ACME Flying Use Case

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Contents

- Domain characteristics
- Data sources
- Analytical software

Domain characteristics

Company characteristics

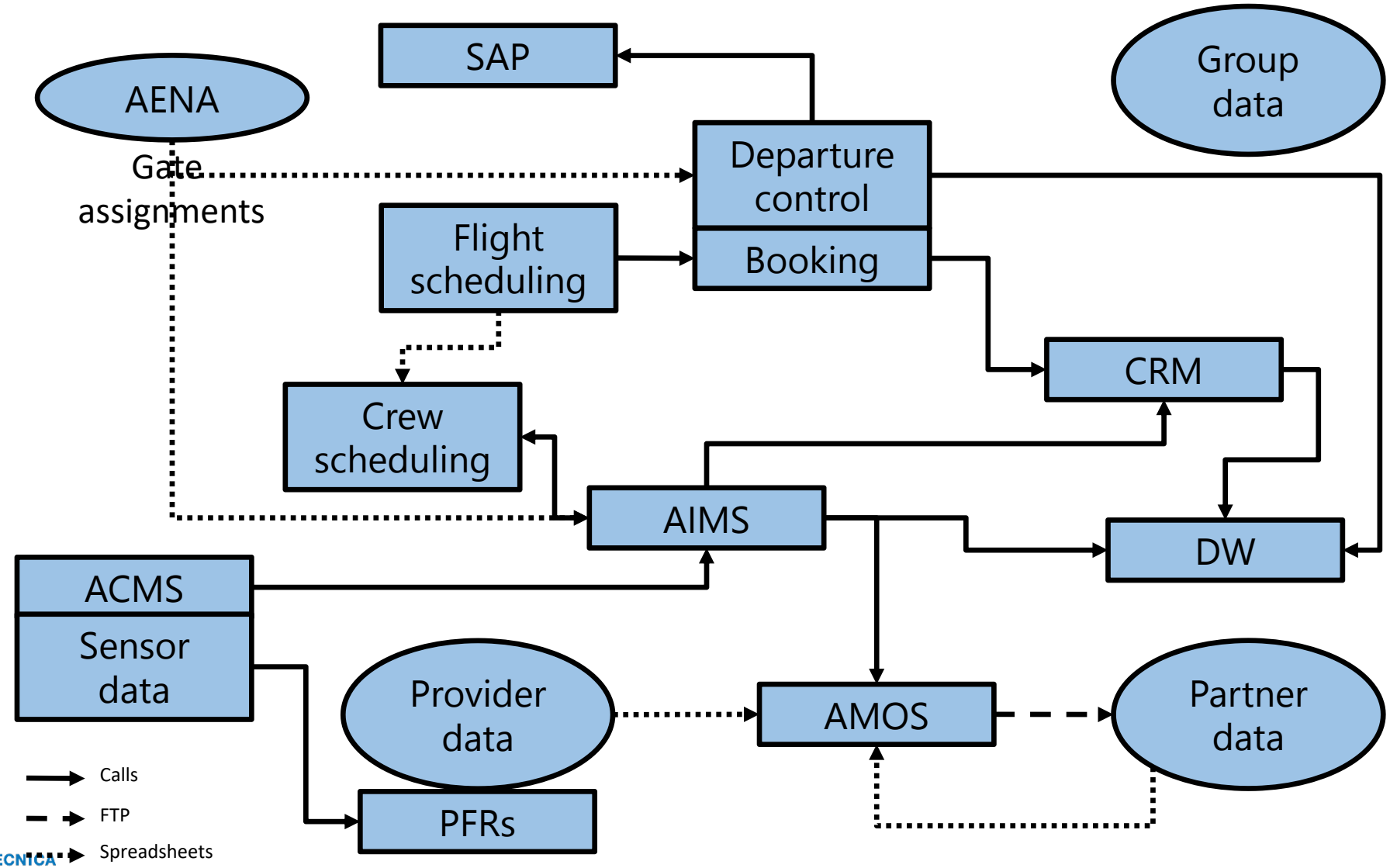
- Planes: 125
- Destinations: 120
- Flights:
  - Per day: ~700
  - Per year: ~300.000
- Post-Flight Report events
  - Per year: ~1.000.000
- Maintenance events:
  - Per year: ~13.000
    - ~10.000 Delays (non-programmed short)
    - ~2.400 Aircraft On Ground (non-programmed long)
    - ~350 Maintenance (programmed short)
    - ~100 Revision (programmed long)

Difficulties of the analysis

- Each plane is unique
  - Hard to train because of lack of data
- Heterogeneous information
  - Different sources
  - Different data types
    - Binary, numeric, photographs, video

Data sources

Systems diagram



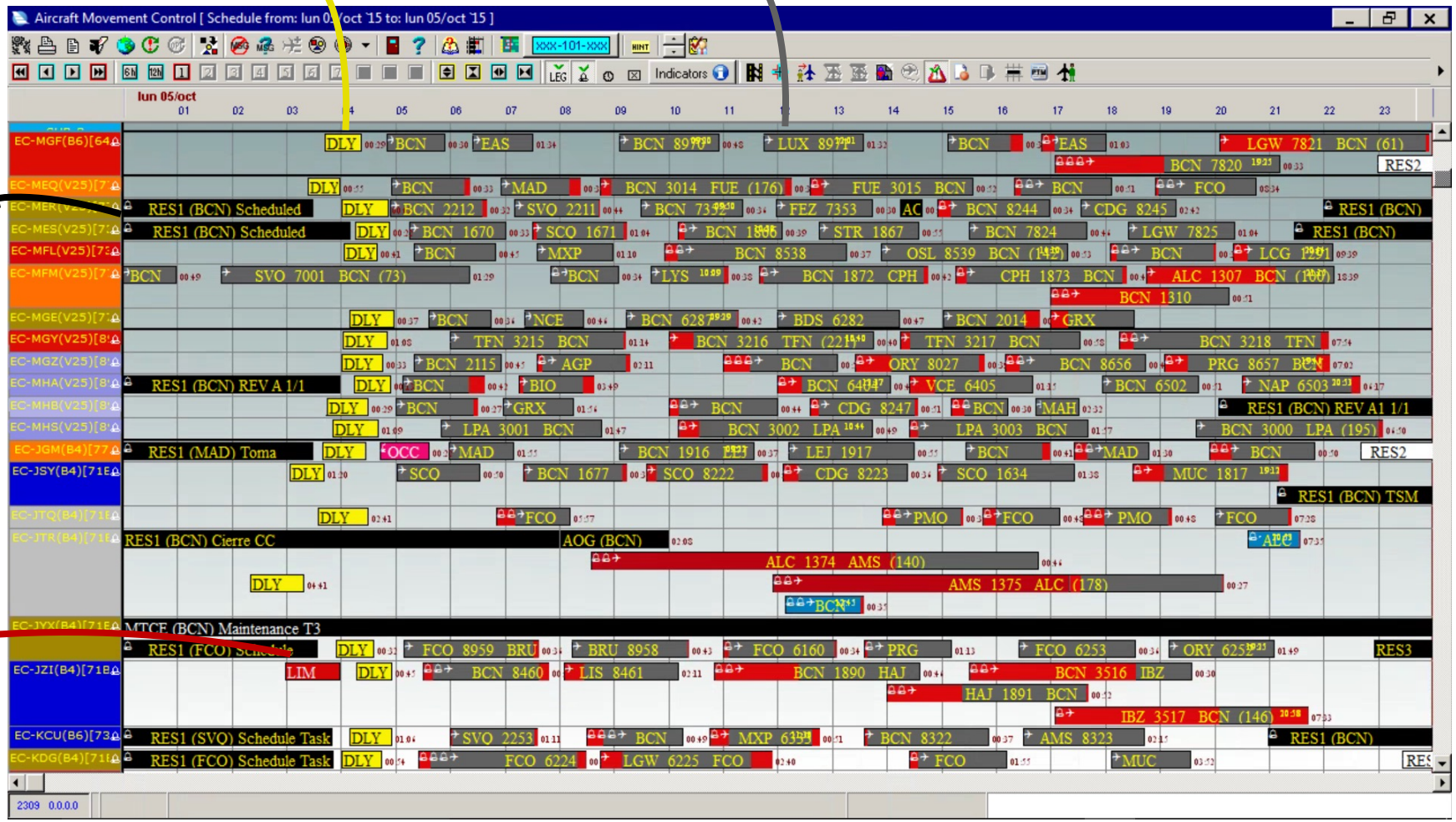
Air Information Management System (I)

Daily check

Flight

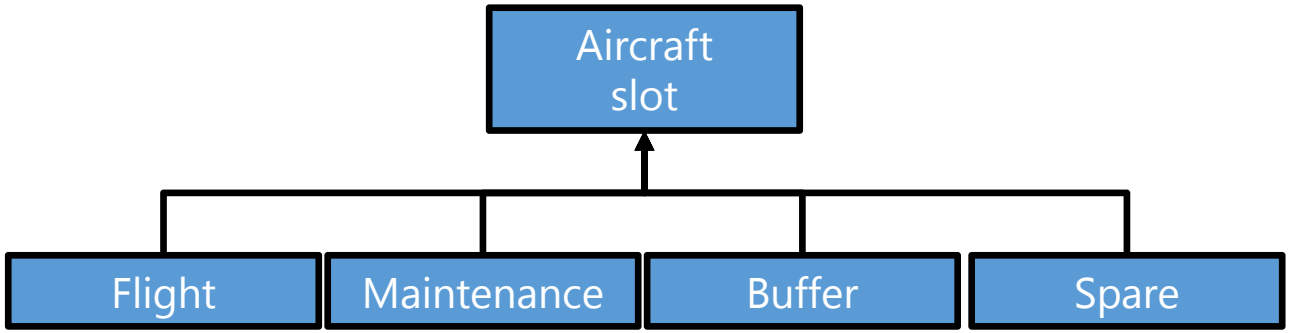
Maintenance

Delay



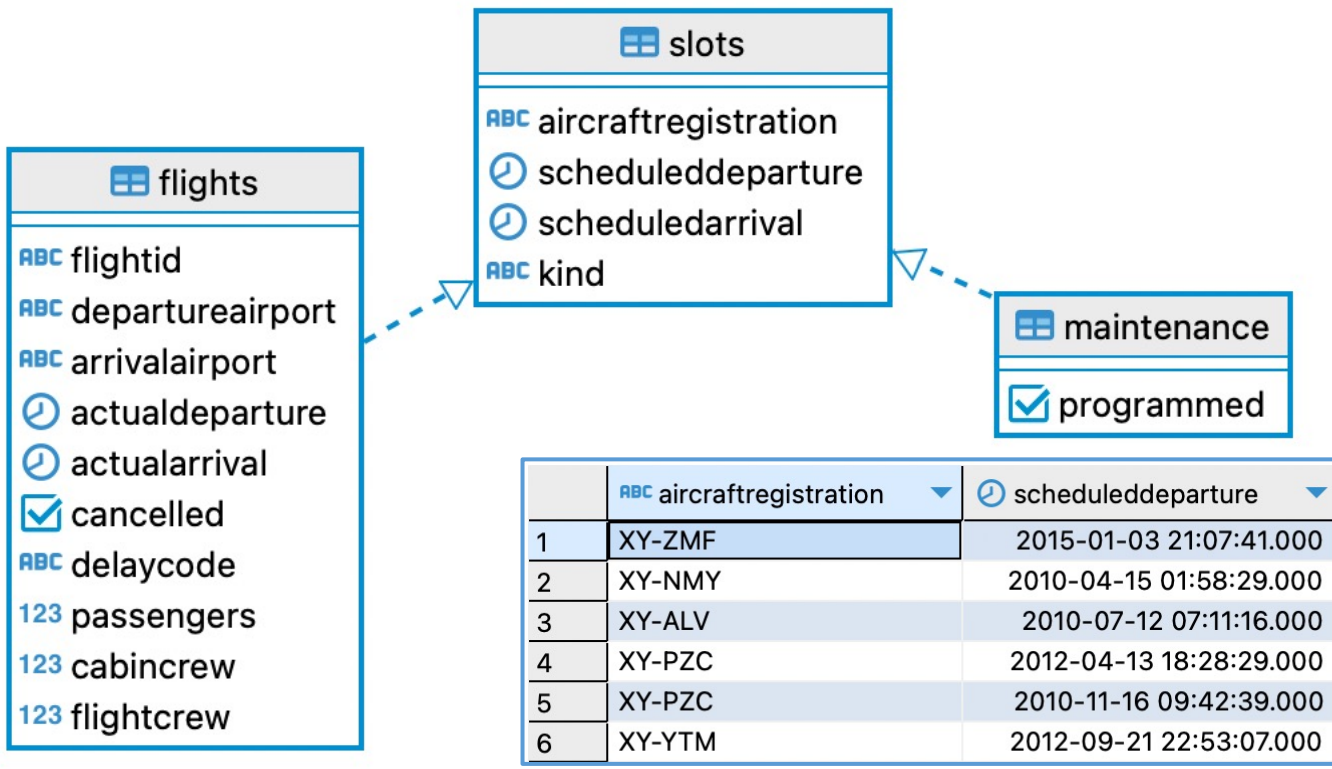
Air Information Management System (II)

- Aircraft slot
  - Aircraft Registration
  - Slot Start (Scheduled Time Departure)
  - Slot End (Scheduled Time Arrival)
- Flights
  - FlightID
    - Date-Origin-Destination-FlightNumber-AircraftRegistration
  - Arrival Airport
  - Departure Airport
  - Departure Time (actual)
    - Comes directly from ACMS
  - Arrival Time (actual)
    - Comes directly from ACMS
  - Cancelled(Boolean)
  - Delay code (defined by IATA)
  - Passengers
  - CabinCrew
  - FlightCrew
- Maintenance
  - Programmed (bool)
- Buffer (likely use)
- Spare/backup (unlikely use)



AIMS

	aircraftregistration	scheduleddeparture	scheduledarrival	kind
1	XY-IOO	2016-07-23 10:52:11.000	2016-07-23 12:21:17.385	Flight
2	XY-IOO	2014-08-18 20:13:06.000	2014-08-18 22:49:12.312	Flight
3	XY-YAZ	2014-08-20 02:26:32.000	2014-08-20 06:05:44.020	Flight
4	XY-ZWJ	2014-02-01 14:56:20.000	2014-02-01 15:59:19.852	Flight

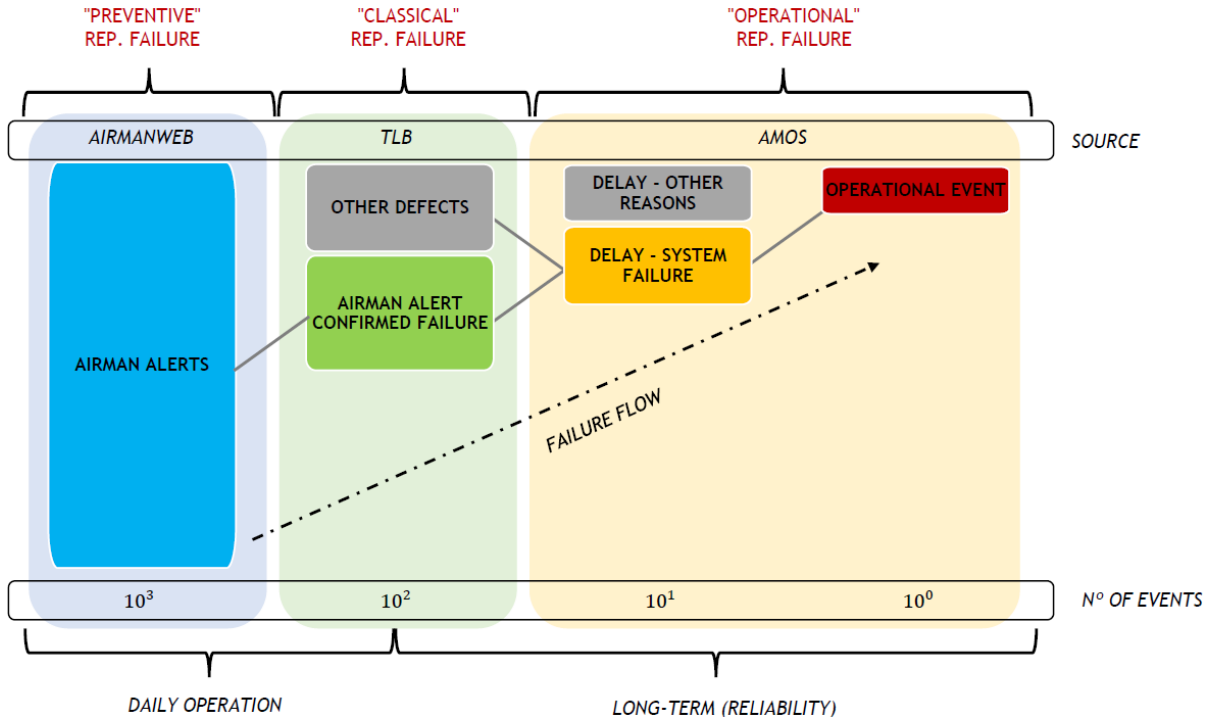


	aircraftregistration	scheduleddeparture	scheduledarrival	kind	programmed
1	XY-ZMF	2015-01-03 21:07:41.000	2015-01-21 22:10:41.000	Maintenance	[ ]
2	XY-NMY	2010-04-15 01:58:29.000	2010-05-12 04:00:29.000	Maintenance	[ ]
3	XY-ALV	2010-07-12 07:11:16.000	2010-08-02 03:13:16.000	Maintenance	[ ]
4	XY-PZC	2012-04-13 18:28:29.000	2012-04-22 02:28:29.000	Maintenance	[ ]
5	XY-PZC	2010-11-16 09:42:39.000	2010-11-26 13:42:39.000	Maintenance	[v]
6	XY-YTM	2012-09-21 22:53:07.000	2012-10-11 07:57:07.000	Maintenance	[v]

	aircra	scheduledde	scheduleda	kind	flightid	depart	arriv	actualde	actuala	car	dela	pass	cabi	flight
1	XY-IOO	-07-23 10:52:11.000	7-23 12:21:17.385	Flight	230716-NYO-VAA-	NYO	VAA	:3 11:29:37.881	3 12:44:53.14	[ ]	[NULL]	157	4	3
2	XY-IOO	08-18 20:13:06.000	3-18 22:49:12.312	Flight	180814-MAD-LED-	MAD	LED	8 20:21:10.642	3 23:26:01.89	[ ]	[NULL]	130	4	2
3	XY-YAZ	)8-20 02:26:32.000	-20 06:05:44.020	Flight	200814-ODS-PRN-	ODS	PRN	0 03:12:29.512	) 06:45:46.98	[ ]	[NULL]	157	3	3
4	XY-ZWJ	02-01 14:56:20.000	2-01 15:59:19.852	Flight	010214-LGW-KSC-	LGW	KSC	I 15:04:02.848	1 16:36:50.45	[ ]	[NULL]	151	3	3

Maintenance flow

Sensors → Post Flight Report → Technical LogBook → Work Order



Sensors (provided by Teledyne)

- Aircraft Condition Monitoring System
  - Technology: Radio frequency (ACARS)
  - Number of sensors per plane: 400
  - Usage: Critical messages (e.g., touch-down)
  - Sampling Frequency: 1-3 times per flight
- DAR
  - Technology: 3G/SSD
  - Number of sensors per plane: 400 (same as above)
  - Usage: Non-critical messages (e.g., valve pressure)
  - Sampling Frequency: sub-second
- FOMAX
  - Technology: 4G
  - Number of sensors per plane: 24.000
  - Usage: Monitoring of aircraft subsystems
  - Sampling Frequency: sub-second
    - Size: 10GB per flight-hour (i.e., Petabytes per year)

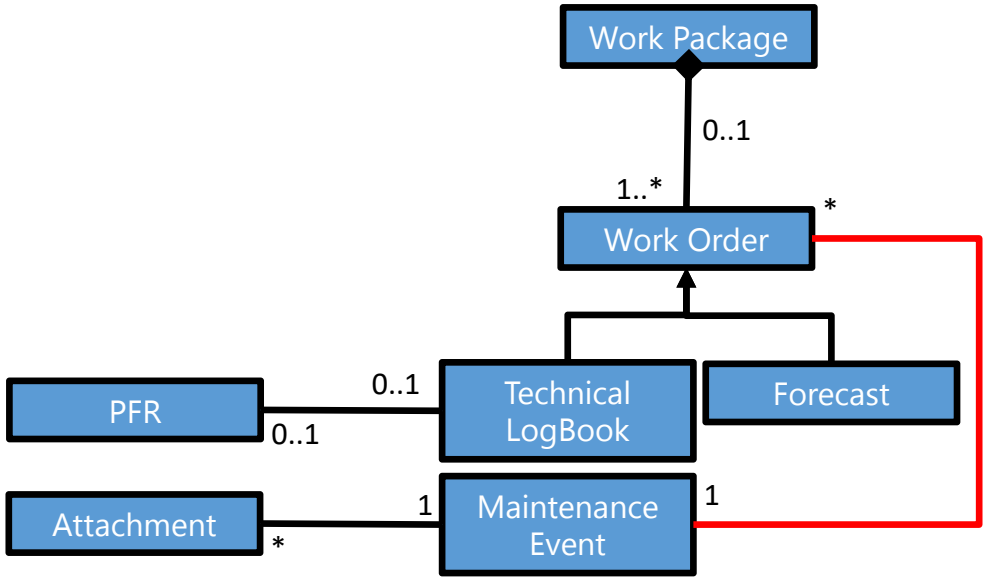
Post-Flight Report

- Sensor Events
  - Manufacturer Serial Number
  - Timestamp
  - Sensor
  - Value

- Post-Flight Events
  - Aircraft Registration
  - Timestamp
  - Aircraft Subsystem ID (ATA code)
  - Kind of event (fault/warning)
  - Standard Message

Aircraft Maintenance Operation System (I)

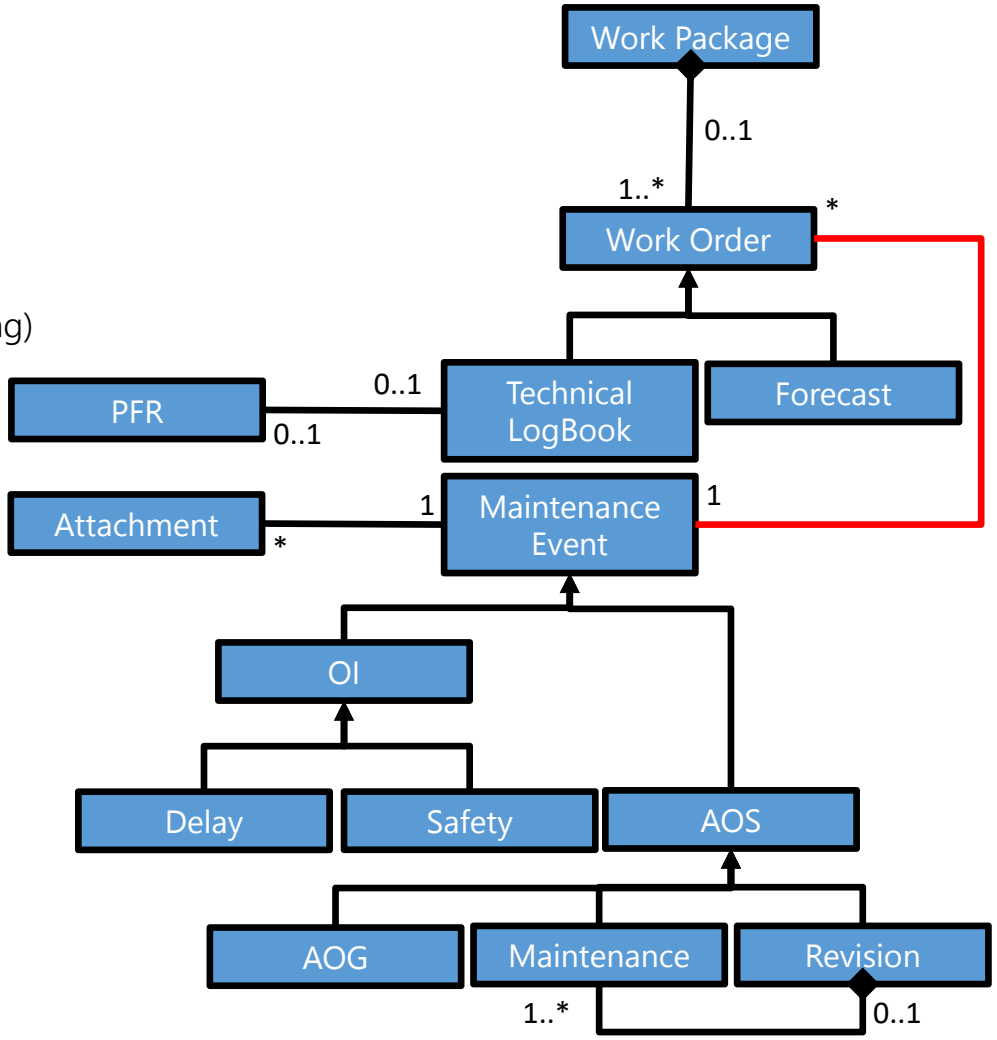
- Work Orders
  - Work Order ID
  - Aircraft Registration
  - Execution date
  - Execution place
  - Subclasses (flagbased)
- Forecasted Orders (scheduled)
  - Deadline date
  - Planned date
  - Frequency (per #flights, per #days, #Miles)
  - AircraftSubsystemID (ATA)
  - ManHours forecasted
- TLB Orders (unscheduled) (correspond to faults in PFR)
  - Due date
  - Deferred (Boolean)
    - MEL cathegory (3/10/30/120 days)
  - Registrar (PIREP/MAREP)
    - Personnel ID (Maintenance or Pilot)
- Maintenance Events
  - Maintenance Reference (ID)
  - Aircraft Registration
  - AirportID
  - AircraftSubsystemID (ATA)
  - Timestamp
  - Duration
  - Subclasses (flagbased)
    - Delays/Safety
      - FlightID
      - DepartureDate
      - DelayCode (IATA)
    - Aircraft On Ground (AOG)/Maintenance/Revision



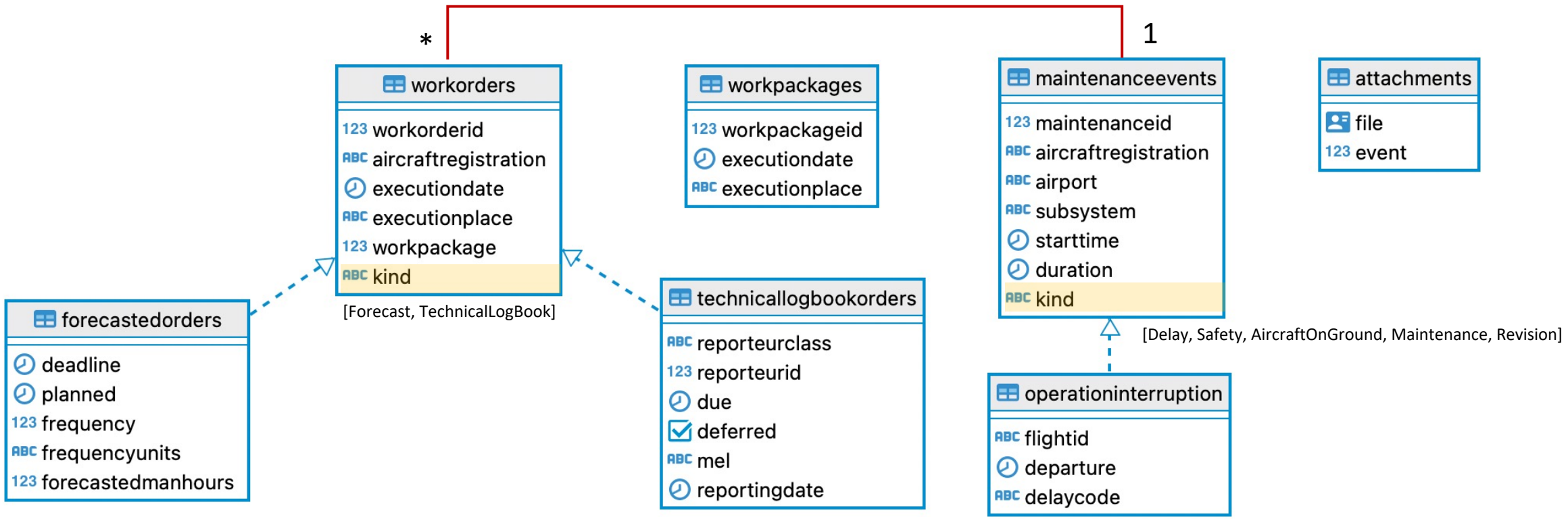
Aircraft Maintenance Operation System (II)

- Operational interruptions (OI)
  - ~~Cancellation generating (not really recorded here)~~
  - Delay generating
    - Duration: Minutes (Very short term)
    - Scheduled: No
    - Frequency: 10.000/year
  - Safety concern generating

  (Return to Parking, Aborted Take Off, In Flight Turn Back, Flight Diverting)
    - Duration: Undetermined
    - Scheduled: No
    - Frequency: 365/year
- Aircraft Out of Service (AOS)
  - Aircraft On Ground (AOG)
    - Duration: Hours
    - Scheduled: No
    - Frequency: 2.400/year
  - Maintenance
    - Duration: Hours to one day (short term)
    - Scheduled: Yes
    - Frequency: 344/year
  - Revision
    - Duration: Days to one month (long term)
    - Scheduled: Yes
    - Frequency: 107/year



AMOS


*
1
workorders
workorderid
aircraftregistration
executiondate
executionplace
workpackage
kind
[Forecast, TechnicalLogBook]
workpackages
workpackageid
executiondate
executionplace
maintenanceevents
maintenanceid
aircraftregistration
airport
subsystem
starttime
duration
kind
[Delay, Safety, AircraftOnGround, Maintenance, Revision]
attachments
file
event
forecastedorders
deadline
planned
frequency
frequencyunits
forecastedmanhours
technicallogbookorders
reporteurclass
reporteurid
due
deferred
mel
reportingdate
operationinterruption
flightid
departure
delaycode

Key Performance Indicators

Aircraft utilization metrics (1/2)

- Flight Hours (FH)
  - Airborne time, i.e. wheels-off to wheels-on
- Flight Cycles (TO)
  - Number of Take off
- Aircraft Days Out-of-Service (ADOS)
  - Cumulated elapsed time (measured in days) that an operational aircraft was unavailable for aircraft operations due to the requirement to perform scheduled or unscheduled maintenance
    - Aircraft Days Out-of-Service **Scheduled** (ADOSS)
      - Cumulated elapsed time (measured in days) that an operational aircraft was unavailable for aircraft operations due to the requirement to perform scheduled maintenance
    - Aircraft Days Out-of-Service **Unscheduled** (ADOSU)
      - Cumulated elapsed time (measured in days) that an operational aircraft was unavailable for aircraft operations due to the requirement to perform unscheduled maintenance
- Aircraft Days In-Service (ADIS)
  - Cumulative elapsed time (measured in days, potentially with decimals) that an aircraft was used in aircraft operation (in-flight or ready for flight) and not undergoing maintenance (this is the complementary of ADOS)

Aircraft utilization metrics (2/2)

- Daily Utilization (DU)
  - The **ratio** between the number of hours for a given period and the number of aircraft in-service for the same given period

    FH/ADIS
- Daily Cycles (DC)
  - The **ratio** between the number of take-offs for a given period and the number of aircraft in-service for the same given period

    TO/ADIS
- Delay Rate (DYR)
  - Delay Rate is the number of delays (between 15 minutes and 6 hours) incurred per 100 departures

    (DY/TO)*100
- Cancellation Rate (CNR)
  - Cancellation Rate is the number of cancellations incurred per 100 departures

    (CN/TO)*100
- **Technical Dispatch Reliability (TDR)**
  - Technical Dispatch Reliability is the percentage of departures that do not incur a delay or cancellation

    100 – ((DY + CN) / TO) x 100
- Average Delay Duration (ADD)
  - Average Delay Duration is the number of minutes in average for all delays incurred per 100 departures

    (Sum of delay duration > 15 minutes and < 6 hours / Nbr of delay duration> 15 minutes and < 6 hours) x 100

LogBook metrics

- Report Rate (RR)
  - General
    - Report Rate per hour (RRh)
      - Number of entries in the logbook per flight hour

        RRh = 1000 x (logbook count)/(total flight-hours)
    - Report Rate per cycle (RRc)
      - Number of entries in the logbook per take off

        RRc = 100 x (logbook count)/(total departures)
- Depending on the role of the person reporting
  - PIREP Rate (PRR)

    PRRh =1000 x (Pilot logbook count)/(total flight-hours)

    PRRc = 100 x (Pilot logbook count)/(total departures)
  - MAREP Rate (MRR)

    MRRh =1000 x (Maintenance logbook count)/(total flight-hours)

    MRRc =100 x (Maintenance logbook count)/(total departures)

Analytical software

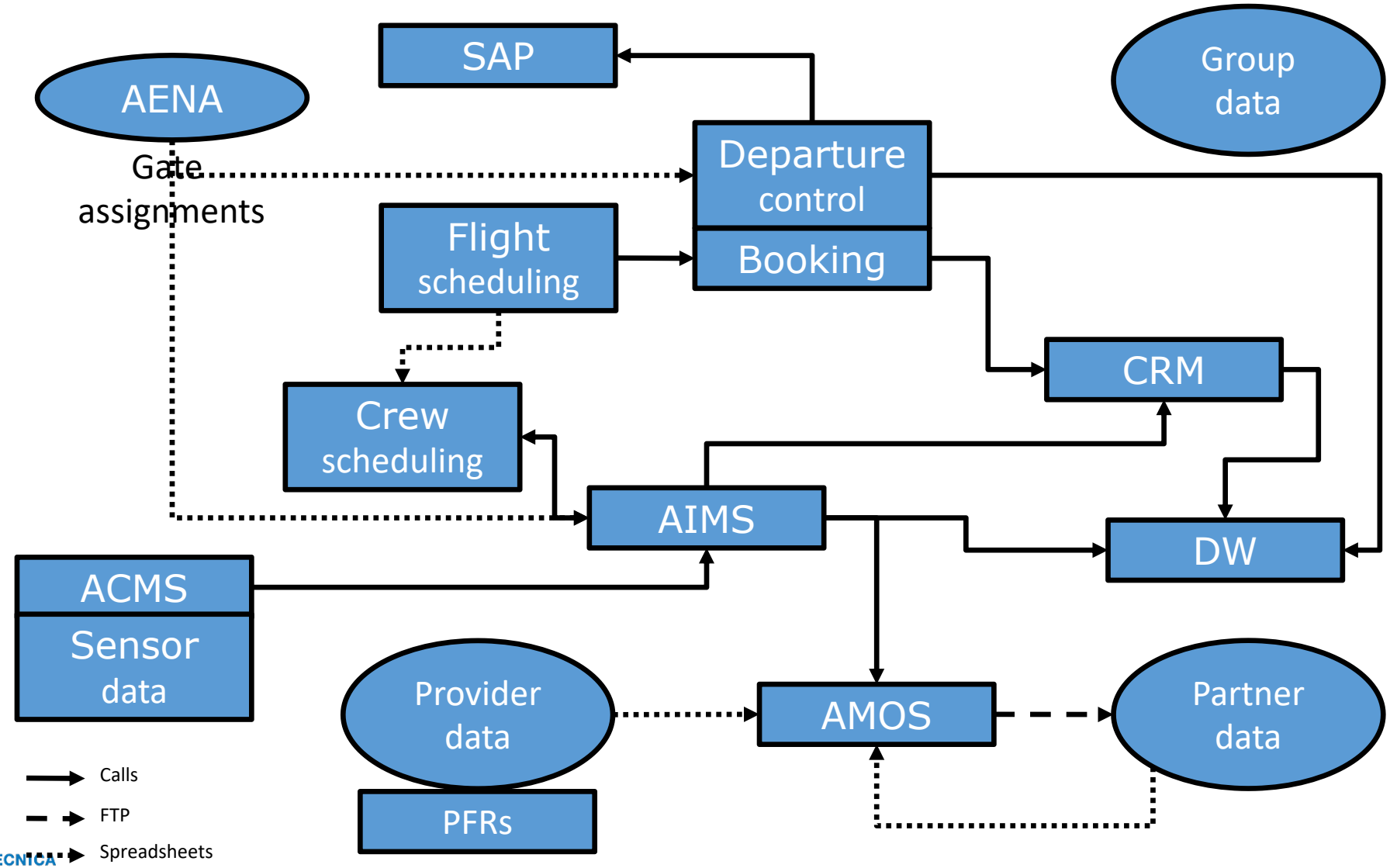
Airbus

Skywise

"Extensible data pool that is harmonised to make it accessible to analytics which run across all of the inputs"

- Contains aircraft maintenance data
- SaaS
  - Multi-tenant
    - Web interface
- Features
  - Scalable
  - Standardized (allows comparison)
    - Ontological knowledge
    - Data governance
      - Regular daily extraction
  - Anonymized
  - Automatized

Relevant sources



Data flows frequency

Frequency		Data Source: Airbus	Field Rep			Field Rep (if any) or Airline	Airline					CSD
		Email	Technical Message via Tech Request and validation in e-collection	E-collection (Field reps)	FSM template	ETOPS template	Spec 2000	DFT template	Misc. Files	Excel file	Airline DMC toolset	CDB template
A/C Reliability	Events (Operational interruptions & Tech. Incidents)		D	D			D	D				
	Flight hours and Take-offs per MSN (Tot and Rev)			M			M	M		M		
	Technical logbook			W			W			W		
	Aircraft days Out of service			M			M	M		M		
	Engine/APU removals details (Level 2)			W			W			W		
Components reliabilit	LRU removable details (Level 2)						W			W		
	Components shop findings (Level 2)						W			W		
ETOPS	ETOPS Flight hours and Take-offs per MSN			M			M	M		M		
	Routes					Y						
	Operator approval					Y						
	Milestosnes and Certifications	OR										
Direct Maint	DMC Airline										Y	
Fleet Mngt	Transfer of A/C								OR			OR
	Change of A/C status								OR			OR
FSM monthly report	General information (Training, Operations, Engineering, Maintenance, Fuel, Services, OEB status…)				M+20							

Data loading means

- Full Automatic Data Transfer
- Data Loading Interface
  - SPEC2000 files upload
  - Direct Excel extracts upload
  - Data File Transfer Template
- Manual Input by Airbus Field Service

Subsystems

- Hubble
  - Purpose: Search data
  - User type: - (new comer)
- Monocle
  - Purpose: Visualize and manage data flows (including code of transformation)
  - User type: Developer
- Countour
  - Purpose: Exploratory analysis of data (descriptive analytics)
  - User type: Domain expert
- Report (static view of Contour)
  - Purpose: Publishing descriptive analysis
  - User type: Manager
- Slate
  - Purpose: OLAP-like dashboard analysis
  - User type: Executive (decisor)
- Quiver
  - Purpose: Analyse flight sensors (for predictive analytics)
  - User type: - (not in use)
- Other

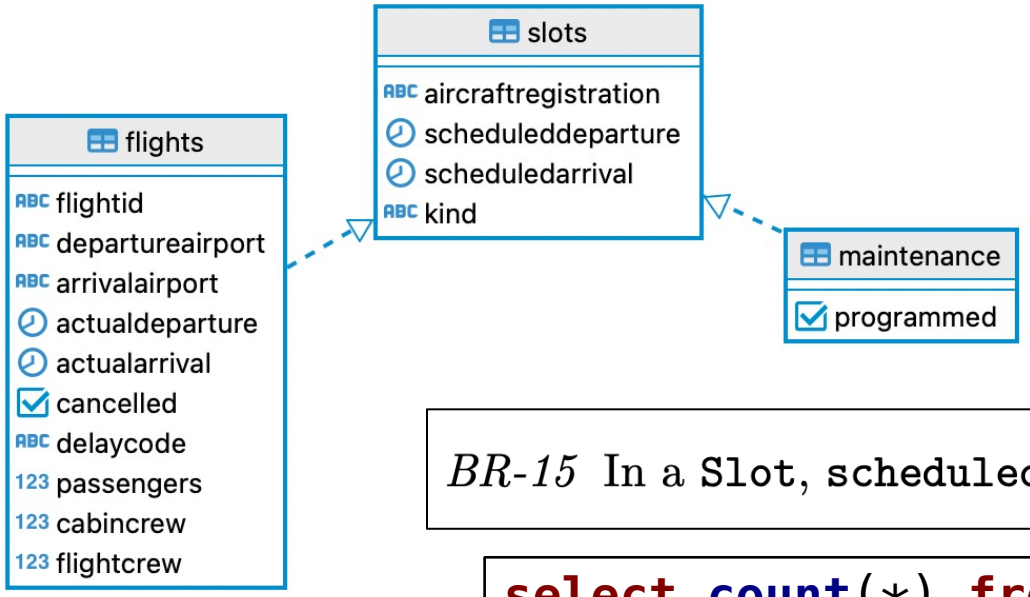
Alternative to Engine Health Monitoring

- Contains engines' data
- Features
  - Pre-defined blackbox indicators

Business Rules

Business rules

- Business rules are rules that are supposed to be **true** in the data. Nevertheless, in our use case **neither the processes nor the DBMS enforced them**. Thus, they may have been violated giving rise to quality problems.



BR-15 In a `Slot`, `scheduledArrival` must be posterior to the `scheduledDeparture`.

```
select count(*) from slots s
where scheduledarrival <= scheduleddeparture;
```

	123 count
1	952

In the ETL process, you are expected to enforce them, that is, check if they are violated and act upon them.

Business rules

AMOS database

Identifiers

BR-1 `WorkPackageID` is an identifier of `WorkPackage`.

BR-2 `workOrderID` is an identifier of `WorkOrders/ForecastedOrders/TechnicalLogBookOrders`.

BR-3 `maintenanceID` is an identifier of `MaintenanceEvents/OperationInterruption`.

Datatypes/Domains

BR-4 `subsystem` of `MaintenanceEvents` should be a 4 digits ATA code[1]

BR-5 `delayCode` in `OperationInterruption` should be a 2 digits IATA code[2]

BR-6 `WorkPackageID/workOrderID/maintenanceID` should be simply SERIAL numbers generated by an autoincrement[3] mechanism.

BR-7 `ReportKind` values "PIREP" and "MAREP" refer to pilot and maintenance personnel as reporters, respectively.

BR-8 `MELCathegory` values `A,B,C,D` refer to `3,10,30,120` days of allowed delay in the repairing of the problem in the aircraft, respectively.

BR-9 `airport` in `MaintenanceEvents` must have a value.

Other business rules

BR-10 In `OperationInterruption`, departure must coincide with the date of the `FlightID` (see below how it is composed).

BR-11 The `Flight` registered in `OperationInterruption`, must exist in the `Flights` of `AIMS` database, and be marked as "delayed" (i.e., `delayCode` is not null) with the same IATA delay code.

BR-12 In `MaintenanceEvents`, maintenance duration must have the expected length according to the kind of maintenance (Delay – minutes, Safety – undetermined/unlimited, `AircraftOnGround` - hours, `Maintenance` – hours to max 1 day, `Revision` – days to 1 month).

AIMS database

Identifiers

BR-13 `FlightID` is an identifier of `Flights`.

Datatypes/Domains

BR-14 `FlightID` is derived by concatenating the following values:
`Date-Origin-Destination-FlightNumber-AircraftRegistration`
(lengths: 6+1+3+1+3+1+4+1+6=26).

Other business rules

BR-15 In a `Slot`, `scheduledArrival` must be posterior to the `scheduledDeparture`.

BR-16 A `Flight` is not longer than 24 hours.

BR-17 All the hours of a `Flight` are imputed to the date of its `scheduledDeparture`.

BR-18 In `Flights`, departure and arrival airports must be those in the `FlightID` (unless this `Flight` has been diverted).

BR-19 In a `Flight`, `actualArrival` is posterior to `actualDeparture`.