

ACME Flying Use Case

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Contents

- Domain characteristics
- Analytical Software
- Data sources
- Key Performance Indicators
- Business rules

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

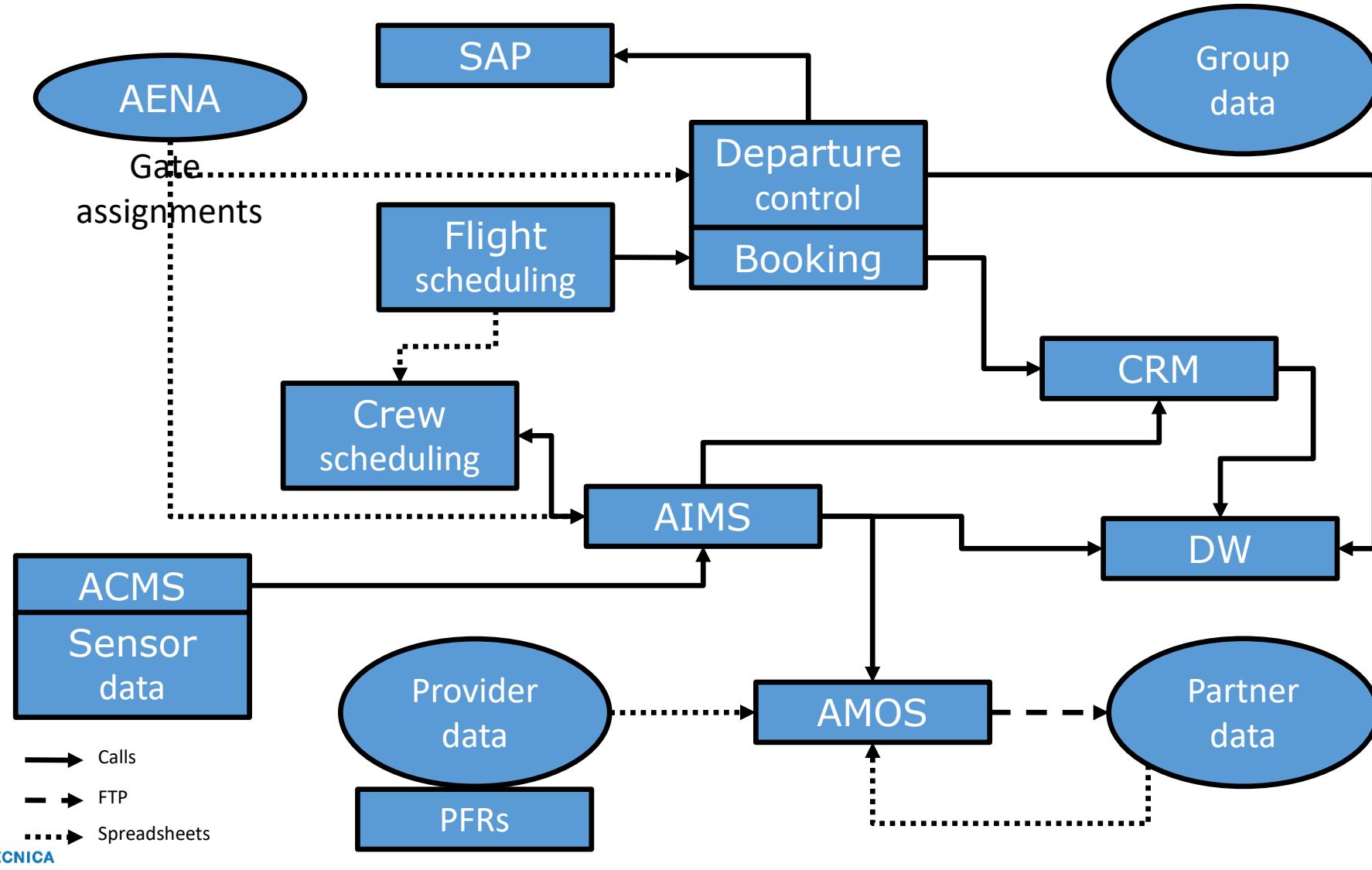
- Each plane is unique
 - Hard to train because of lack of data
- Heterogeneous information
 - Different sources
 - Different data types
 - Binary, numeric, photographs, video

Analytical software

Airbus



Relevant sources



Data flows 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				
Frequency																			
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 reliability	LRU removable details (Level 2)									W				W					
	Components shop findings (Level 2)									W				W					
	ETOPS Flight hours and Take-offs per MSN				M					M	M			M					
ETOPS	Routes								Y										
	Operator approval								Y										
	Milestones and Certifications	OR																	
Fleet Maint	DMC Airline													Y					
	Transfer of A/C											OR				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

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



Subsystems

- **Hubble**
 - Purpose: Search data
 - User type: - (new comer)
- **Monocle**
 - Purpose: Visualize and manage data flows (including code of transformation)
 - User type: Developer
- **Contour**
 - 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**



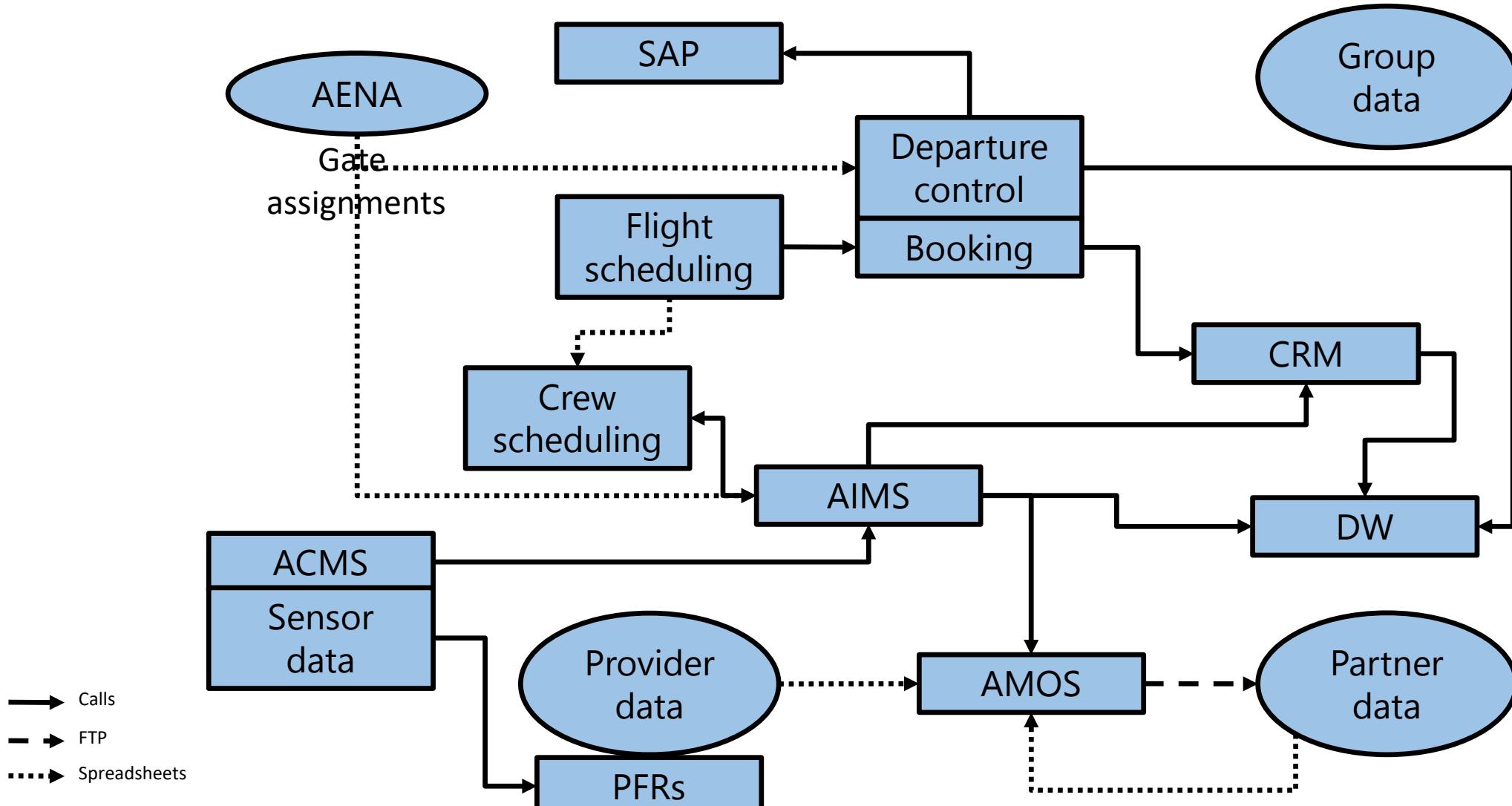
Data sources

AIMS

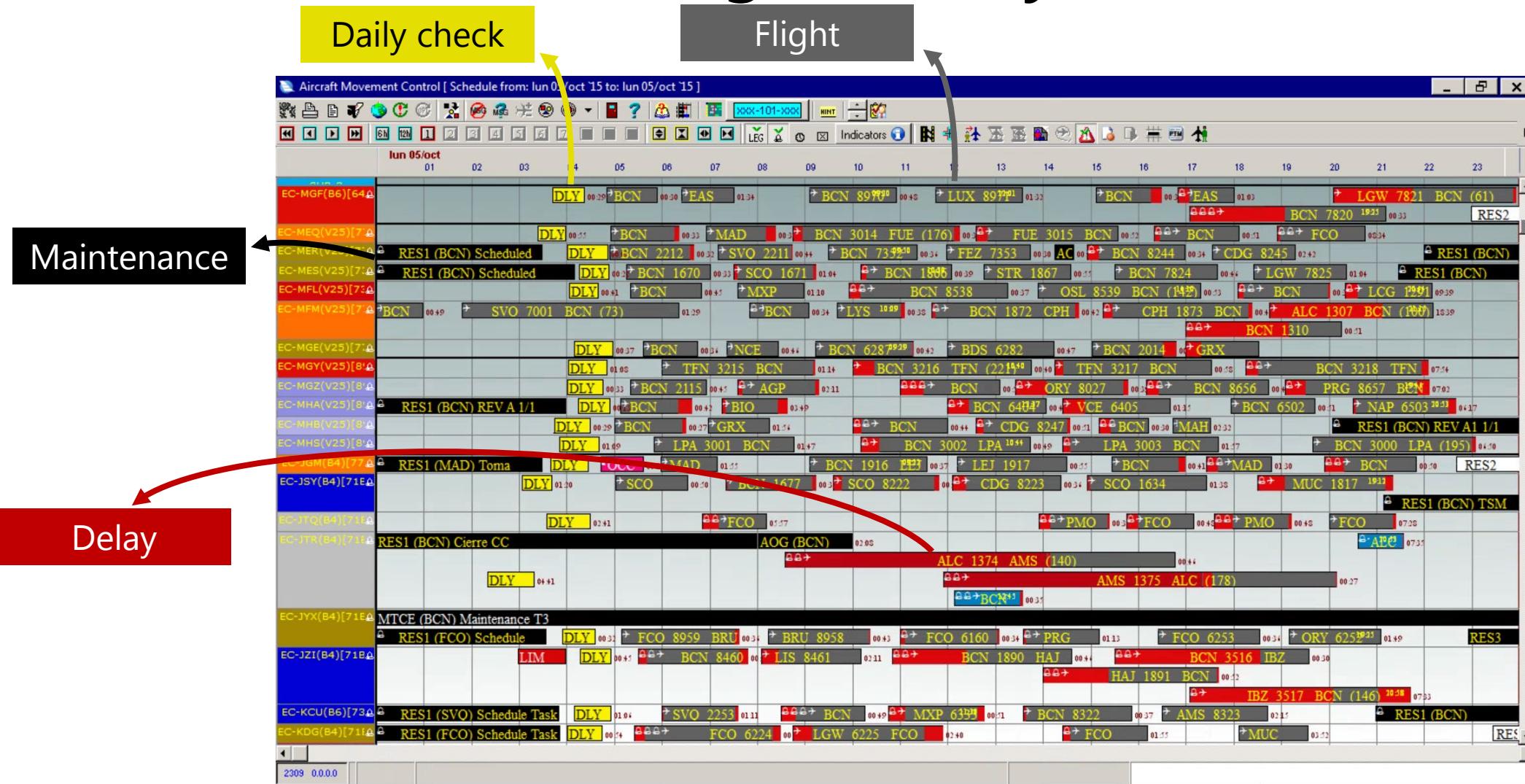
AMOS



Systems diagram

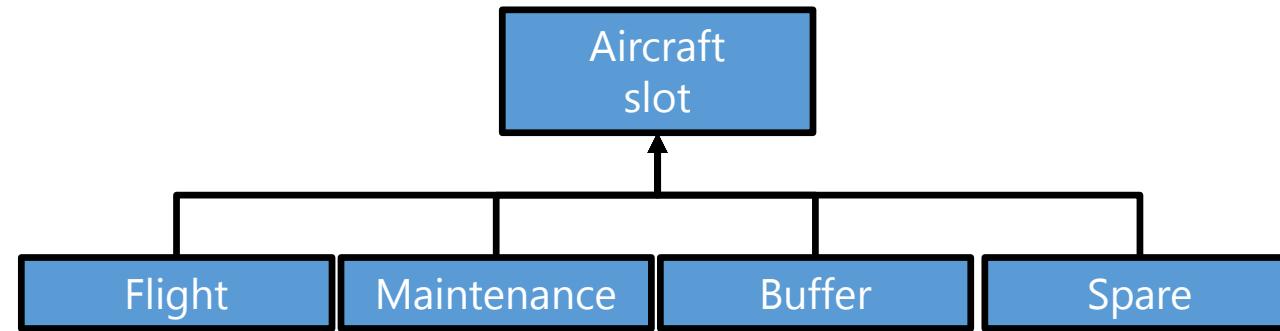


Air Information Management System (I)

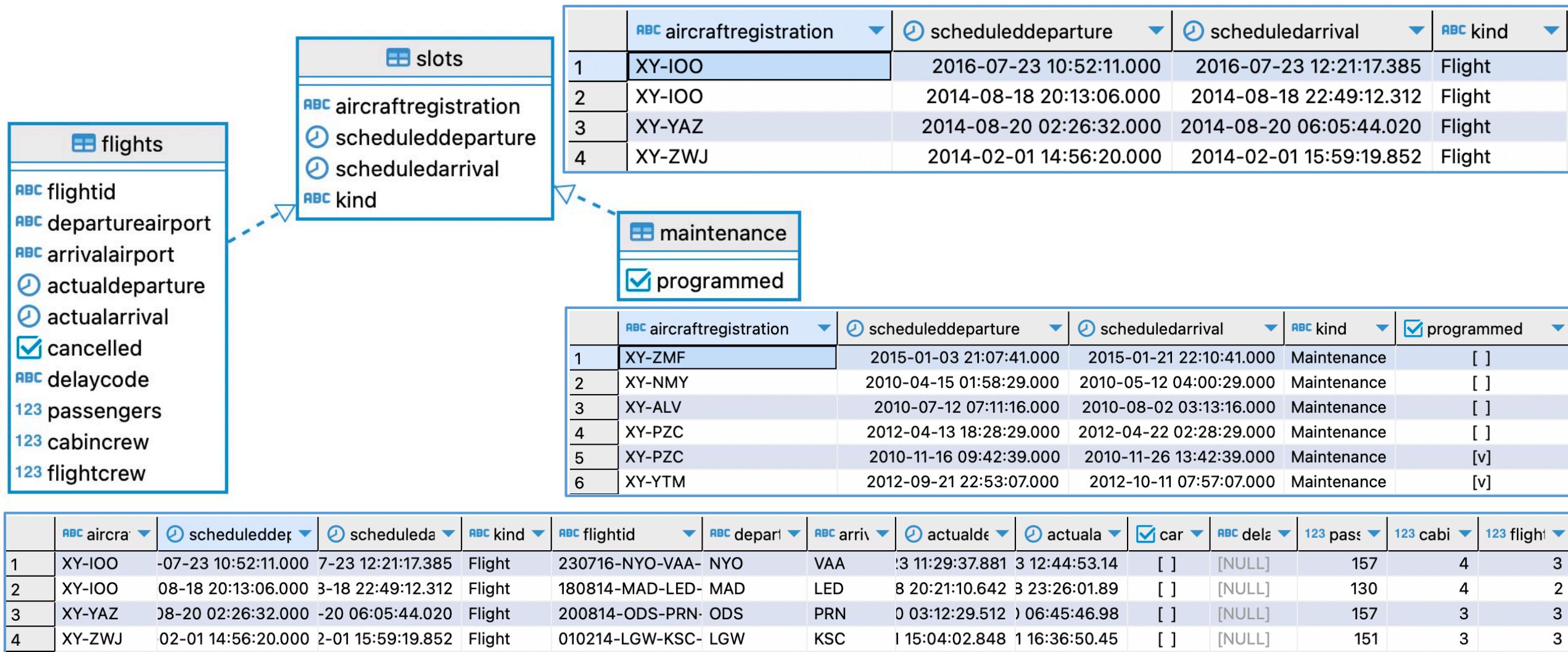


Air Information Management System (II)

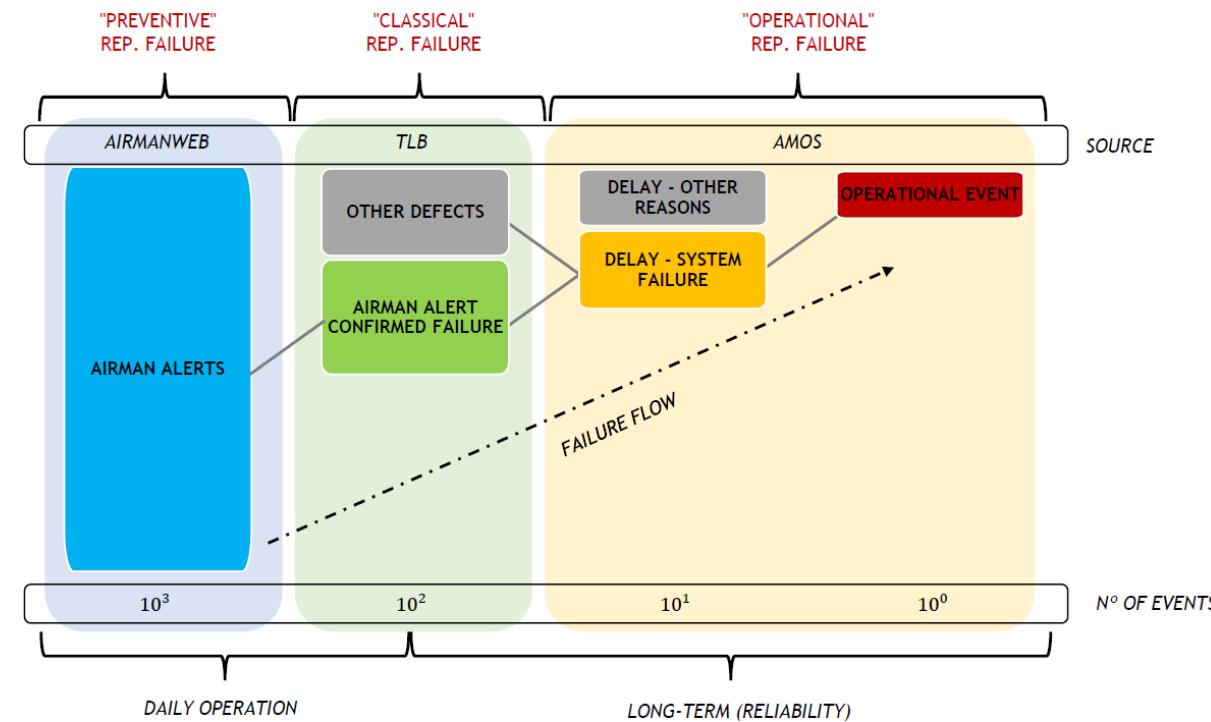
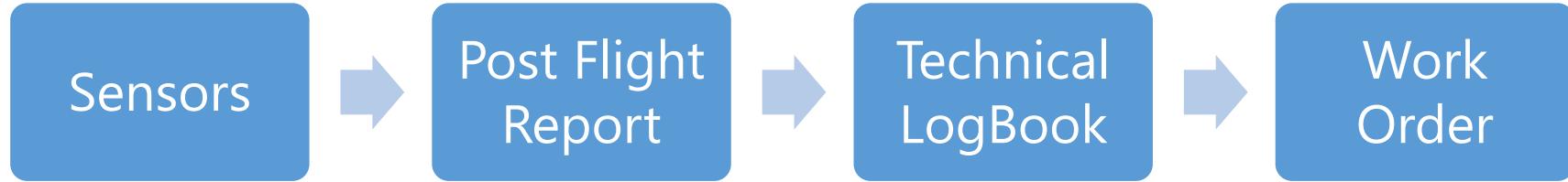
- Aircraft slot
 - Aircraft Registration
 - Slot Start (Scheduled Time Departure)
 - Slot End (Scheduled Time Arrival)
- Flights
 - FlightID
 - Date-Origin-Destination-FlightNumber-AircraftRegistration
 - Arrival Airport
 - Departure Airport
 - Departure Time (actual)
 - Comes directly from ACMS
 - Arrival 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)



Air Information Management System (III)



Maintenance flow

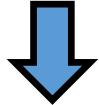


Sensors (provided by Teledyne)

- 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

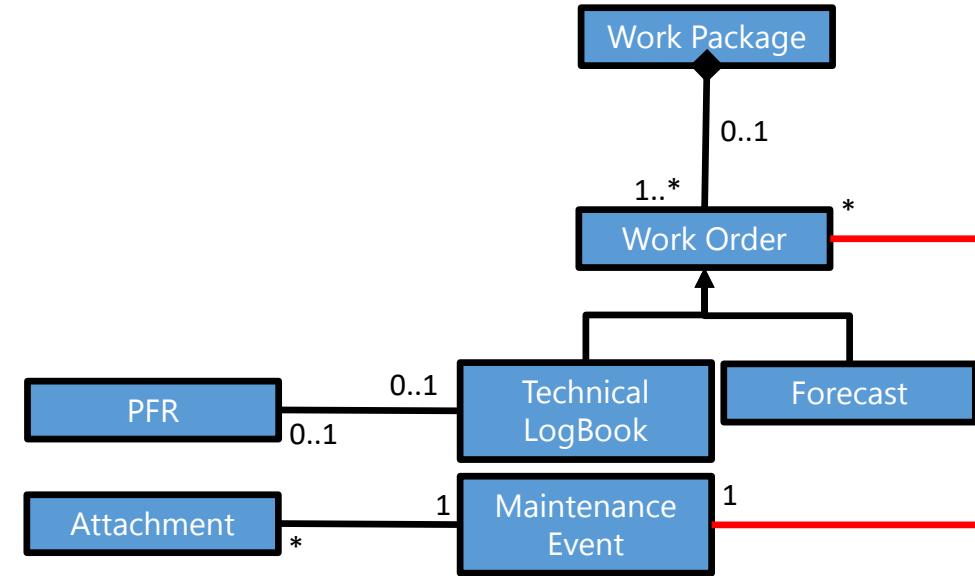
- Sensor Events
 - Manufacturer Serial Number
 - Timestamp
 - Sensor
 - Value



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

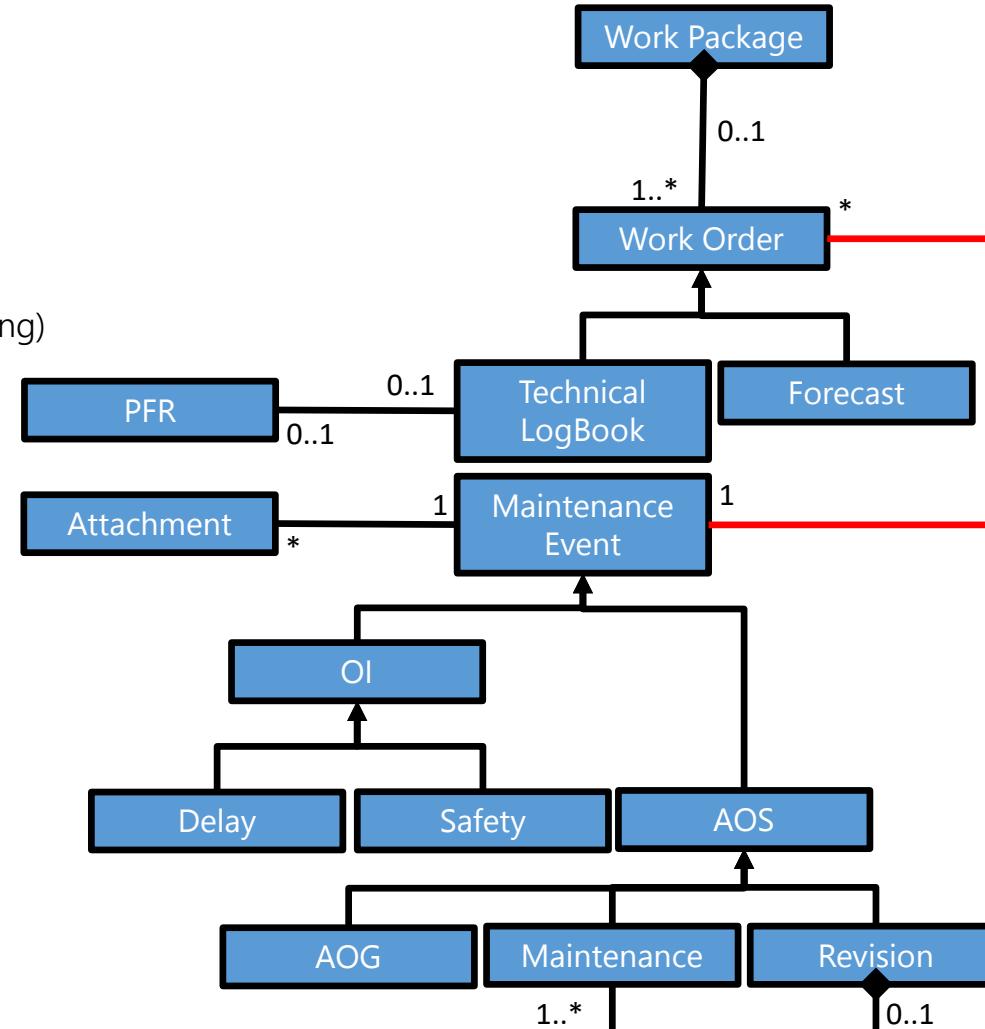
Aircraft Maintenance Operation System (I)

- 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 category (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

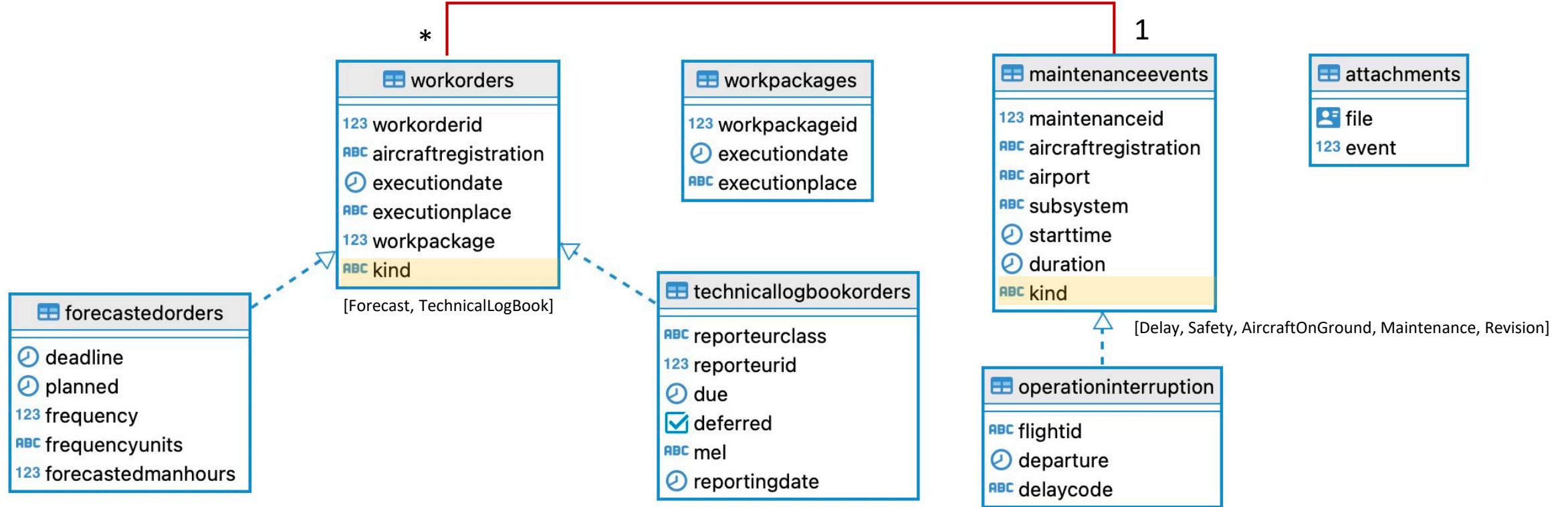


Aircraft Maintenance Operation System (II)

- 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



Aircraft Maintenance Operation System (III)



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 (DVR)
 - 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
 $100 - ((DY + CN) / TO) \times 100$
- Average Delay Duration (ADD)
 - Average Delay Duration is the number of minutes in average for all delays incurred per 100 departures
 $(\text{Sum of delay duration} > 15 \text{ minutes and } < 6 \text{ hours} / \text{Nbr of delay duration} > 15 \text{ minutes and } < 6 \text{ hours}) \times 100$

LogBook metrics

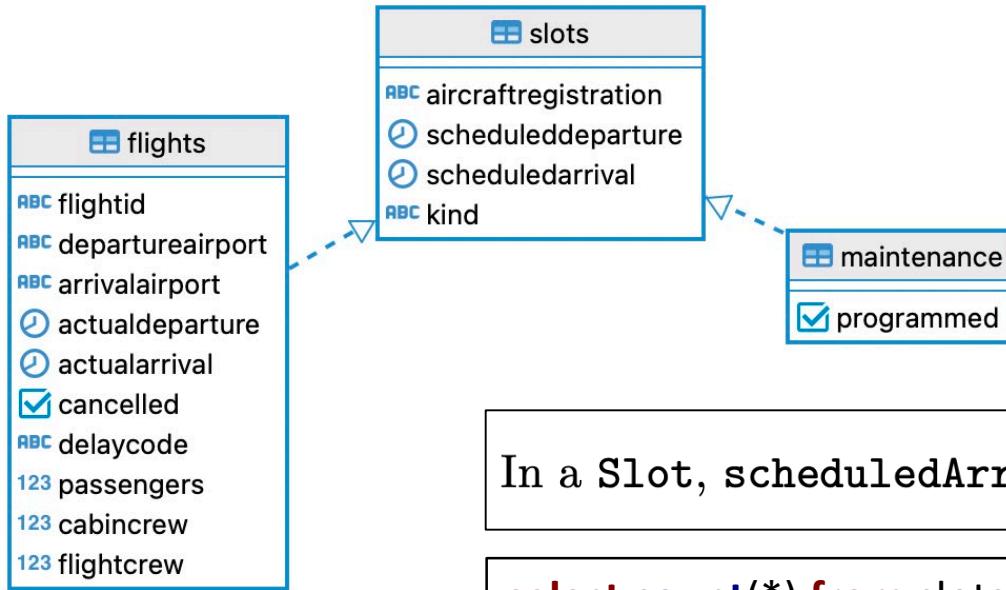
- Report Rate (RR)
 - General
 - Report Rate per hour (RRh)
 - Number of entries in the logbook per flight hour
$$RRh = 1000 \times (\text{logbook count}) / (\text{total flight-hours})$$
 - Report Rate per cycle (RRc)
 - Number of entries in the logbook per take off
$$RRc = 100 \times (\text{logbook count}) / (\text{total departures})$$
 - Depending on the role of the person reporting
 - PIREP Rate (PRR)
$$PRRh = 1000 \times (\text{Pilot logbook count}) / (\text{total flight-hours})$$
$$PRRc = 100 \times (\text{Pilot logbook count}) / (\text{total departures})$$
 - MAREP Rate (MRR)
$$MRRh = 1000 \times (\text{Maintenance logbook count}) / (\text{total flight-hours})$$
$$MRRc = 100 \times (\text{Maintenance logbook count}) / (\text{total departures})$$

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.



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 detect and fix them, that is, check if they are violated and act upon them.

Rules in AMOS

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.

BR-4 file is an identifier of Attachments.

References

BR-5 event of an Attachement is a reference to maintenanceID of MaintenanceEvents.

Datatypes/Domains

BR-6 subsystem of MaintenanceEvents should be a 4 digits ATA code²

BR-7 delayCode in OperationInterruption should be a 2 digits IATA code³

BR-8 ReportKind values “PIREP” and “MAREP” refer to pilot and maintenance personnel as reporters, respectively.

BR-9 MELCategory 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-10 airport in MaintenanceEvents must have a value.

Other business rules

BR-11 In OperationInterruption, departure must coincide with the date of the FlightID (see below how it is composed).

BR-12 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-13 In MaintenanceEvents, the events of kind Maintenance that correspond to a Revision, are those of the same aircraft whose interval is completely included in that of the Revision. For all of them, the airport must be the same.

- In MaintenanceEvents, the events of kind Maintenance cannot partially intersect that of a Revision of the same aircraft.

BR-14 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).

²ATA codes for commercial aircrafts: https://en.wikipedia.org/wiki/ATA_100

³IATA delay codes: https://en.wikipedia.org/wiki/IATA_delay_codes

Rules in AIMS

AIMS database

Identifiers

BR-15 FlightID is an identifier of Flights.

Datatypes/Domains

BR-16 FlightID is derived by concatenating the following values:

Date-Origin-Destination-FlightNumber-AircraftRegistration
(lengths: 6+1+3+1+3+1+4+1+6=26).

BR-17 delayCode in OperationInterruption is a 2 digits IATA code⁴

Other business rules

BR-18 In a Slot, scheduledArrival must be posterior to the scheduledDeparture.

BR-19 A Flight is not longer than 24 hours.

BR-20 All the hours of a Flight are imputed to the date of its scheduledDeparture.

BR-21 Two Slots of the same aircraft cannot overlap.

BR-22 In Flights, departure and arrival airports must be those in the FlightID (unless this Flight has been diverted).

BR-23 In a Flight, actualArrival is posterior to actualDeparture.

BR-24 In a Maintenance, the corresponding events must exist in AMOS inside the corresponding time interval.

⁴IATA delay codes: https://en.wikipedia.org/wiki/IATA_delay_codes