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Management*

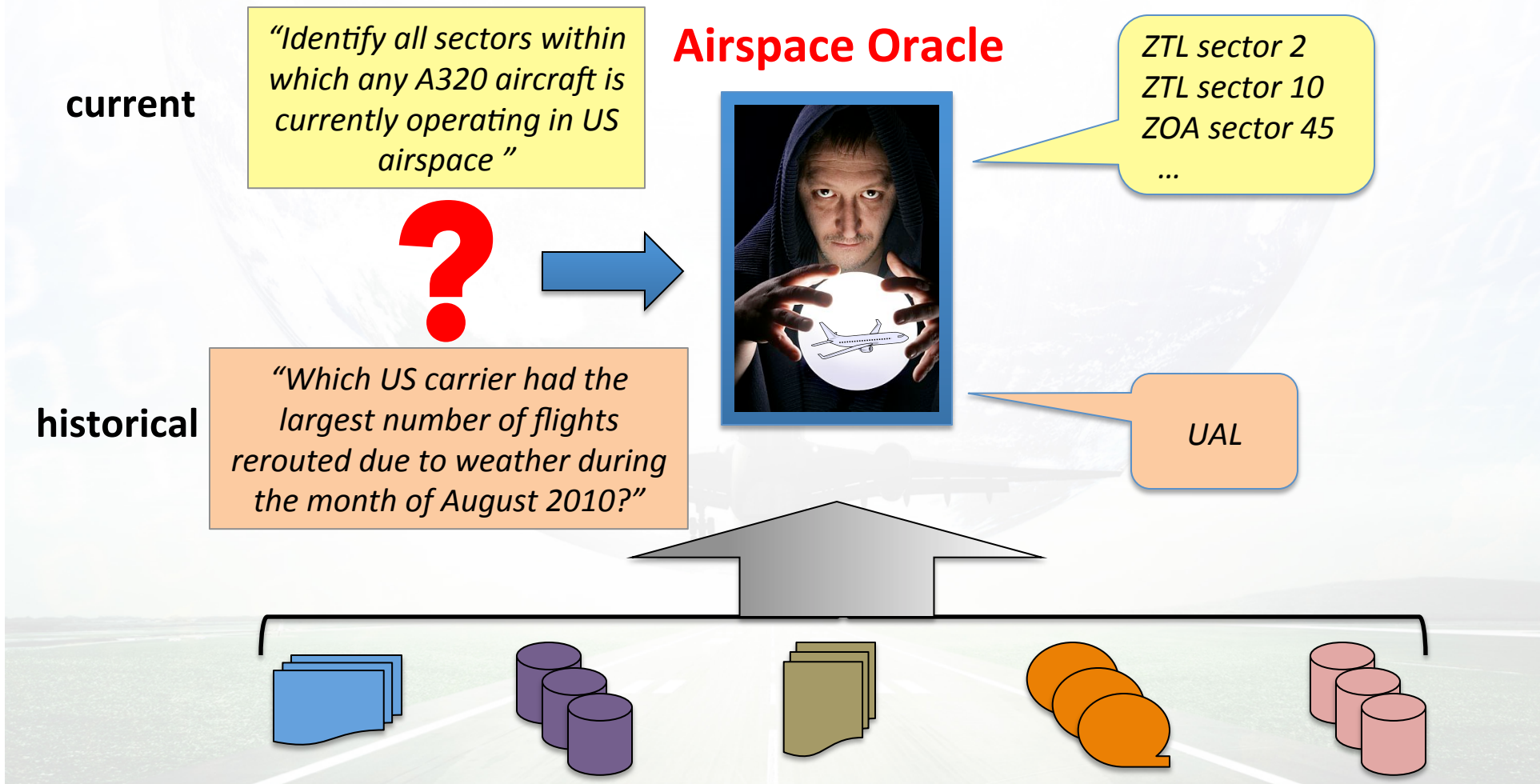
NASA's ATM Ontology: Semantic Integration and Querying across NAS Data Sources

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Long Term Vision: A Global Airspace Question-Answering System



Many Challenges!

- Question understanding
- Automated reasoning
- Information retrieval
- Natural language generation
- **Data exchange & integration**
 - **Data exchange:** How do you facilitate aviation data sharing and system interoperability?
 - Using *standards*: AIXM, FIXM, WXXM
 - **Data integration:** How do you take heterogeneous data from multiple sources and weave together a harmonized picture of global airspace operations?
 - Using *semantics*!

Some Small Steps Toward the Vision

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NASA has developed a *semantics-based* data integration prototype capable of answering a limited set of queries about airspace operations

Outline

- Background and Motivation
- Semantic Integration Approach
- Prototype: Integrating and querying data for airspace operations at KATL on 2012/09/08

NASA Project Background

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- NASA researchers need historical ATM data
 - NASA Ames conducts research on future ATM concepts
 - Researchers require data for analysis and concept validation
- NASA Ames' **ATM Data Warehouse** archives data collected from FAA, NASA, NOAA, DOT, industry
 - Warehouse captures:
 - live streamed data
 - published periodic data
 - Data holdings available back to 2009



Federal Aviation
Administration



A Sampling of Archived Data Warehouse Holdings

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- ATCSCC Advisories
 - Airline Situation Display to Industry (ASDI)*
 - Air Route Traffic Control Center (flight plans & tracks)
 - Corridor Integrated Weather Service (CIWS)
 - Center-TRACON Automation System (CTAS)
 - Exelis Commercial Track Feed
 - METAR
 - AIREP, PIREP
 - Rapid Refresh (RR) Weather Forecast
 - Terminal Aerodrome Forecast (TAF)
 - Time-based Flow Management (TBFM)
 - TRACON(flight plans & tracks)
- *SWIM conversion underway for available sources*

ATM Data Warehouse: A microcosm of the NAS data environment

Problem: Non-integrated Data

- ATM Warehouse data is replicated & archived in its original format
- Data sets lack standardization
 - data formats
 - nomenclature
 - conceptual structure
- To analyze and mine data, researchers must write special-purpose code to integrate data for each new task
 - ➔ Huge time sink!

- **Possible cross-dataset mismatches:**
 - terminology
 - scientific units
 - temporal alignment
 - spatial alignment
 - conceptualization organization

Proposed Solution

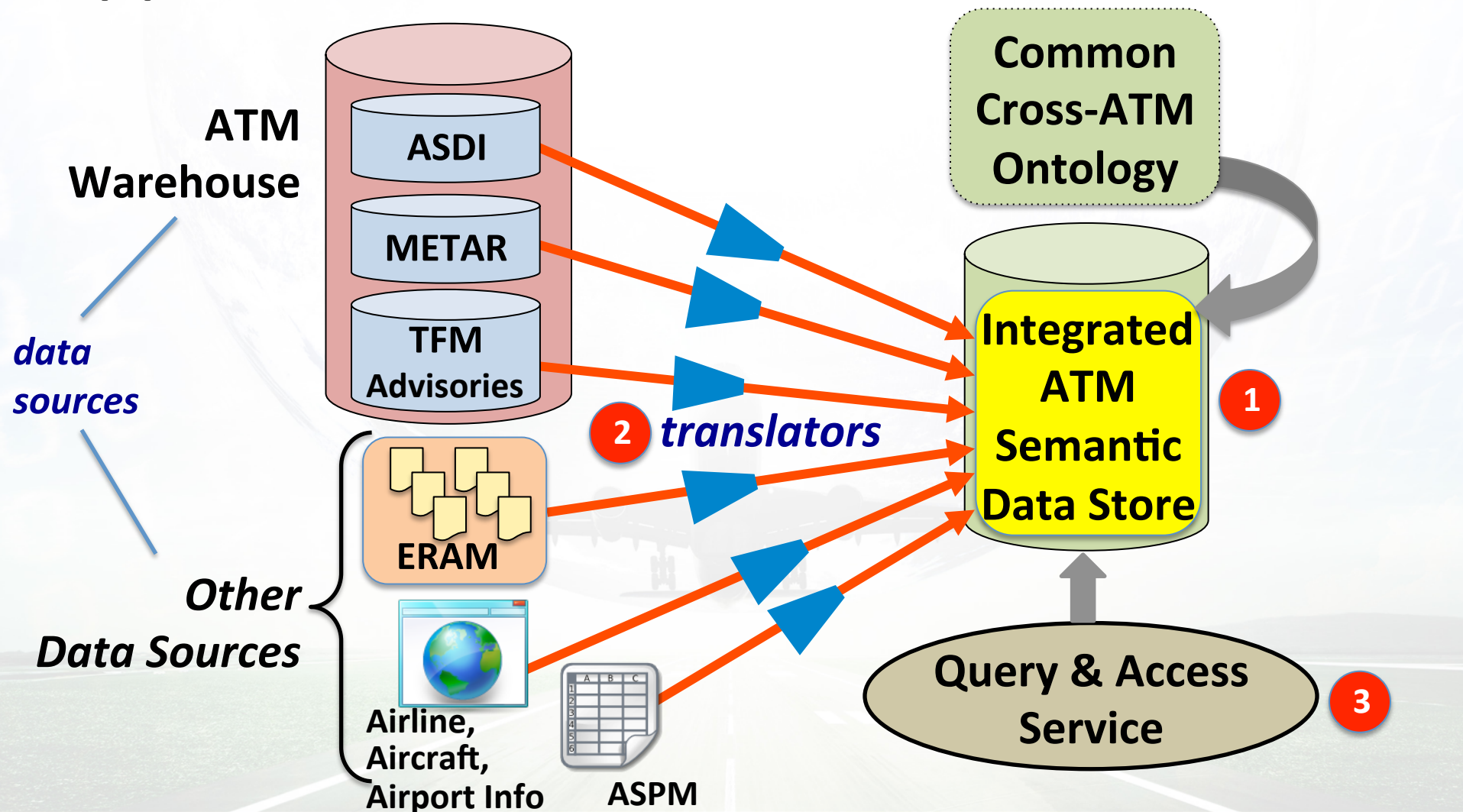
Relieve users of responsibility for integration!

‘Pre-integrate’ the Warehouse data sources using
Semantic Integration

- 1 Develop an integrated data repository based on a common semantic data model (“an ontology”)
- 2 Write translators to transform data from the original sources into an integrated common data repository
- 3 Expose integrated repository, not individual sources, to users for query and access

Semantic Integration Approach:

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What is an Ontology??

- Ontology = data model + database
 - **data model:** provides a unified framework for describing, interrelating, and reasoning about different types of ATM data

The data model provides a basis for integrating heterogeneous ATM data from multiple sources

- **database:** contains integrated air traffic management information from multiple sources, stored as per data model

This database can be queried like a conventional database. But it can also draw inferences from the data and generate new data using inference rules.

- Plays similar role as UML, but adds inference and reasoning



What is modeled by the NASA ATM Ontology?

Covers selection of concepts found in the
AIXM, FIXM, WXXM conceptual models

❖ 150+ object types

- Flights •Aircraft and manufacturers •Airlines •Airports and physical infrastructure •NAS facilities •Air traffic management initiatives •Surface weather conditions and forecasts •Airspace sectors, fixes, routes, airways •Flight plans and paths

❖ 150+ object properties

- actualDepartureTime •actualArrivalTime •airportArrivalRate •cloudType •dewpoint •EDCTarrivalHold •equipmentCode •groundSpeed •heading •hourlyPrecipitation •IATACarrierCode •issuedTime •manufactureYear •maxVisibility

❖ 100+ relationship types

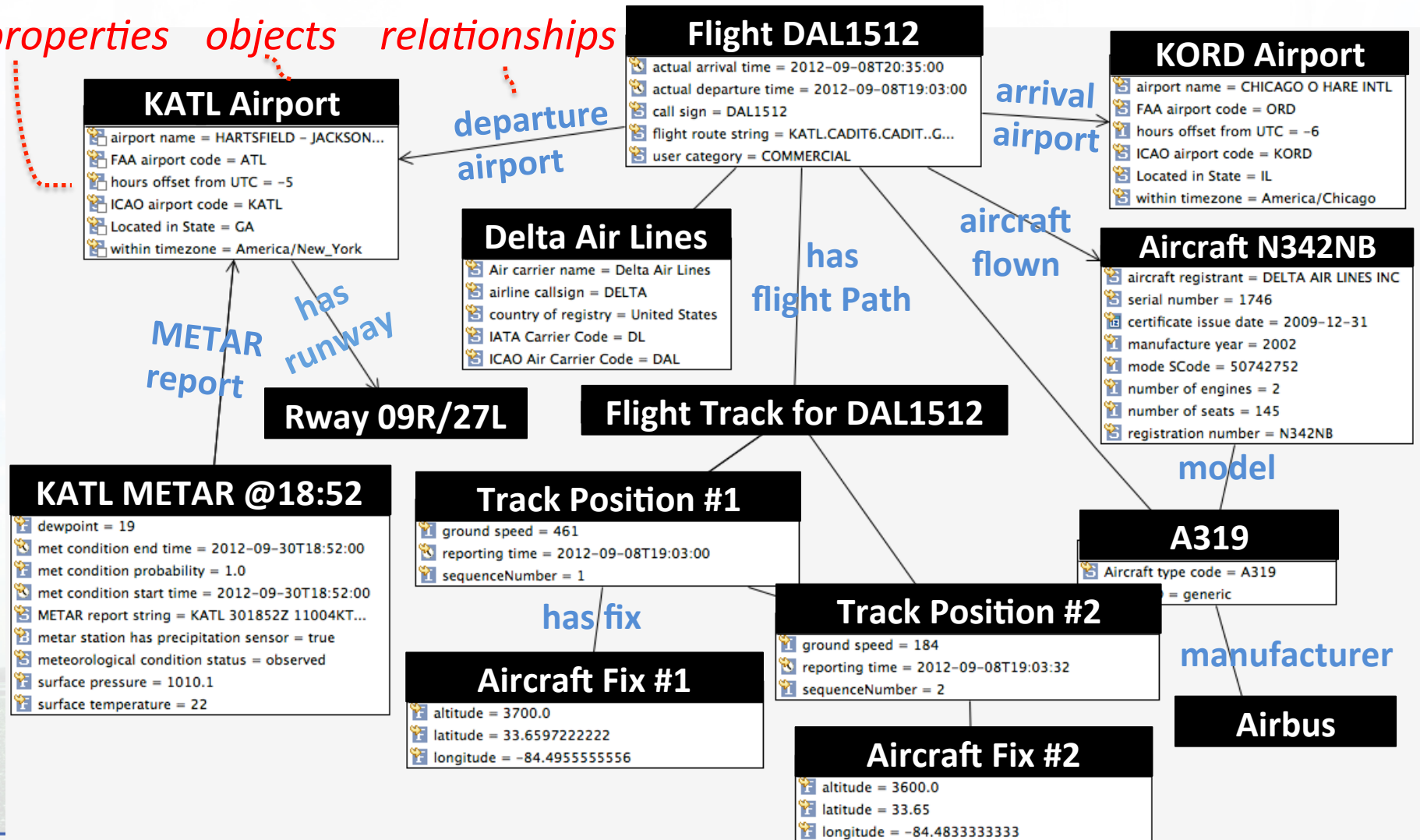
- hasRampTower •hasRunway •operatedBy •locatedInSector •manufacturedBy •hasSurfaceWindCondition •hasLOAwith •exemptedAFP •departureScope •ADLday •adjacentSector •aircraftFix •aircraftFlown •arrivalRunway •reRouteConstraint

❖ Object/property/relationship instances also stored in ontology

Ontology Representation of a Flight (viewed as graph)

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properties objects relationships



Ontology crosses AIXM, FIXM, WXXM boundaries

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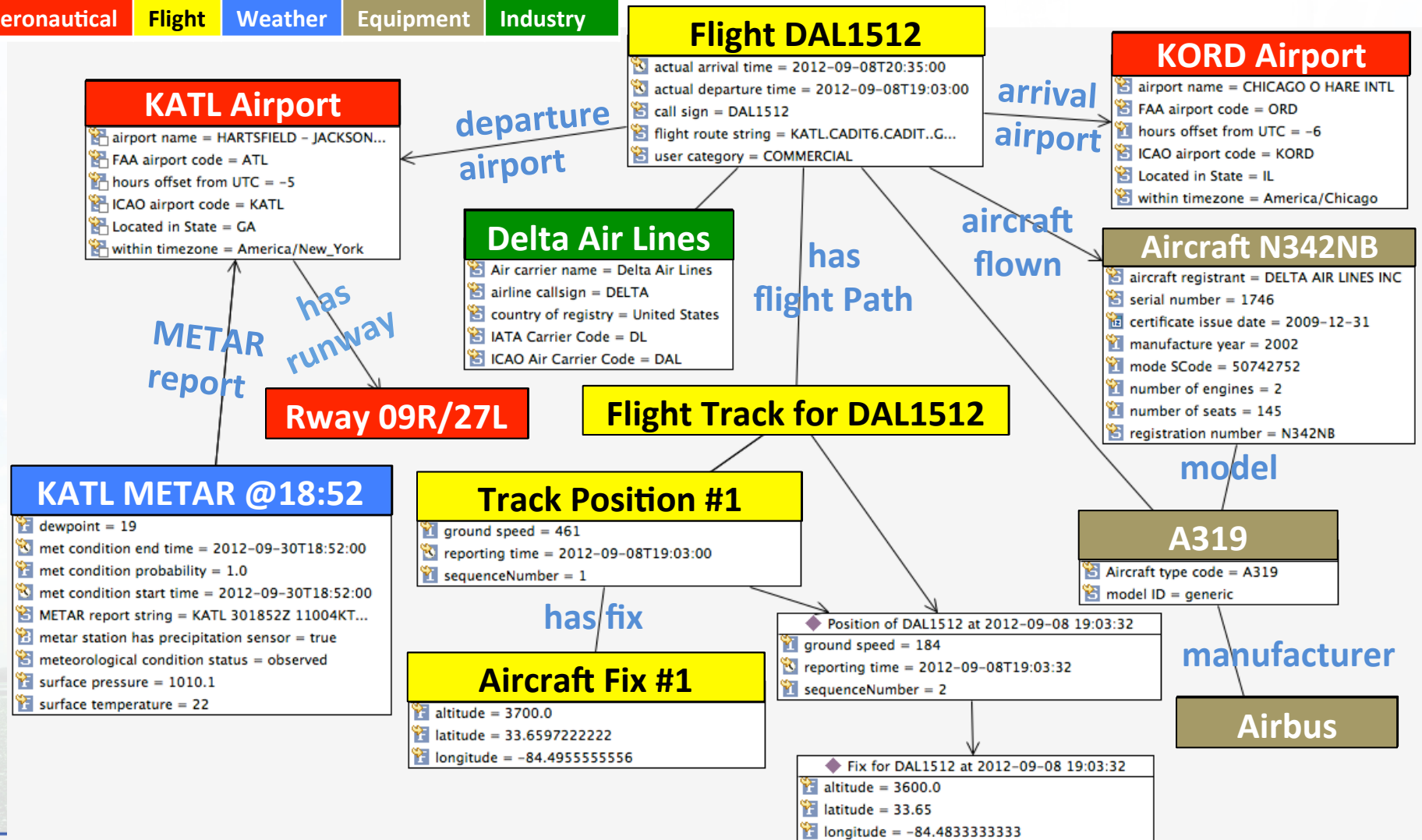
Aeronautical

Flight

Weather

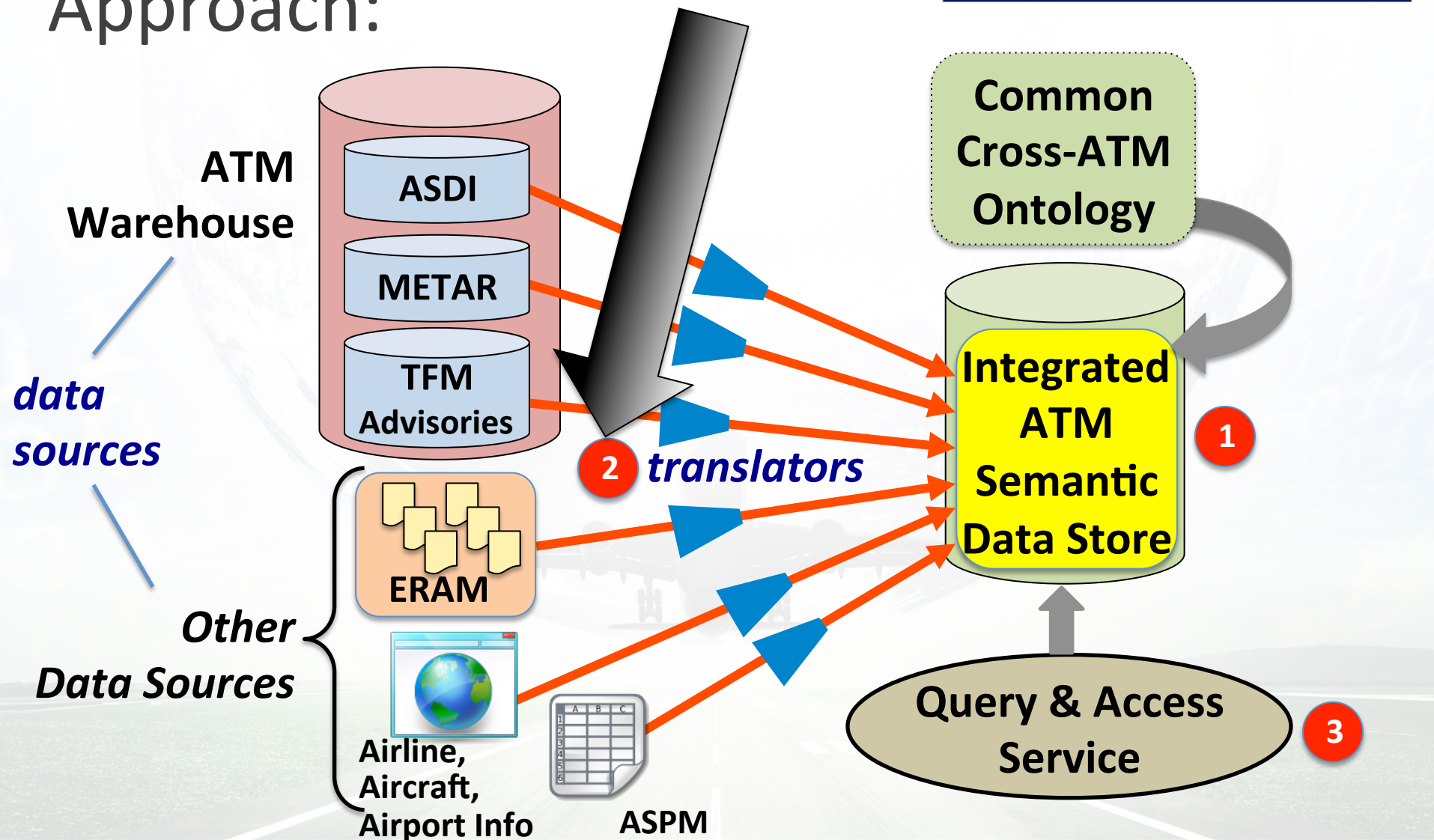
Equipment

Industry



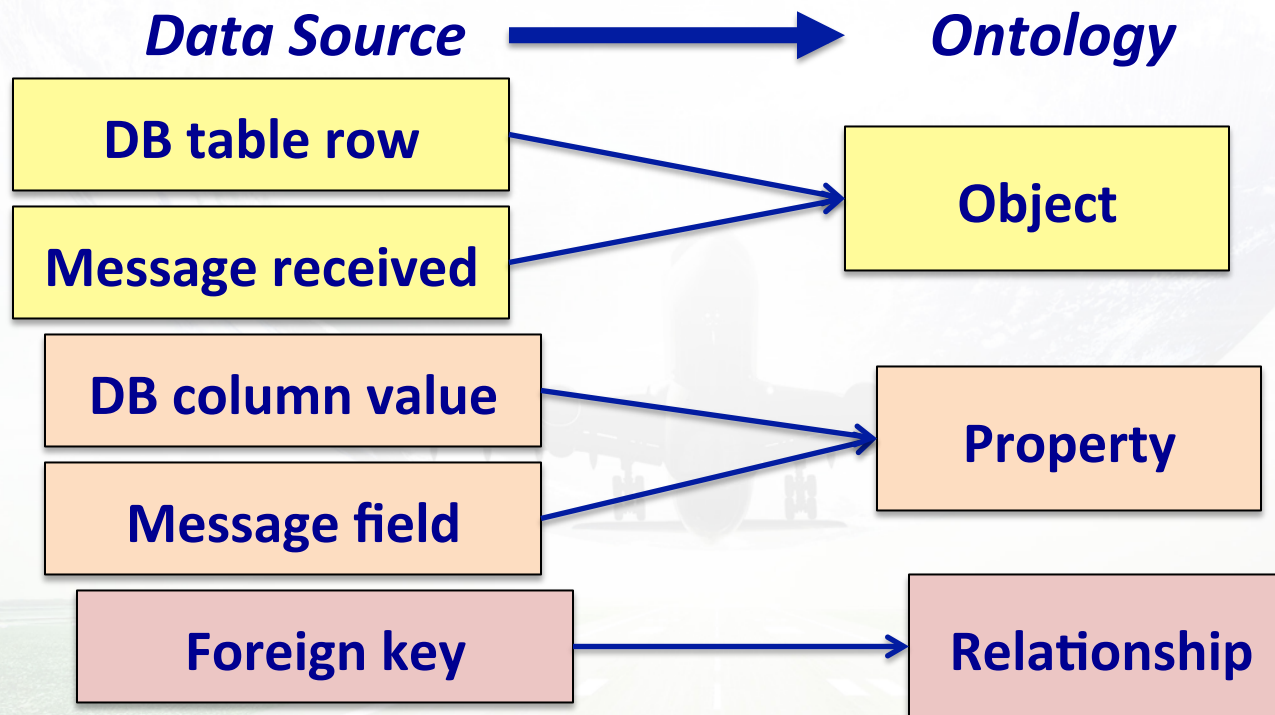
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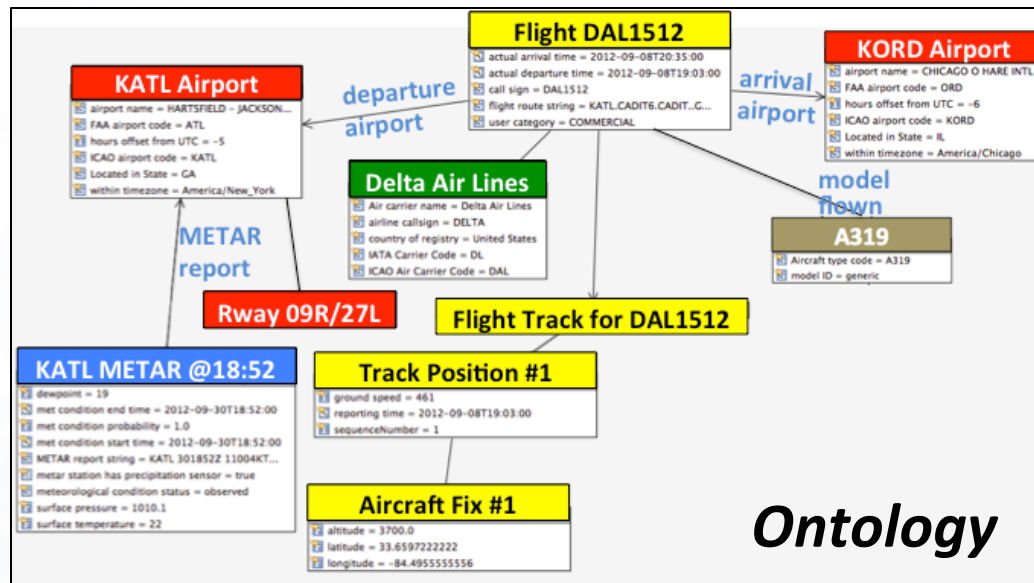
Data Translators

- How is data mapped from the source schemas into the ontology schema?
 - custom translator is written for each data source



- similar in spirit to data warehouse ETL tools

Example: Mapping an ASDI Departure Message



Ontology

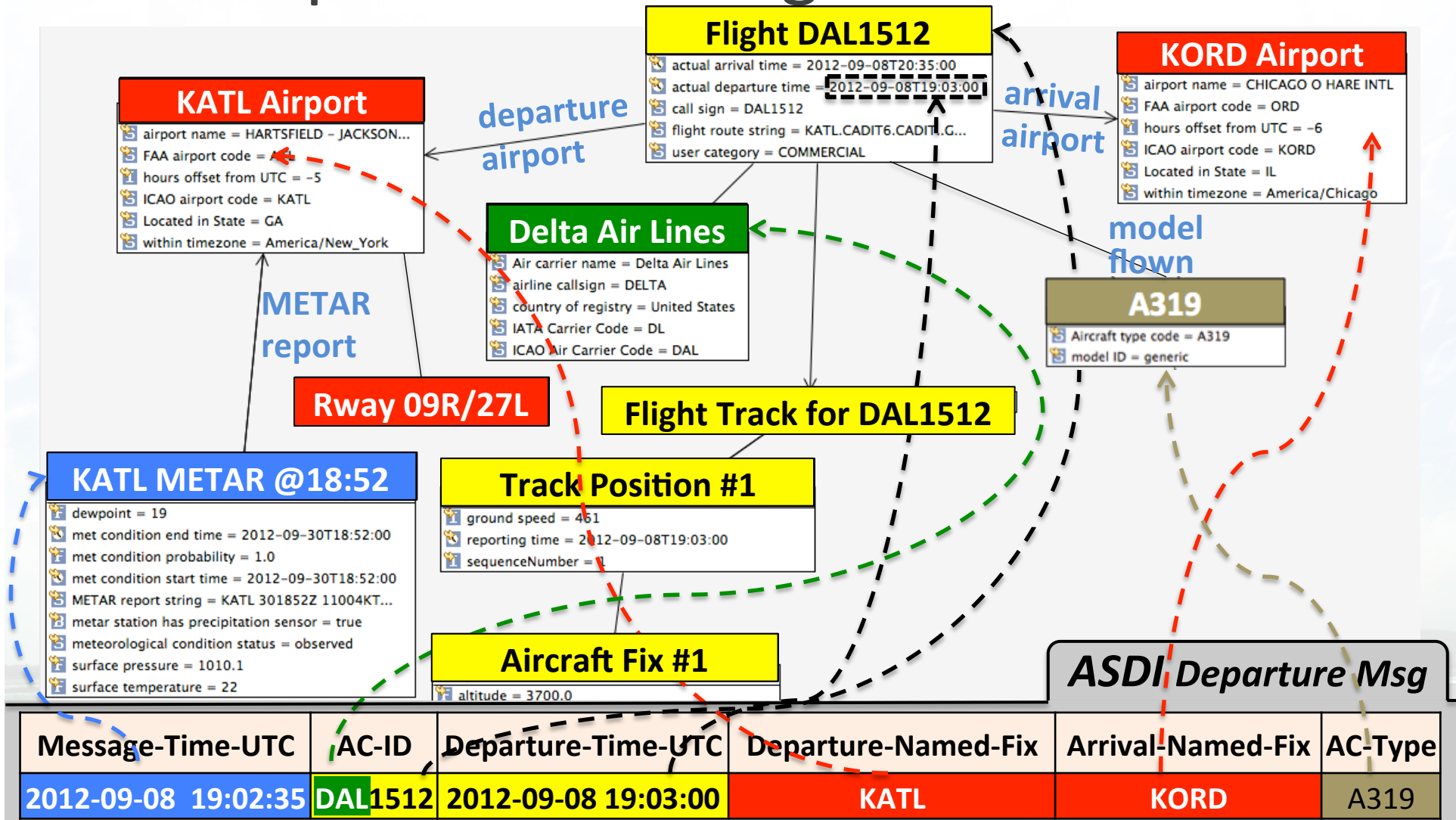
Data Transformation

ASDI Departure Msg

Message-Time-UTC	AC-ID	Departure-Time-UTC	Departure-Named-Fix	Arrival-Named-Fix	AC-Type
2012-09-08 19:02:35	DAL1512	2012-09-08 19:03:00	KATL	KORD	A319

Example: Mapping an ASDI Departure Message

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Querying the Ontology

- Querying = graph-matching:
 - Each query represents a graph pattern
 - The pattern is matched against the ontology network and all possible matches are returned
- SPARQL: W3C standard ontology query language (uses SQL-like syntactic constructs)
- Benchmark Queries:
 - Set of 17 queries developed to evaluate query performance as ontology scales up
 - Query solutions all require integrated data; none can be answered using a single data source alone

Representative Queries

(restricted to flights on 9/8/12, arriving/departing KATL)

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- **Flight Demographics:**
 - F1: Find Delta flights using A319s departing ZTL airports
 - F3: Find flights with rainy departures from ATL
- **Sector Capacity:**
 - S4: Find which sector controlled the most flights during a given hour
 - S6: Find the busiest sectors in the NAS on a given day, aggregating hourly
- **FAA Advisories / TMIs**
 - T1: Find flights that were subject to GDP Advisories
- **Weather-Impacted Traffic (WITI) Calculation**
 - W1: Calculate hourly WITI values (High Wind, Low Ceiling, Low Visibility)
- **ASPM (Flight Delay) Data**
 - A3: Compare ASPM AAR with Arrival Demand on an hourly basis at an airport

Status

- Right now, ATM Ontology is just a prototype
 - Includes over 380K instances of ATM objects/properties
- Working to deploy a test version @ NASA
- Initial results promising, but scale-up will be challenging
- Key tasks ahead:
 - Increase scale
 - Increase scope
 - Develop query interface

Collaborators and Funding

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Aviation Operations & Safety Program



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?? Questions ??

?? Comments ??