8cs	10:15	EDDM	12006KT …
…	…	…	…	…



Fusing traffic context from ADS-B is also possible, but hard



QAR

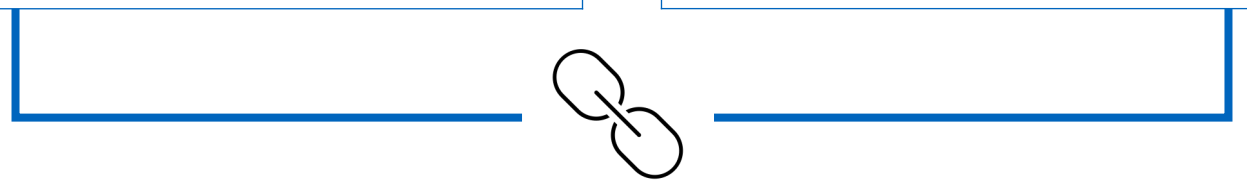


this table is HUGE!

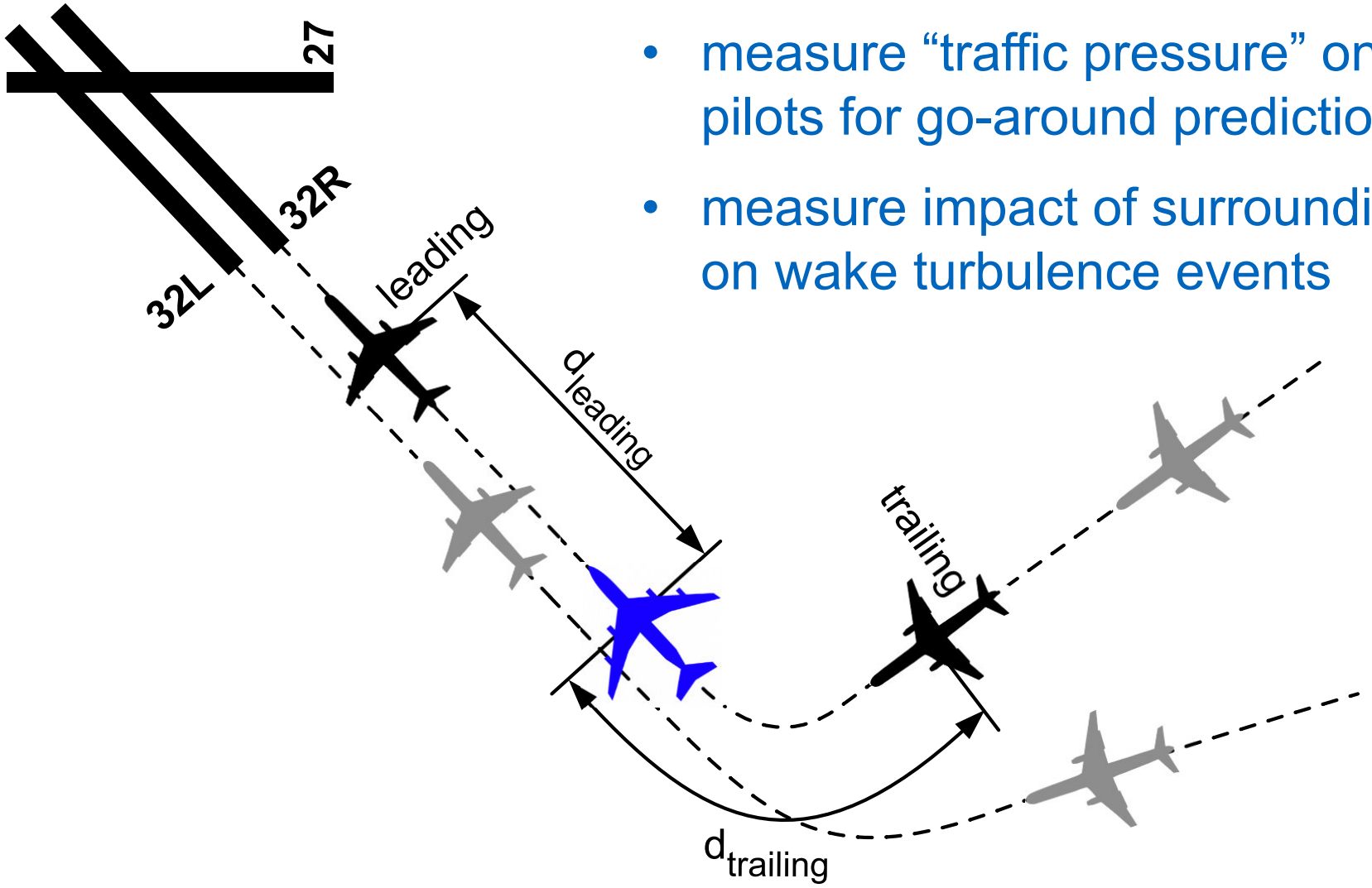
ADS-B

#	DATE	TIME	AIRPORT	CALLSIGN	…
1000	7s53jw9s	10:20:42	EDDM	a8a5as1g	…
1016	7s53jw9s	10:20:43	EDDM	a8a5as1g	…
1032	7s53jw9s	10:20:44	EDDM	a8a5as1g	…
1048	7s53jw9s	10:20:45	EDDM	a8a5as1g	…
…	…	…	…	…	…

#	DATE	TIME	CALLSIGN	TRAIL
551	7s53jw9s	10:20	us5sjow7	…
552	7s53jw9s	10:20	a8a5as1g	…
553	7s53jw9s	10:20	65si2osjd	…
554	7s53jw9s	10:20	s633nsd7	…
…	…	…	…	…

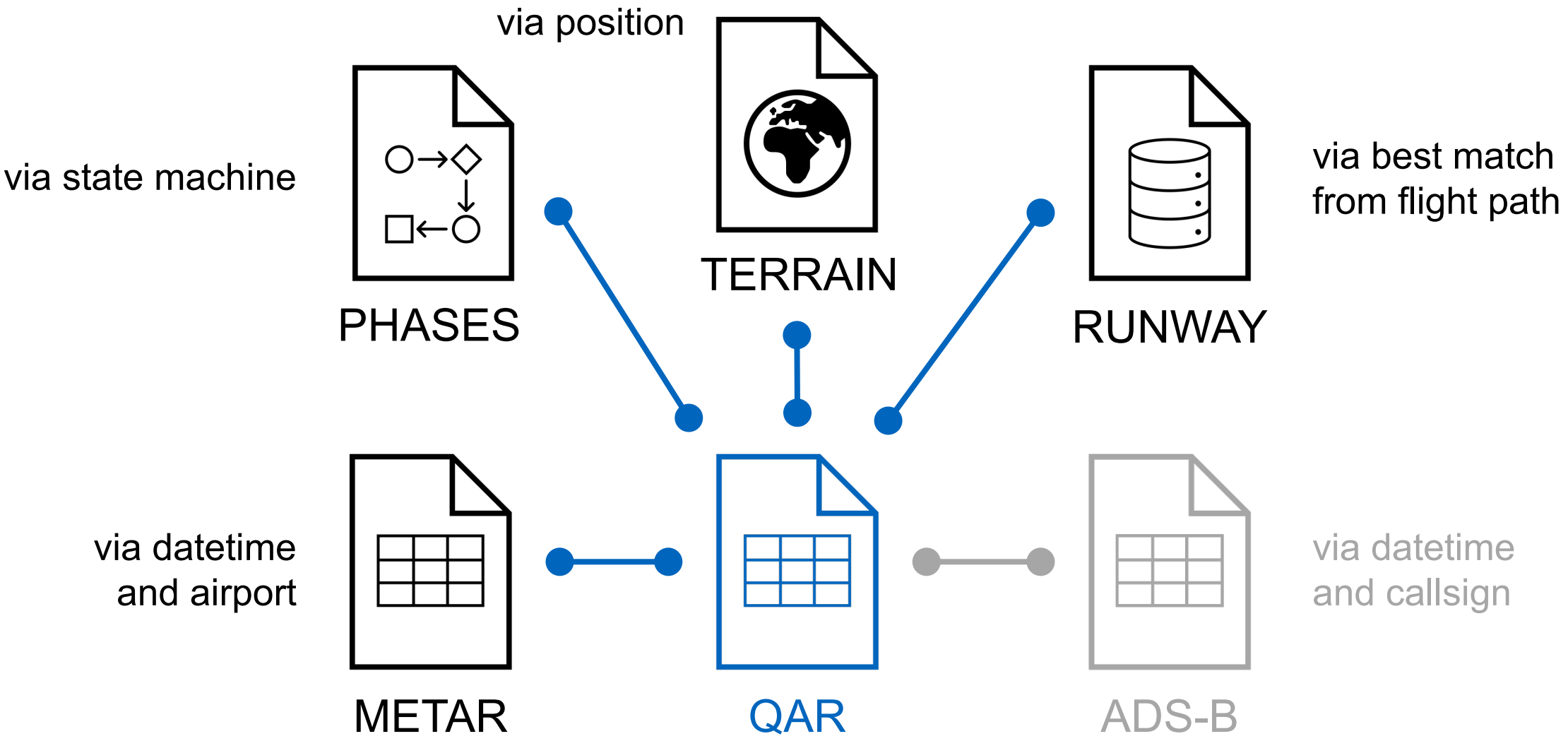


Example feature from combining ADS-B with QAR



- measure “traffic pressure” on pilots for go-around prediction
- measure impact of surrounding A/C on wake turbulence events

Possible joins between the flight (QAR) and other datasets



Possible Applications for QAR Data

Unstable Approach

https://www.flickr.com/photos/27609180@N00

Aircraft Performance

https://www.flickr.com/photos/curimedia/5567789129/

Predictive Maintenance

Possible Applications for QAR Data

Runway Overrun

https://en.wikipedia.org/wiki/Runway_excursion#/media/File:Southwest_Airlines_Flight_1248_-1.jpg

Ground Contact

https://commons.wikimedia.org/wiki/File:Thomas_Cook_Airbus_A321-231(WL)_D-AZAF_(16381103593).jpg

Ground Proximity

https://commons.wikimedia.org/wiki/File:Airport_Approach_Madeira_2015.jpg

Thank you for listening!
I'll see you in the Q&A
And a special thanks to my colleagues
for assisting me with this talk.
Find us on https://www.fsd.lrg.tum.de/team
Photo: Andreas Heddergott