Ontologies: Weather and Flight Information

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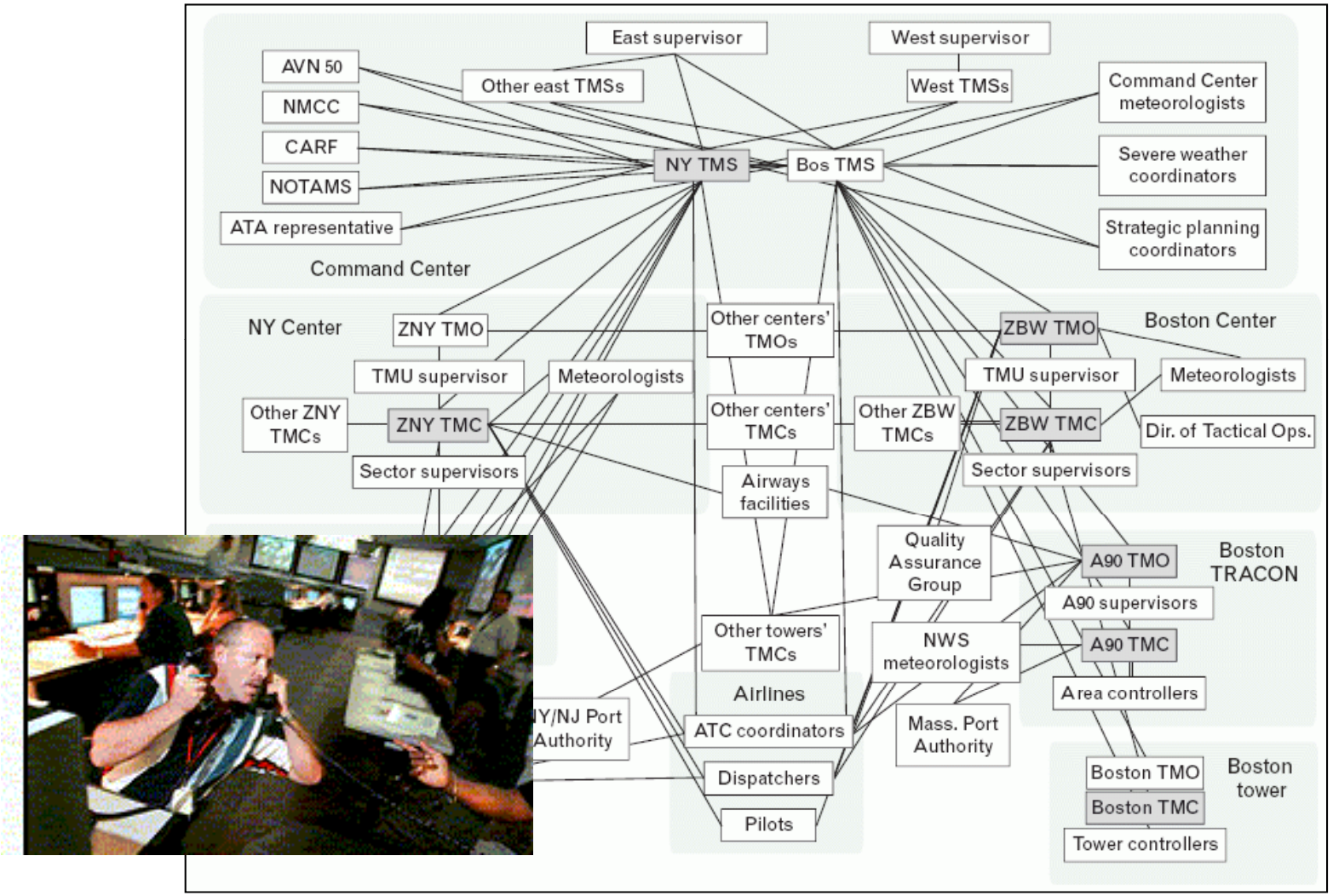
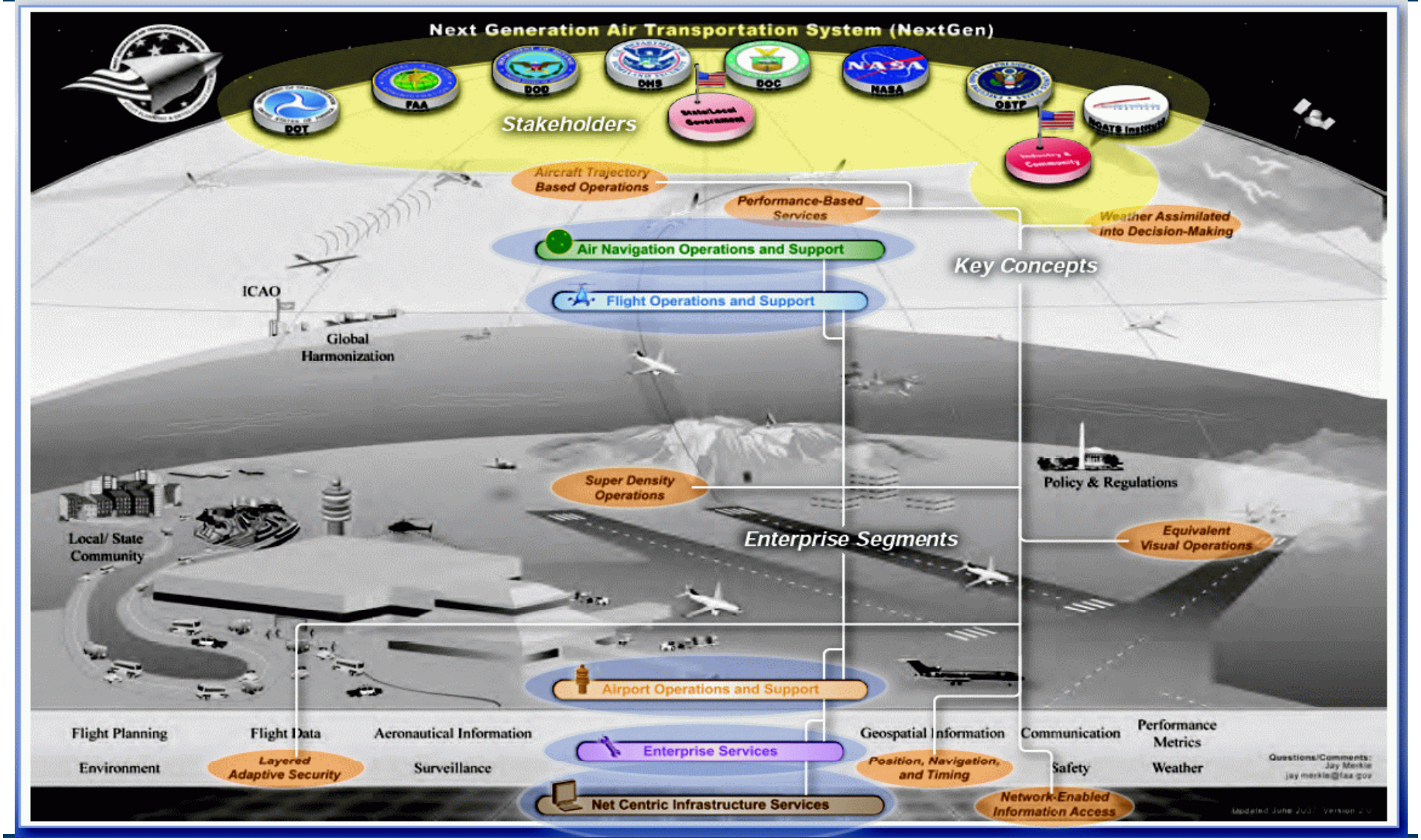
This work was sponsored by the Federal Aviation Administration under Air Force Contract No. FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the United States Government.

Interactions between FAA Facilities and Airlines for Newark Congestion Problems

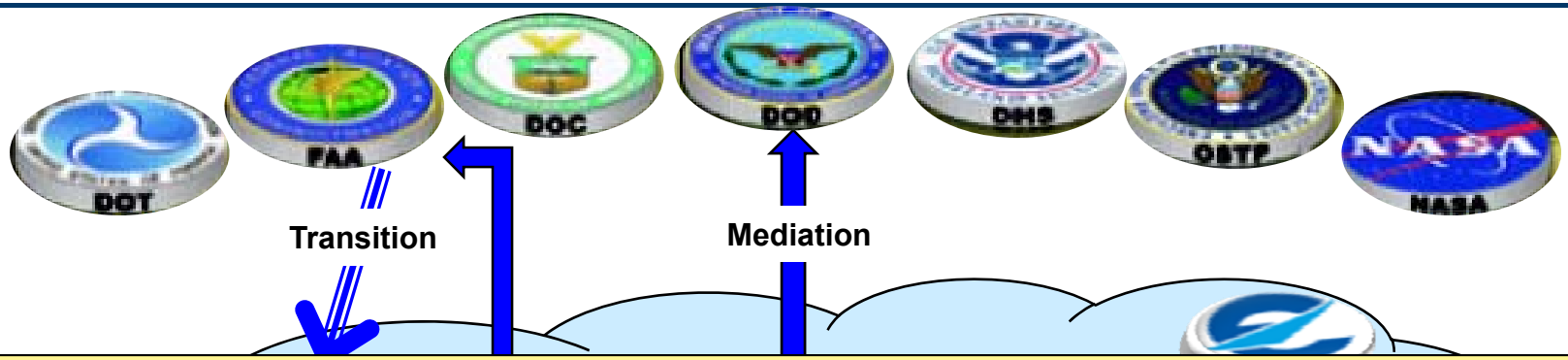


Evans, J. Ducot, E., "Corridor Integrated Weather System, Lincoln Laboratory Journal, Volume 16, Number 1, 2006

Next Generation Air Transportation System Operational Concept



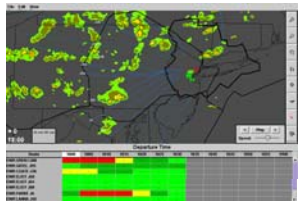
Semantic Interoperability Framework



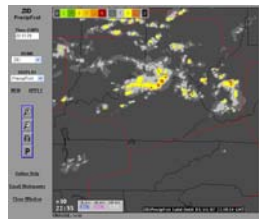
Semantic Interoperability Framework must be able to support

- Mediation for systems that will never switch over
- Transition of legacy systems to net-centric systems
- New systems

Cockpit Weather Displays



Decision Support Tools



Web-based Tools

Outline

- Background

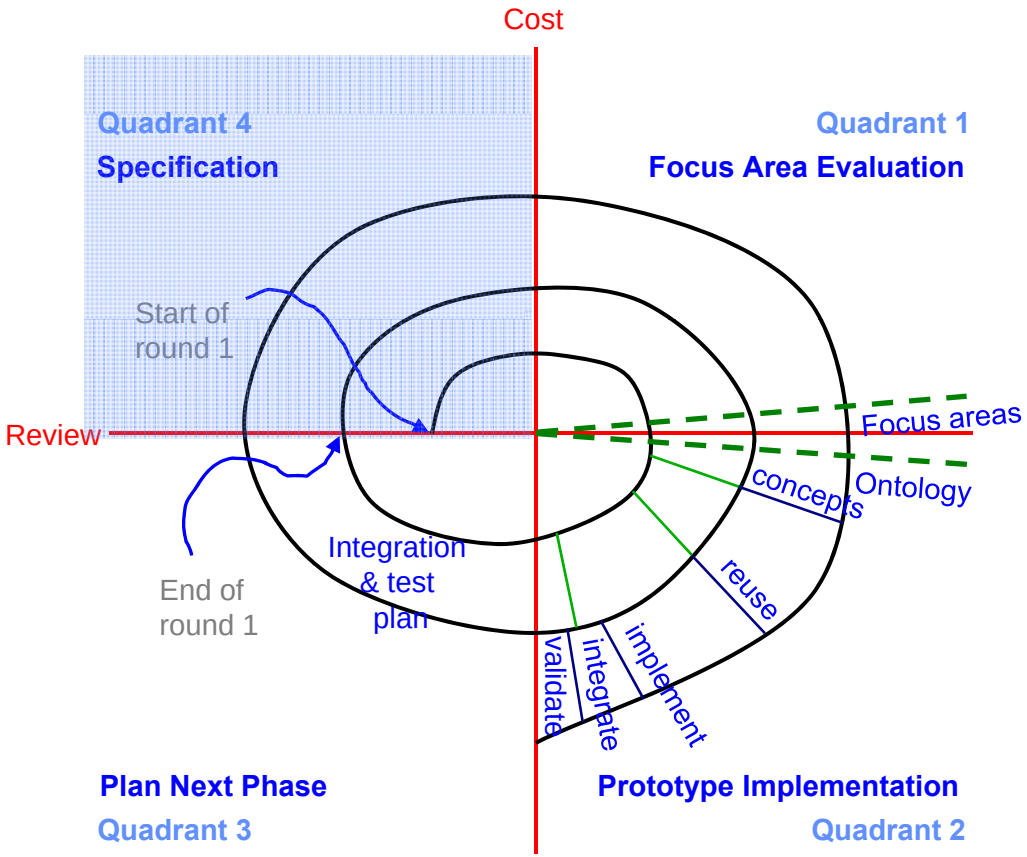
- Ontology Engineering (Kajal)
  - NNEW Weather Ontology
  - Flight Object Ontology

- Ontology Alignment (Kelly)
  - Ontology Alignment
  - Semantic Discovery in NextGen Network Enabled Weather (NNEW)

- Summary

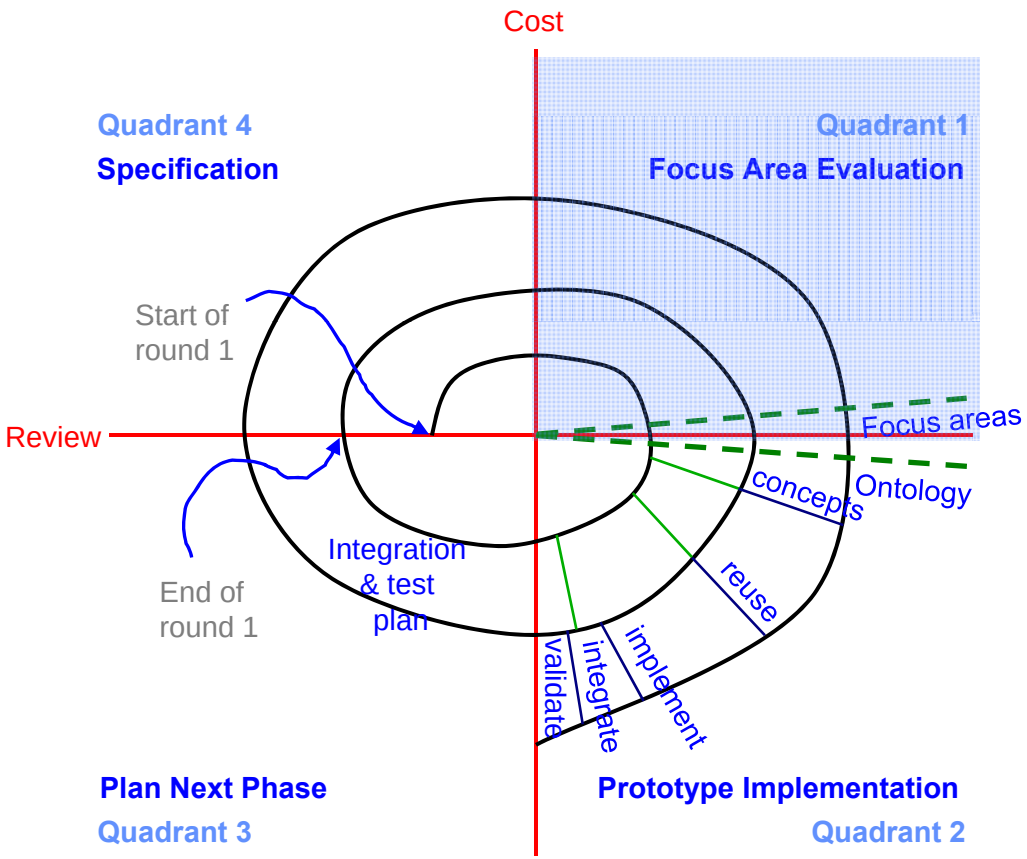
NNEW Ontology Development Methodology – "Green" Engineering

- **Ontology-level method:**
  - Spiral development methodology
  - **Specification:** Define the domain and scope of the ontology



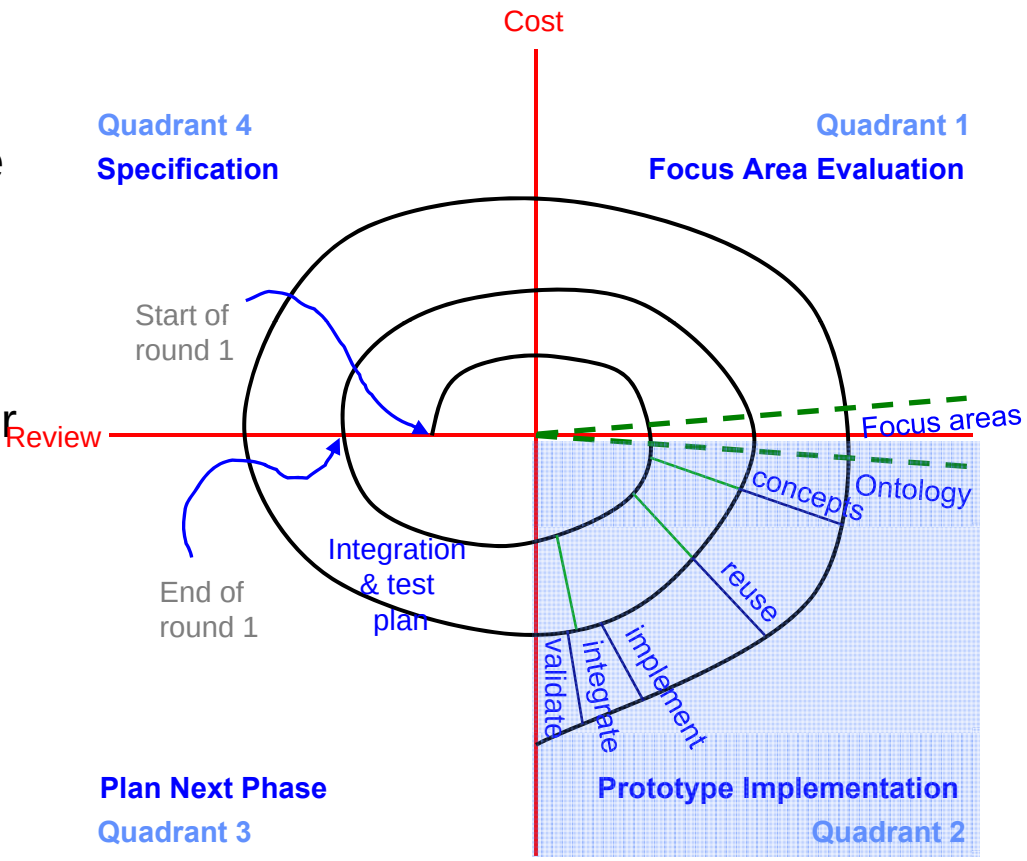
NNEW Ontology Development Methodology

- **Ontology-level method:**
  - **Focus Area Evaluation:** Segment the overall domain and scope of ontology into smaller focus areas. Prioritize the focus area.



NNEW Ontology Development Methodology

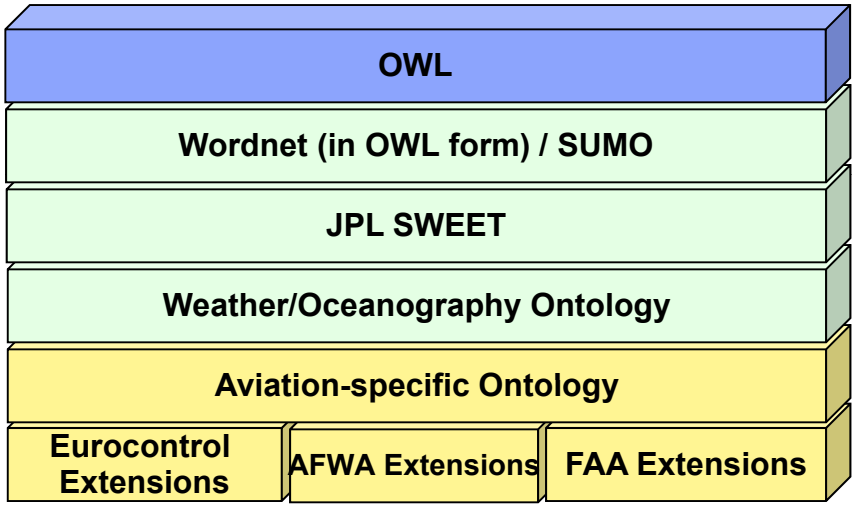
- **Prototype implementation:**
  - **Conceptualize**: Enumerate important concepts
  - **Reuse:** Identify reuse opportunities at upper/mid/low ontologies for straight reuse or as starting point
  - **Implement:** Define the classes, class hierarchy, and properties for the concept
  - **Validate:** Validate the ontology focus area



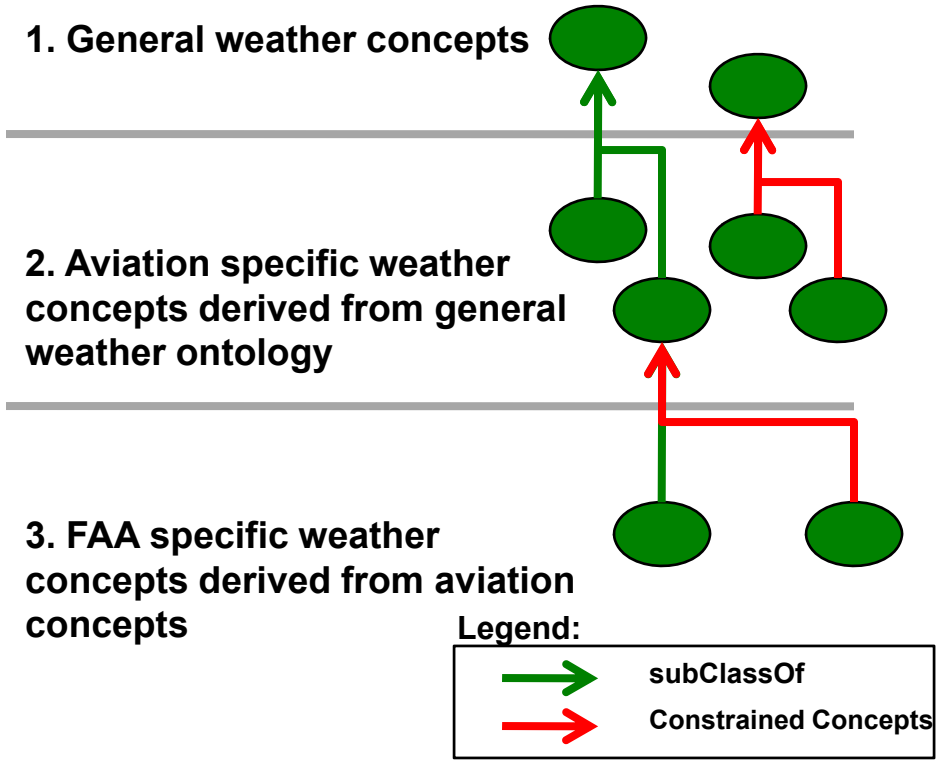
Design Principles

- **Design principles:**
  - **Expressive representation**
    Model concepts with hierarchies and relationships, not with flat term concatenation
  - **Internal concept reuse**
    Reusing concepts *within* an ontology ensures consistency and reduces ambiguity
  - **Consistent scoping**
    Converge on a common granularity for each sub-domain

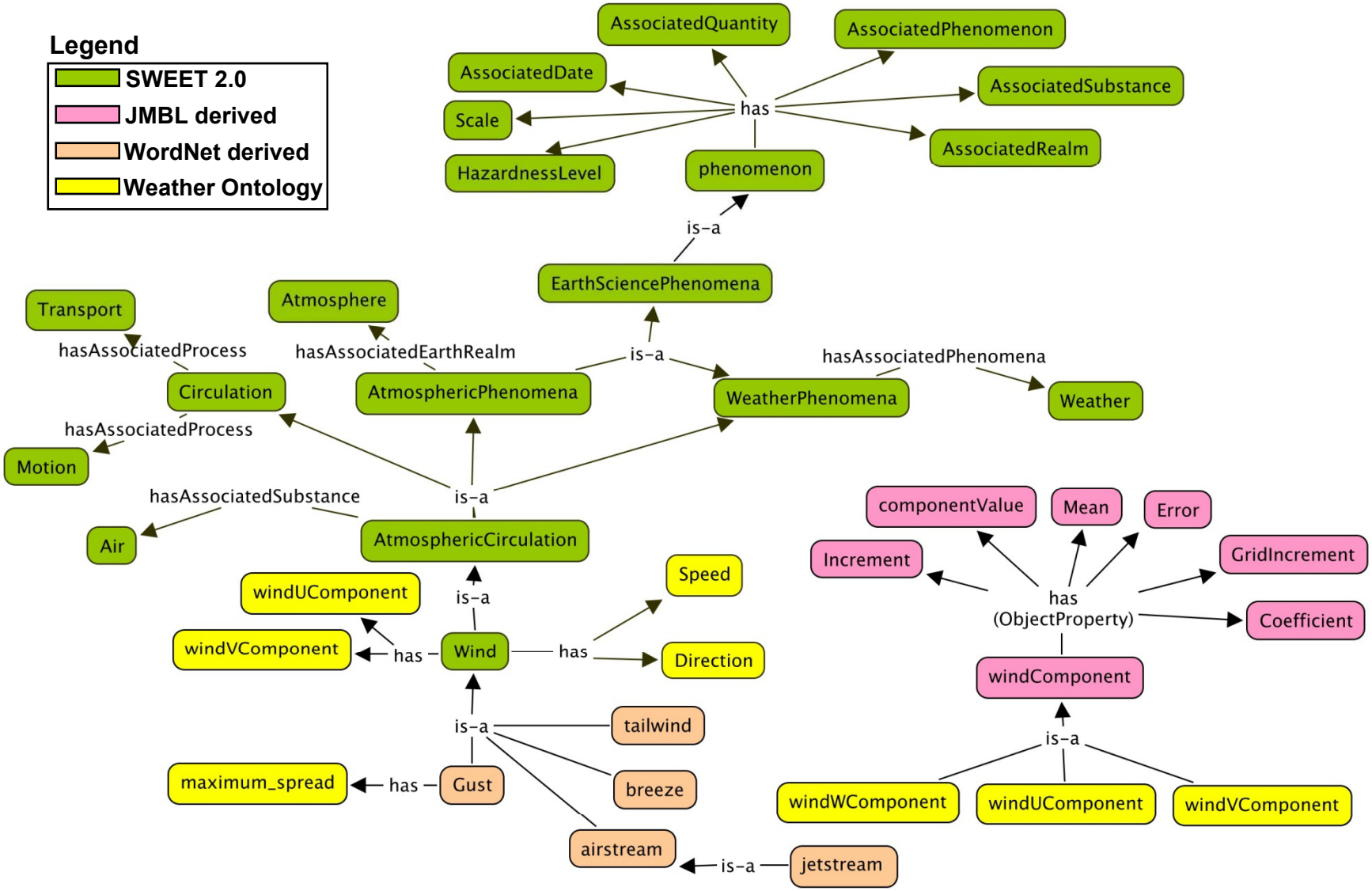
NNEW Weather Ontology



Layered Approach to Ontology Design



Example: Wind Ontology



Flight Information Ontology: Data Dictionary to Ontology

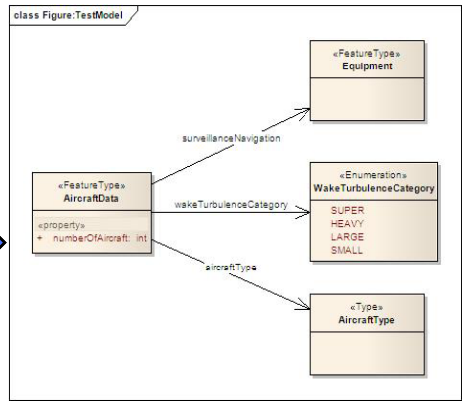
Flight Information & Modeling Process

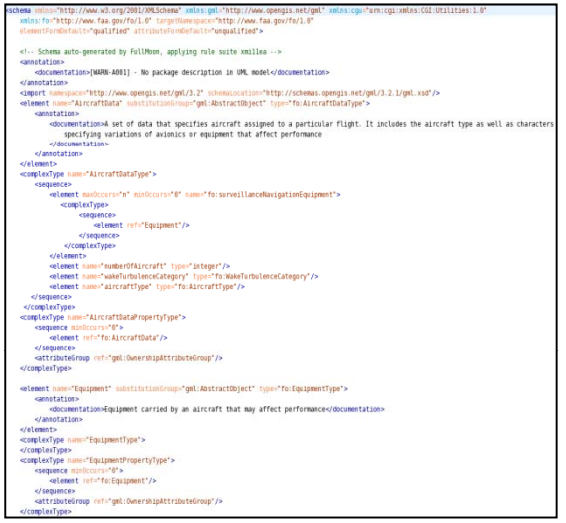
7.9 Aircraft Data

Aircraft Data	
Name	**Taxonomy**
Aircraft Data	[TBD]
Synonyms	**Keywords**
None	Flight plan, aircraft, number, wake, turbulence, category, type, navigation, surveillance, characteristics, performance, capability, navigation
Description	
A set of data that specifies aircraft assigned to a particular flight. It includes the aircraft type (e.g., B757), as well as characters specifying variations of avionics or equipment that affect performance.	
Has Parts	**Is Part Of**
Number of aircraft (optional) Wake turbulence category Aircraft type Navigation and surveillance equipment (optional)	Flight plan
Creator	**Source**
Airspace user	Prior to the flight plan being filed, TFMS is the source of the current Aircraft Data. After a flight plan is filed, ERAM is the source.
Contributors	**Altering Events**
Airspace user	Defined when flight first created. Modified whenever there is a change to the aircraft is assigned to make the flight.
Audience	**Data Usage**
Airspace users Traffic managers Controllers Many systems (TFMS, ERAM, TMA, STARS, CARTS)	Identifies significant characteristics related to aircraft performance and capability, e.g., type indicates climb performance, equipment type indicates navigation capability. Used to model trajectories, determine separation requirements, and determine impact on capacity.

Data Type	Format	Units	Range
compound	n/a	n/a	n/a
Example			
T6, B727, H/B747, B757/A, 4T/DC10/B, B744/H-SDGHIJRWXYZ/SD			

Access Restriction	Maturity	Accrual Method	Accrual Periodicity
None	Current	Automated	Defined when flight first created, updated rarely.
Disposition			**Mandatory**
[TBD]			Yes





Data Dictionary **Data Model** **XML Schema**

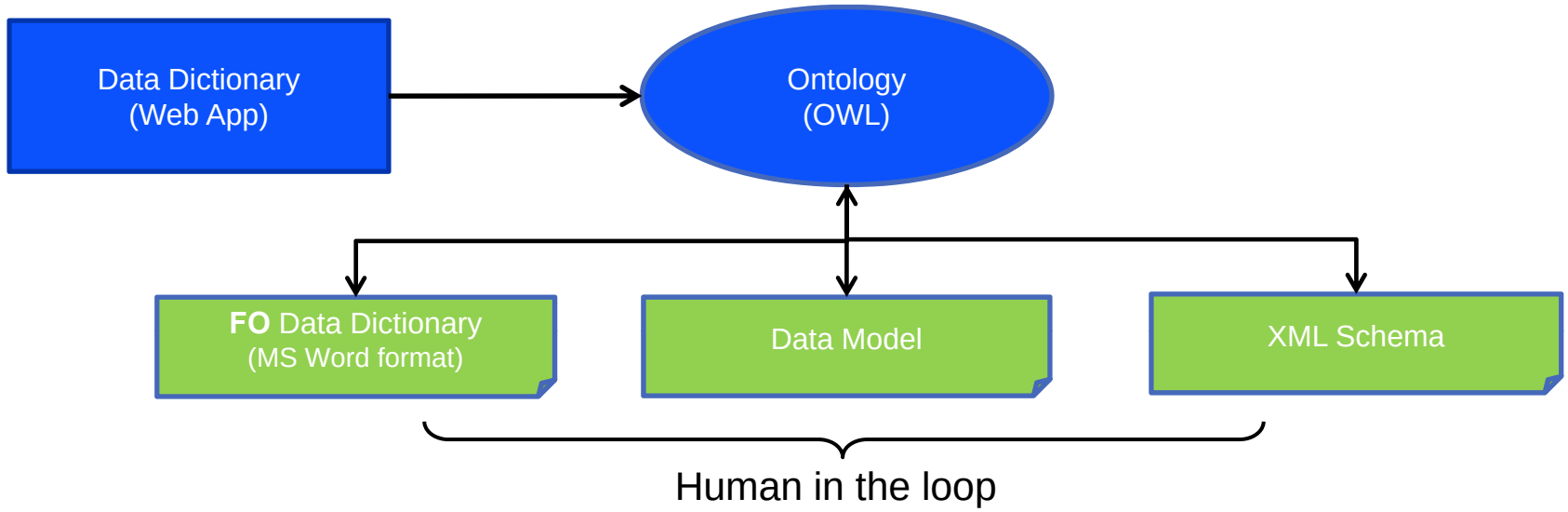
Manual
Time consuming

Automated
FullMoon + extensions

Key Issue:

- DD - human readable not machine readable

Ontology: Capturing Knowledge



- **Machine readable: Semi-automate generation of data model**
- **Machine process-able:**
  - **Can be reasoned over**
  - **Can support mediation for transition systems**
- **Searchable/indexable**
- **Basis of capturing agreement, and of applying knowledge**

An Ontology Embedded in Word Template !

Concept

Concept label

Axiom: Equivalent class

Annotation: dc:description

Object property: hasPart

Object property: createdBy

Object property: hasContributor

Object property: hasAudience

Datatype property: hasFormat [range: string]

Datatype property: hasMaturity [range: string]

Object property: hasAccess

Datatype property: hasDisposition [range: string]

Object property: requires

Annotation: references (custom)

Datatype property: hasDataTransaction [range: string]

Annotation: dc:date [type:date]

7.24 ASSIGNED_RTE

ASSIGNED_RTE	
Name	**Taxonomy**
ASSIGNED_RTE	[TBD]
Synonyms	**Keywords**
Assigned Route	TFMDI, TFMS
Description	
A route assigned to a flight as part of a reroute traffic management initiative. A flight can have more than one assigned route.	
Has Parts	**Is Part Of**
Route elements (fixes, airways etc.)	none
Creator	**Source**
Traffic Manager	TFMS
Contributors	**Altering Events**
Traffic Manager	Created when a reroute is issued for a flight. Can be modified by the traffic manager if the reroute is edited.
Audience	**Data Usage**
TFMDI users (airlines etc.) Traffic Managers	Identifies an assigned route. Users are supposed to file and follow assigned routes. Reroute monitor compares assigned routes to current field routes to determine reroute conformance. Traffic managers at the TMUs monitor reroute conformance and put flights on their assigned routes if the users do not file them.

Data Type	Format	Units	Range
string	A list of route elements (fixes, airways etc.) separated by spaces.	n/a	Up to 1024 characters.

Example
<CTR_ASSIGNED_RTE>ROD MIE SHM TARNE1</CTR_ASSIGNED_RTE>

Access Restriction	Maturity	Accrual Method	Accrual Periodicity
[TBD]	current	assigned	rarely

Disposition	Mandatory
Exists until reroute expires or is cancelled or flight is disposed of.	No

Requires	Is Required By
ASSIGNED_RTE_TYPE	none

References
[TBD]

Data Transactions or Interfaces
TFMDI data exchanges.

Notes
n/a

Version	Date	Author	Description of Changes
1.0	6 August 2010	Michael Harris (Volpe)	Initial version for review.

Datatype property: hasKeyword [range: string]

Axiom: Inverse properties

Object property: hasSource

Object property: hasAlteringEvent [range: string]

Datatype property: hasDataUsage [range: string]

Object property: measurement.owl#hasUnit

Instance data

Datatype property: hasAccrualMethod [range: string]

Datatype property: hasAccuralPeriodicity [range: string]

Datatype property: isMandatory [range: boolean]

Axiom: Inverse properties

Annotation: rdf:comment

Annotation: dc:creator

Annotation: dc:versionInfo

Concept | Object property | Datatype property | Axiom | Annotation | Instance Data

Ontology Example

Text

7.24 ASSIGNED_RTE

Name	Taxonomy
ASSIGNED_RTE	[TBD]
Synonyms	**Keywords**
Assigned Route	TFMDI, TFMS

Description

A route assigned to a flight as part of a reroute traffic management initiative. A flight can have more than one assigned route.

Has Parts	Is Part Of
Route elements (fixes, airways etc.)	none
Creator	**Source**
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Requires	Is Required By
ASSIGNED_RTE_TYPE	none

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[TBD]

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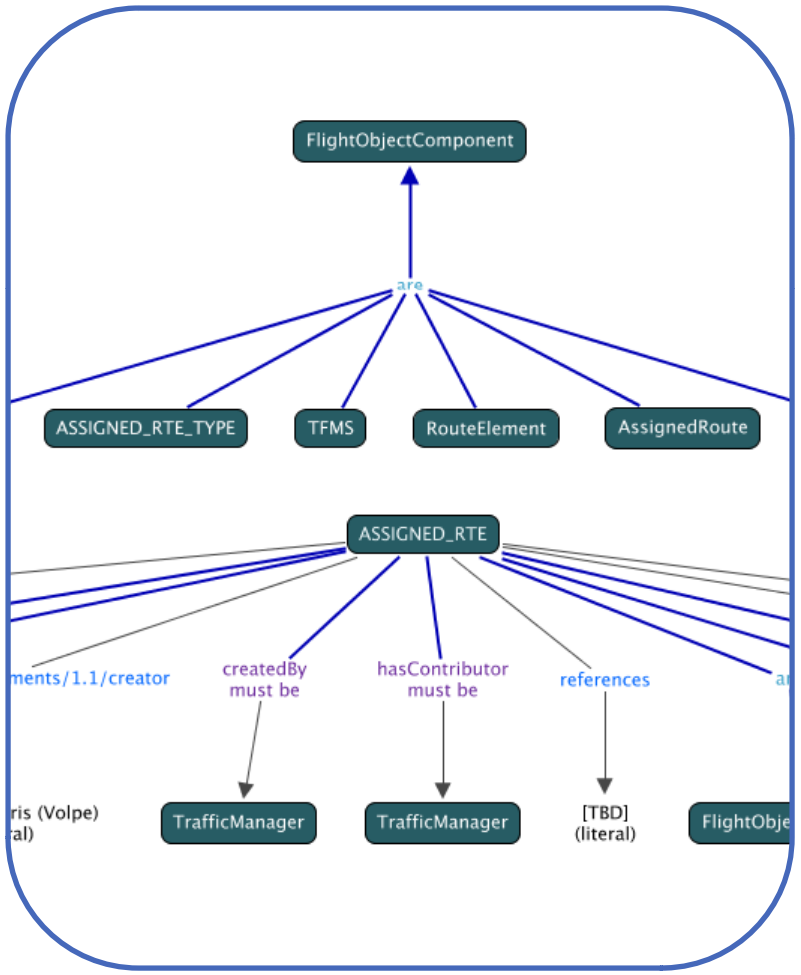
Ontology



Outline

- Background
- **Semantic Interoperability Framework**
  - NNEW Weather Ontology
  - **Ontology/Vocabulary Alignment**
  - **Semantic Discovery in NextGen Network Enabled Weather (NNEW)**
- **Summary**

Interoperability Challenges

National Weather Service Vocabulary
(Climate and Forecast)

aerosol_angstrom_exponent
age_of_stratospheric_air
air_density
air_potential_temperature
air_pressure
air_pressure_anomaly
air_pressure_at_cloud_base
air_pressure_at_cloud_top
air_pressure_at_convective_cloud_base
air_pressure_at_convective_cloud_top
air_pressure_at_freezing_level
air_pressure_at_sea_level
air_temperature
air_temperature_anomaly
air_temperature_at_cloud_top
air_temperature_lapse_rate
air_temperature_threshold
altimeter_range
altimeter_range_correction_due_to_dry_troposphere
altimeter_range_correction_due_to_ionosphere
altimeter_range_correction_due_to_wet_troposphere
altitude
altitude_at_top_of_dry_convection
angle_of_emergence
angle_of_incidence
angle_of_rotation_from_east_to_x
angle_of_rotation_from_east_to_y
angstrom_exponent_of_ambient_aerosol_in_air

air_temperature

atmosphere_absolute_vorticity

1046

Department of Defense Vocabulary
(Joint METOC Broker Language – JMBL)

temperatureAdiabaticLapseRate temperatureAir
temperatureAirDifferenceStandard
temperatureAirError temperatureAirErrorEstimate
temperatureAirIncrement temperatureAirMean
temperatureAnomaly temperatureAntenna
temperatureBoundary temperatureBrightness
temperatureBrightnessCorrected
temperatureBrightnessCount
temperatureBrightnessOccurrence
temperatureBrightnessStandardDeviation
temperatureDewpoint
temperatureDewpointDepression
temperatureDewpointDepressionCoefficient
temperatureDewpointDepressionErrorEstimate
temperatureDewpointDepressionIncrement
temperatureDewpointDepressionMinimum
temperatureDewpointMaximum
temperatureDewpointMaximumMean
temperatureDewpointMaximumStandardDeviation
temperatureDewpointMean
temperatureDewpointMinimum
temperatureDewpointMinimumMean
temperatureDewpointMinimumStandardDeviation
temperatureDewpointStandardDeviation
temperatureDifference temperatureEarthSkin
temperatureFrequency temperatureGradient
temperatureHeatIndex
temperatureInfraredStandardDeviation

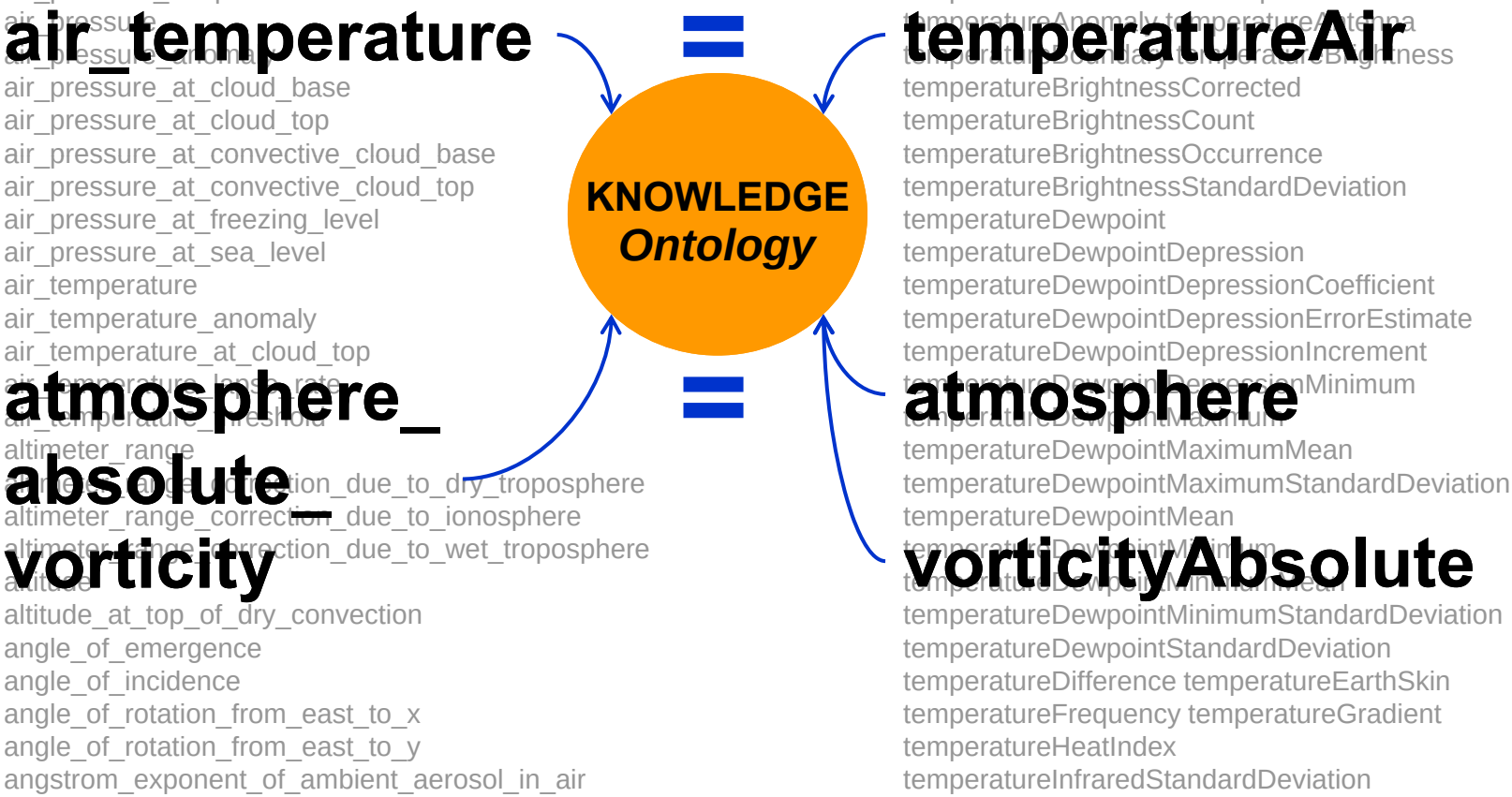
temperatureAir

atmosphere

verticityAbsolute

1270

But What If…


Scientific Community Vocabulary
(Climate and Forecast)
aerosol_angstrom_exponent
age_of_stratospheric_air
air_density
air_potential_temperature
air_pressure
air_pressure_anomaly
air_pressure_at_cloud_base
air_pressure_at_cloud_top
air_pressure_at_convective_cloud_base
air_pressure_at_convective_cloud_top
air_pressure_at_freezing_level
air_pressure_at_sea_level
air_temperature
air_temperature_anomaly
air_temperature_at_cloud_top
air_temperature_lapse_rate
air_temperature_threshold
altimeter_range
altimeter_range_correction_due_to_dry_troposphere
altimeter_range_correction_due_to_ionosphere
altimeter_range_correction_due_to_wet_troposphere
altitude
altitude_at_top_of_dry_convection
angle_of_emergence
angle_of_incidence
angle_of_rotation_from_east_to_x
angle_of_rotation_from_east_to_y
angstrom_exponent_of_ambient_aerosol_in_air
air_temperature
=
temperatureAir
KNOWLEDGE
Ontology
atmosphere_
absolute_
vorticity
=
atmosphere
vorticityAbsolute
Department of Defense Vocabulary
(Joint METOC Broker Language – JMBL)
temperatureAdiabaticLapseRate temperatureAir
temperatureAirDifferenceStandard
temperatureAirError temperatureAirErrorEstimate
temperatureAirIncrement temperatureAirMean
temperatureAnomaly temperatureAntenna
temperatureBoundary temperatureBrightness
temperatureBrightnessCorrected
temperatureBrightnessCount
temperatureBrightnessOccurrence
temperatureBrightnessStandardDeviation
temperatureDewpoint
temperatureDewpointDepression
temperatureDewpointDepressionCoefficient
temperatureDewpointDepressionErrorEstimate
temperatureDewpointDepressionIncrement
temperatureDewpointDepressionMinimum
temperatureDewpointMaximum
temperatureDewpointMaximumMean
temperatureDewpointMaximumStandardDeviation
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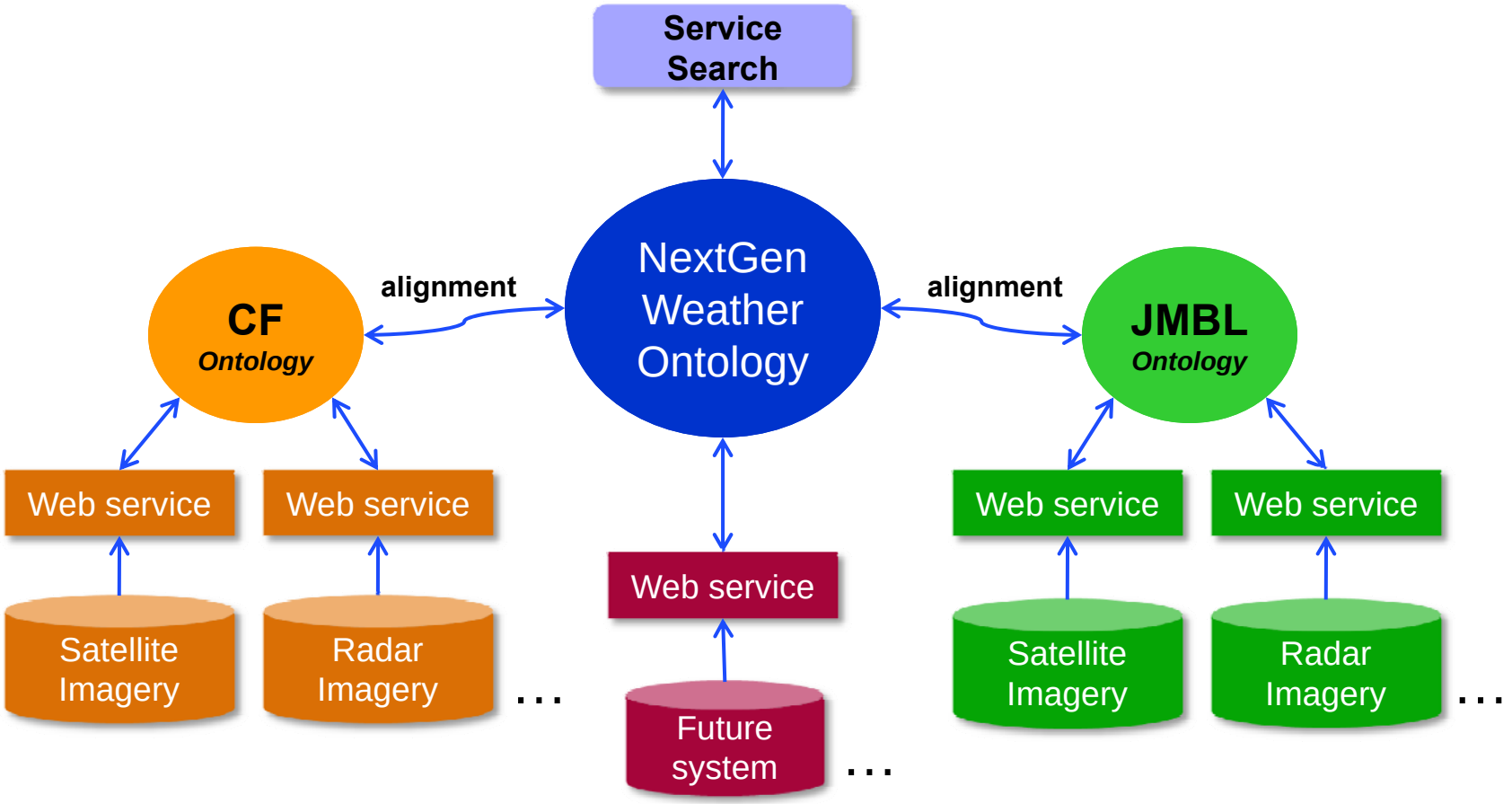
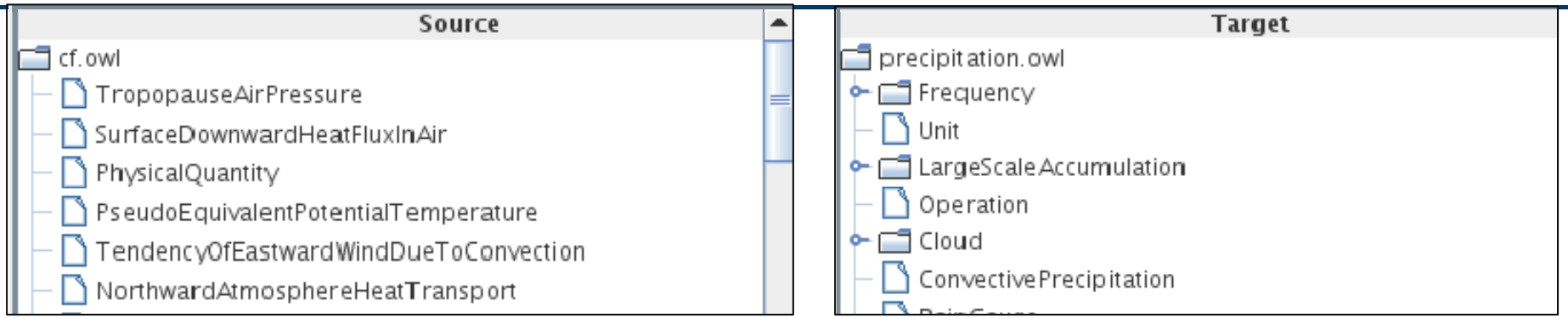
temperatureDewpointMinimumStandardDeviation
temperatureDewpointStandardDeviation
temperatureDifference temperatureEarthSkin
temperatureFrequency temperatureGradient
temperatureHeatIndex
temperatureInfraredStandardDeviation

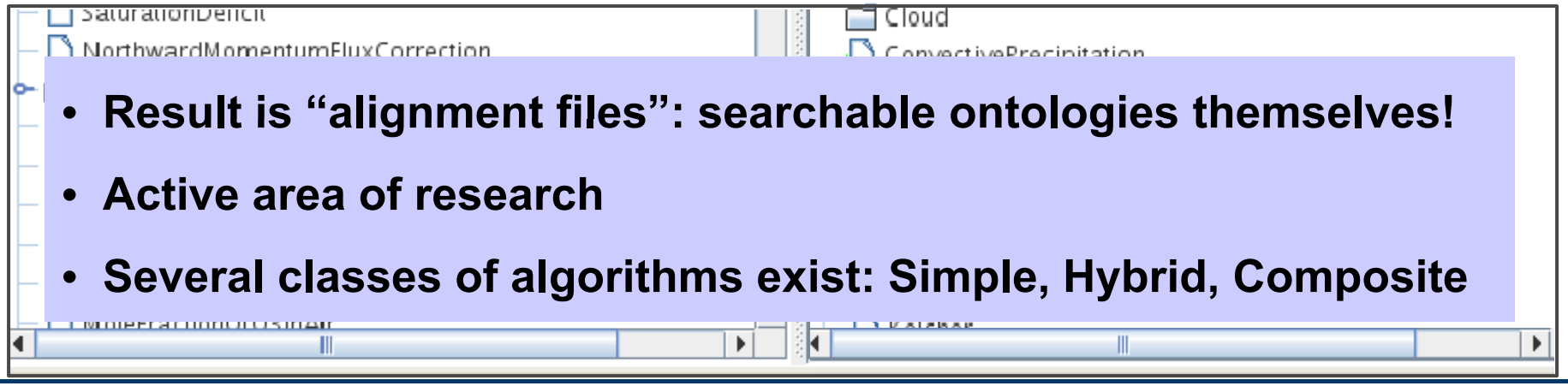
Ontologies in NNEW



Ontology Alignment Process



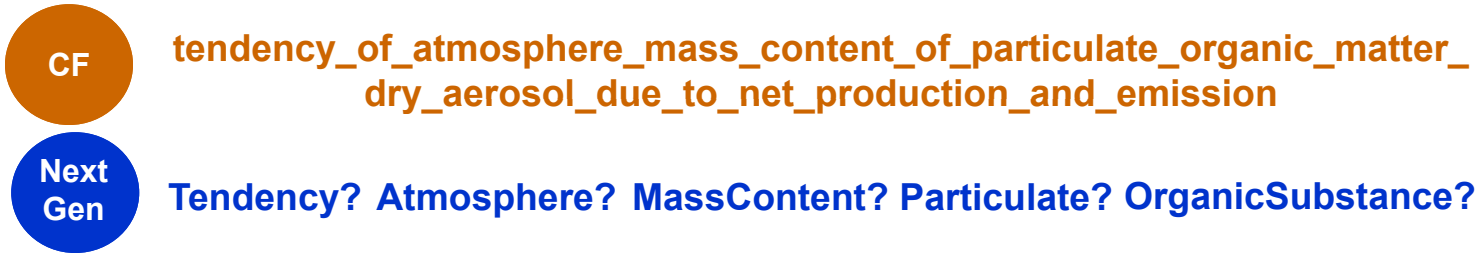
Alignment Algorithm



- **Result is "alignment files": searchable ontologies themselves!**
- **Active area of research**
- **Several classes of algorithms exist: Simple, Hybrid, Composite**

Ontology Alignment in the Weather Domain

- Most algorithms are developed to map between expressive ontologies[1, 2]
  - Leverage the semantics encapsulated within the ontologies
- Weather domain often includes less expressive ontologies that contain long concatenations of terms
  - Often mapped to more modular central ontologies (NextGen)



- Typical alignment algorithms are not suited to this problem
  - Can only detect 1:1 matches
- Need an algorithm that can detect n-ary matches (n:1, 1:n)

CompositeMatch Algorithm

- Lincoln-developed alignment algorithm identifies both 1:1 and n-ary (or "composite") matches[3]
- Hybrid algorithm
  - Uses four scoring methods to determine *what is a match*

    Lexical

    Linguistic

    Context

    Metadata

CompositeMatch Scoring Methods

Lexical

- Compares two concept names based on their *syntax*
  - String and substring comparison (reordering)
  - Tokenization
  - Acronym detection
  - Abbreviation detection
  - Plural detection

VeritcallyIntegratedLiquid ≈ Liquid_Integrated_Vertically ≈ VIL

CompositeMatch Scoring Methods

Linguistic

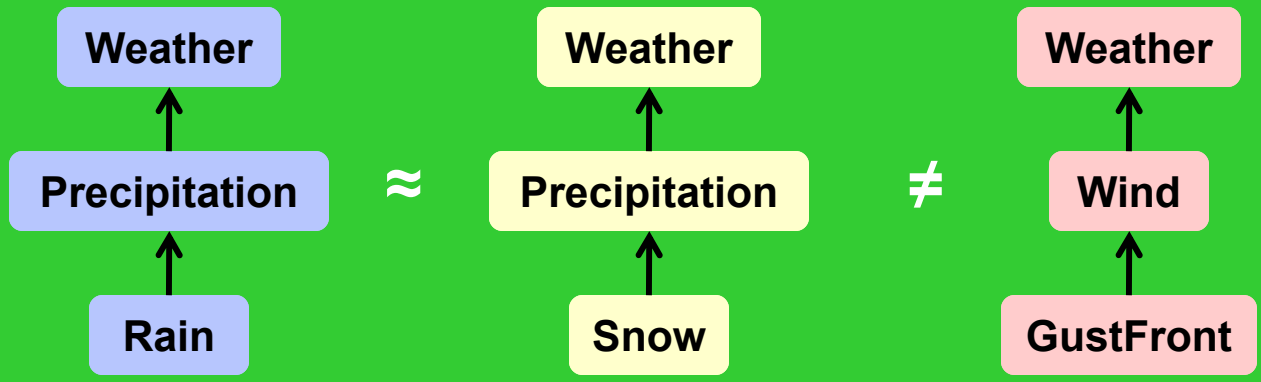
- Compares two concept names based on their *semantics*
  - WordNet: Large English database of terms grouped into synonyms, linked by semantic relations
  - Performs WordNet lookup to get semantic similarity

WaterVapor ≈ AqueousVapor

CompositeMatch Scoring Methods

Context

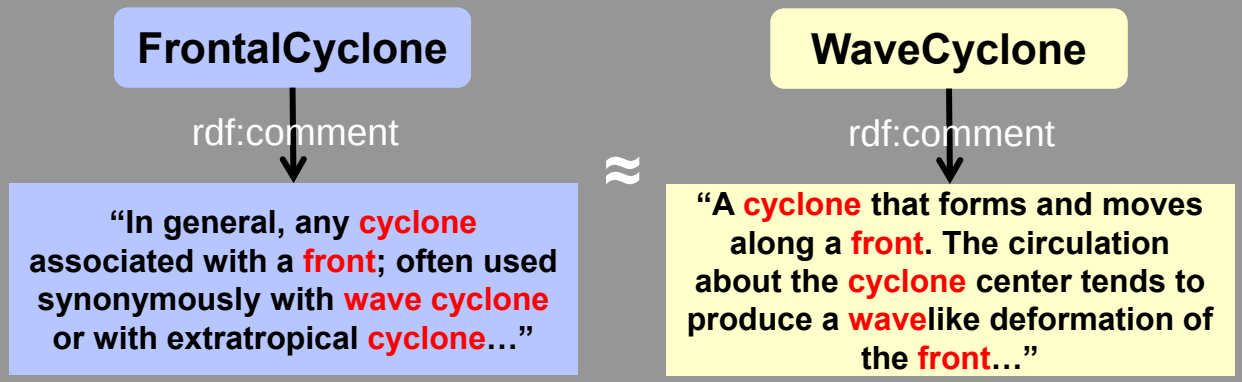
- Compares the "context" of two concepts
  - Compares two concepts' weighted subgraphs to a given depth *d*



CompositeMatch Scoring Methods

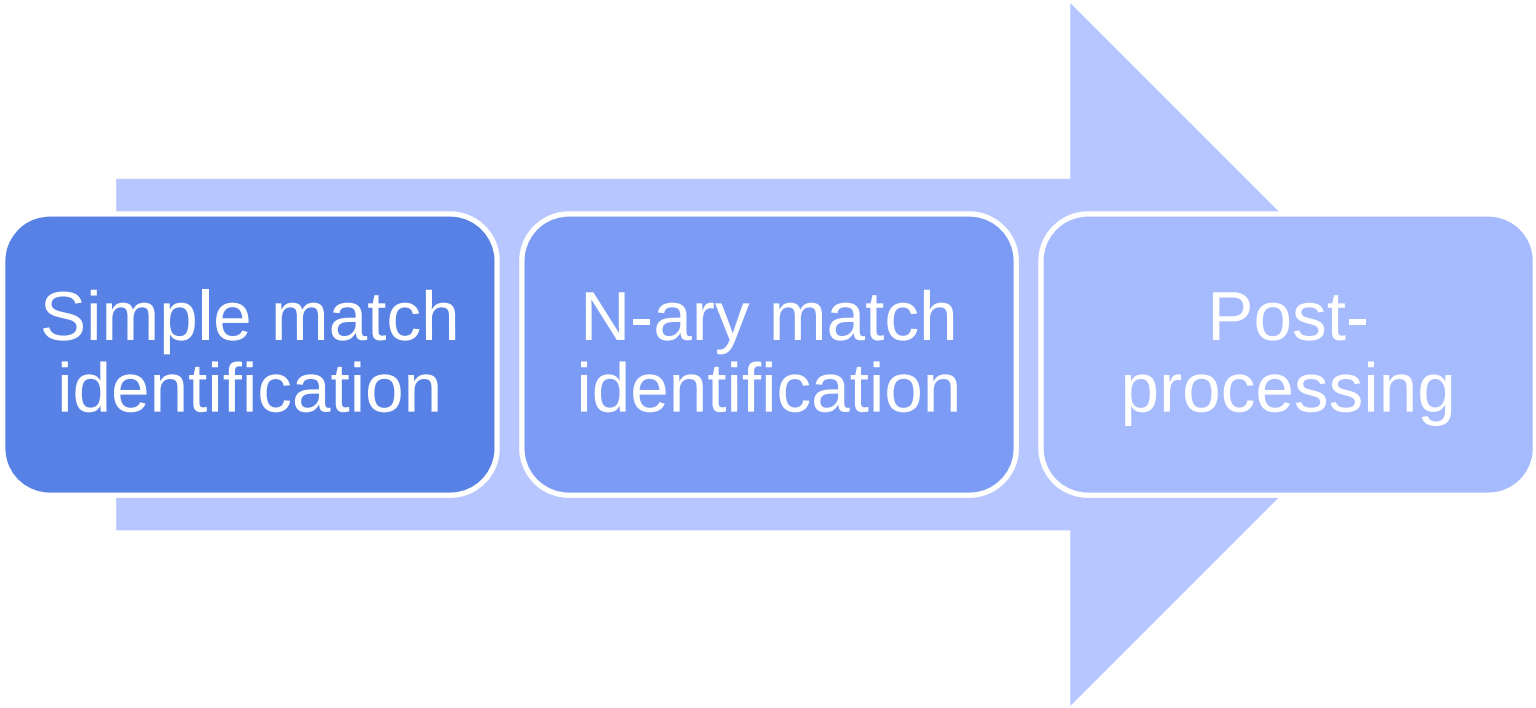
Metadata

- Compares the comments of two concepts
  - Comments contain descriptions of concepts
  - Lexical comparison of comments renders a metadata similarity score



CompositeMatch Process

- **Three-pass algorithm**



CompositeMatch Process

1 Simple match identification

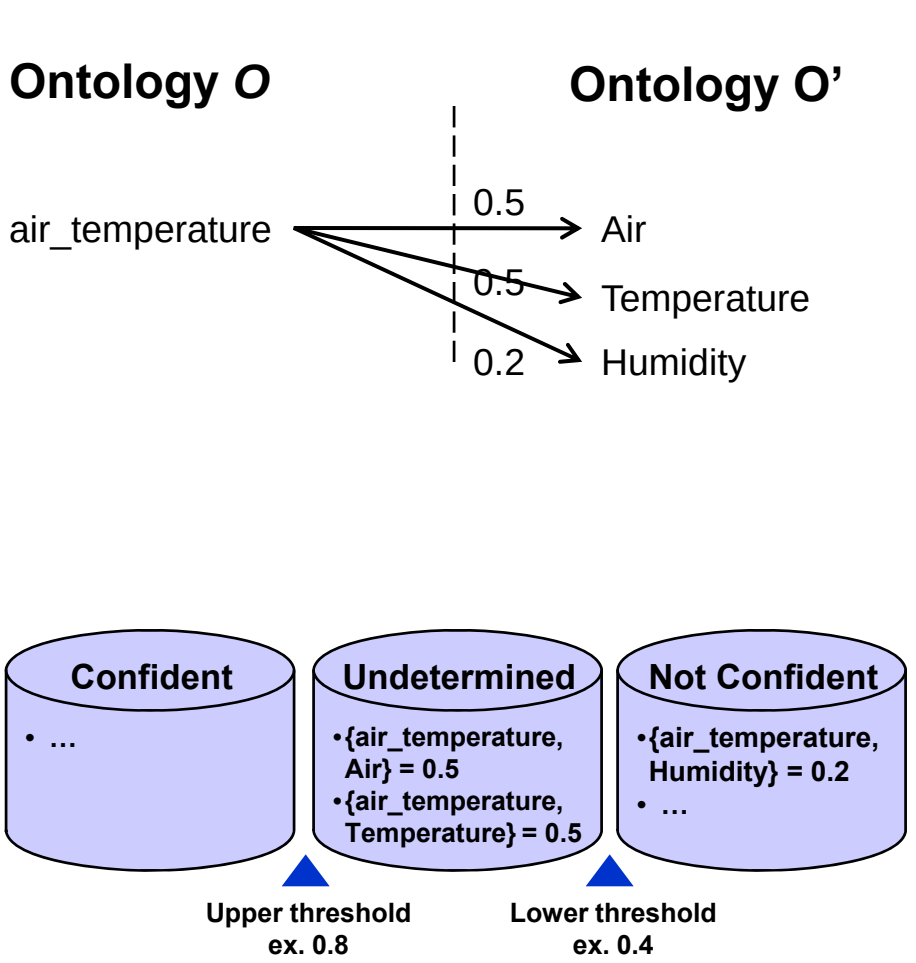
- Score every concept *c* from *O* with every concept *c*' from *O*'
- Sort pairs into "buckets"

2 N-ary match identification

- Generate composites from "conflict sets" using subsetting
- Sort pairs into "buckets"

3 Post-processing

- Optionally reduce to single best match per concept ("best match only" option)



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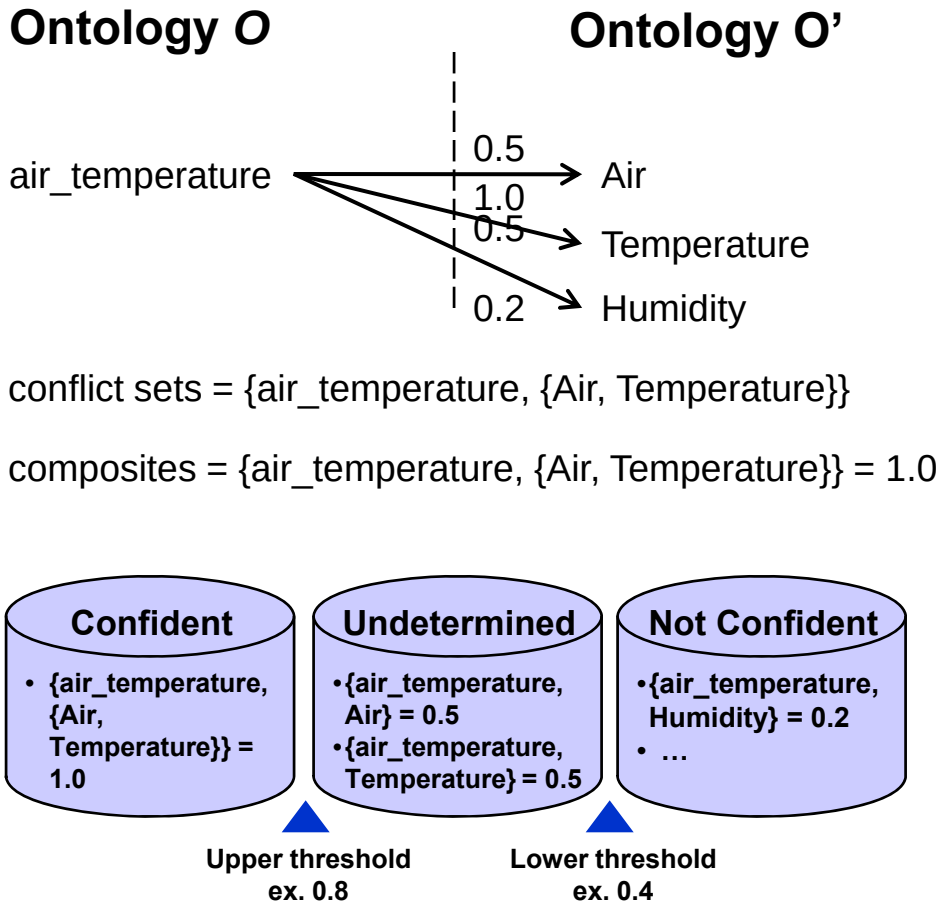

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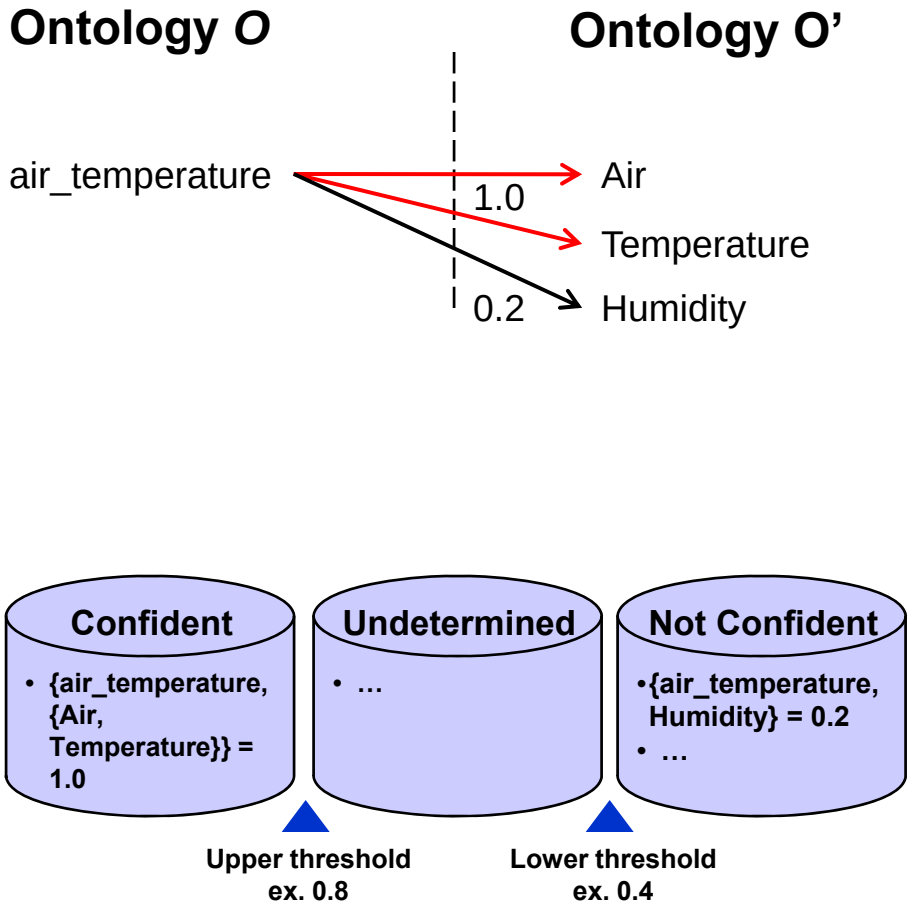
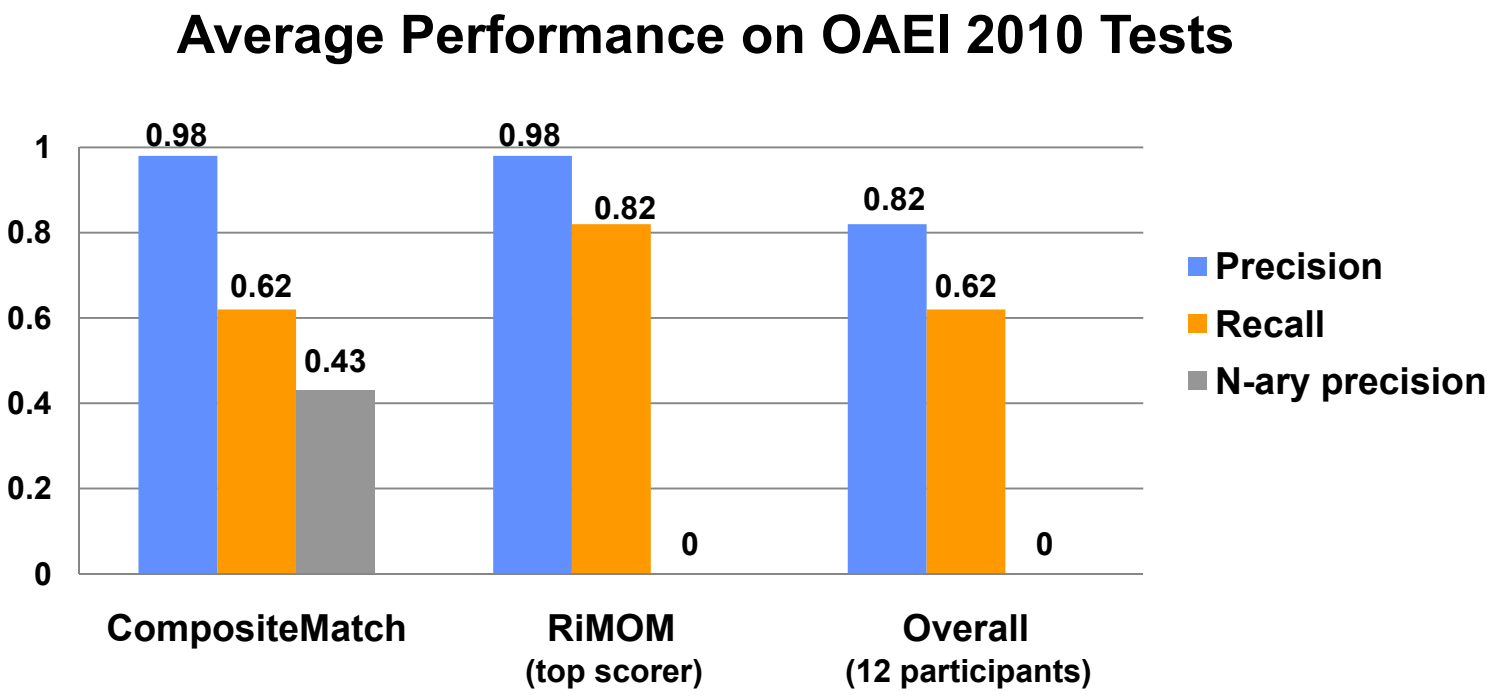
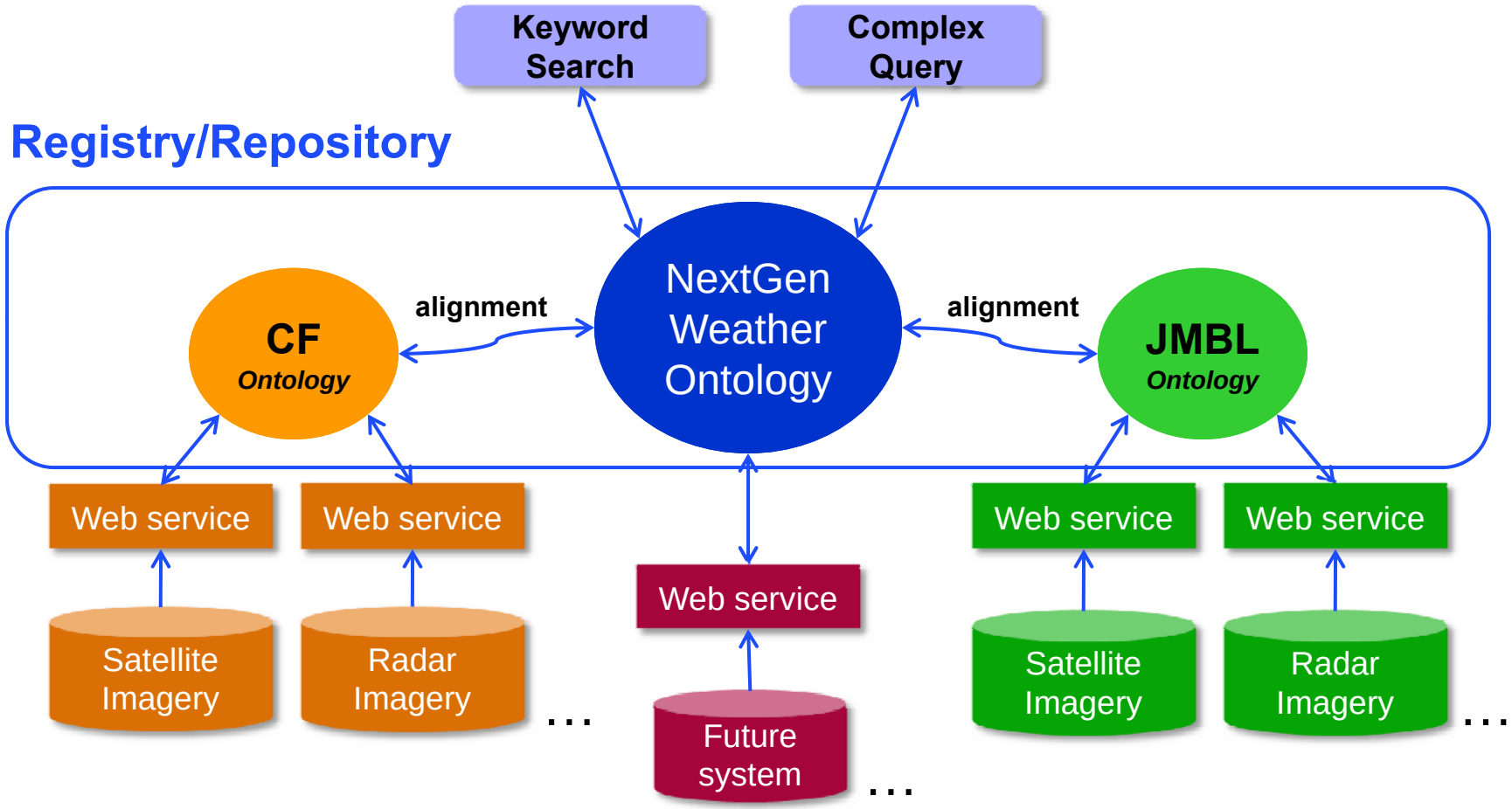


Evaluation Results

- Test suite: OAEI 2010 Benchmark[4]
  - 12 participants total
  - Top scorer: Risk Minimization-Based Ontology Mapping (RiMOM)[5]

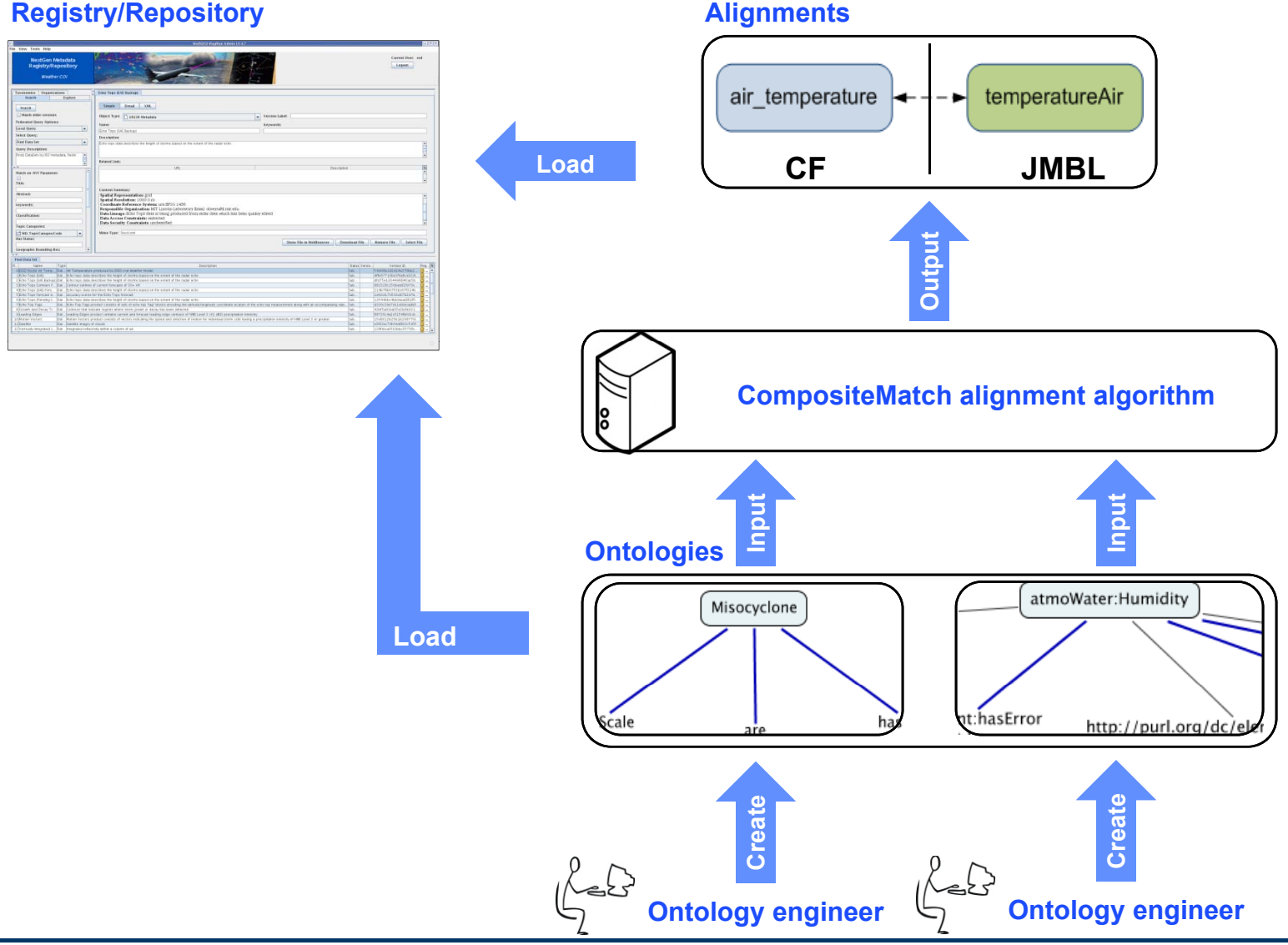


Semantic Search



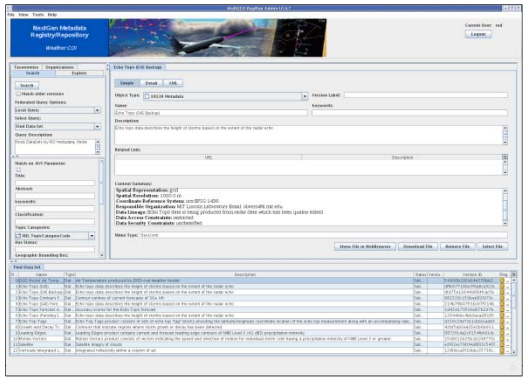
air_temperature ⟷ {Air, Temperature} ⟷ TemperatureAir

Semantic Search: Design Time



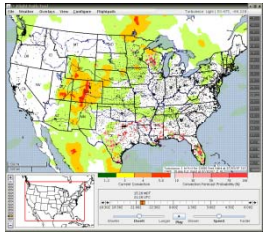
Semantic Search: Runtime

Registry/Repository



Clients

End user



OGC service-enabled display client

"Find the sources for air temperature information in the CONUS"

Service discovery

SPARQL Query

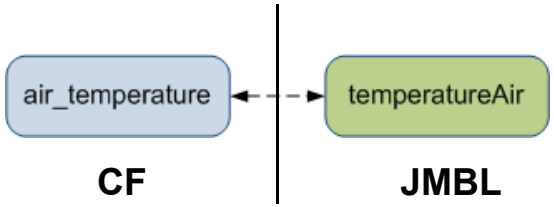
"Give me the air temperature grid for the entire CONUS from now until 2 days from now"

Request/ Response

Publish/ Subscribe

"Give me air temperature information as it becomes available within the CONUS"

NNEW Weather Ontology and Alignments



Loaded at design time

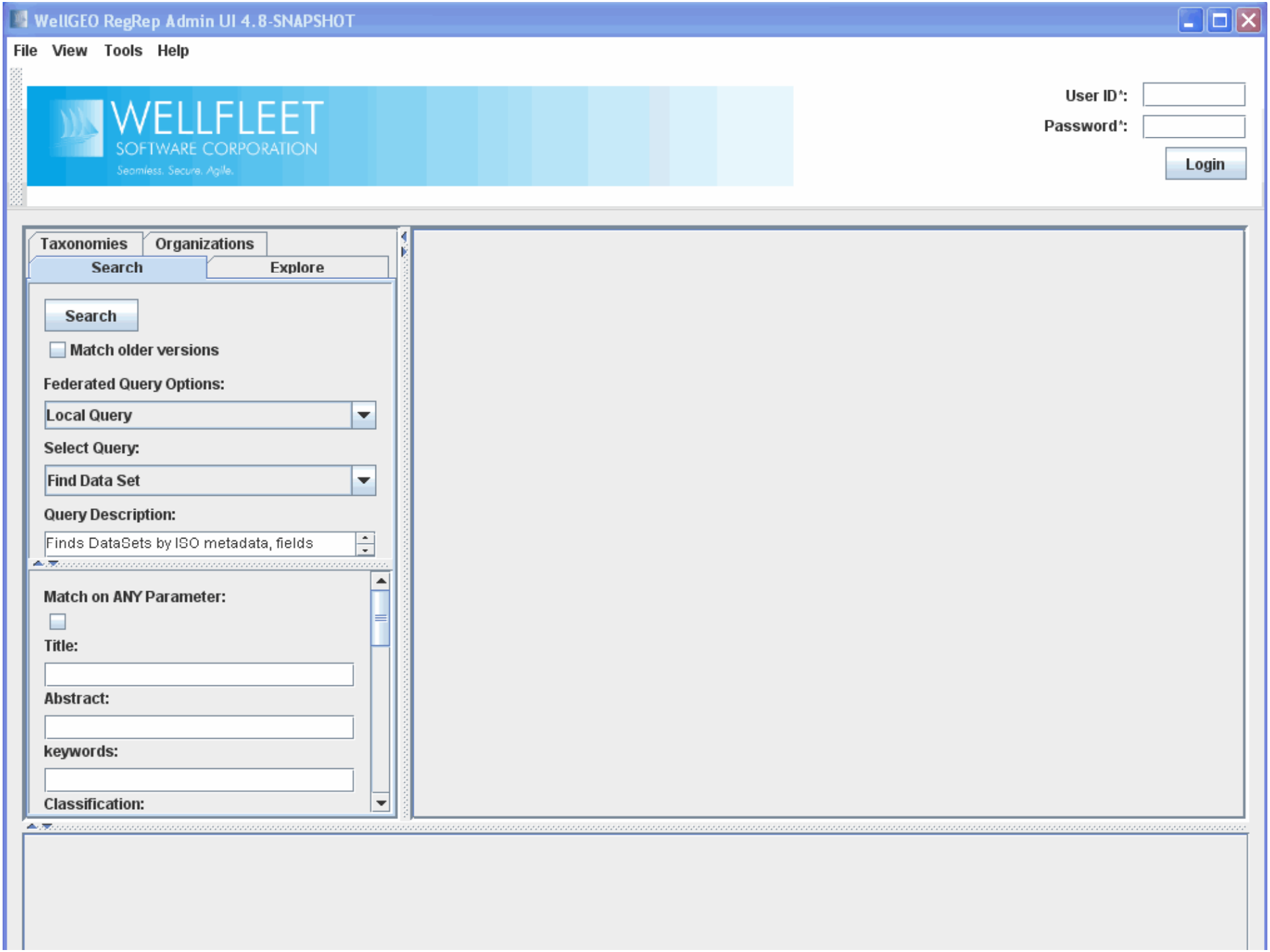
Data Providers

Web Feature Service

Non-Gridded Data

Web Coverage Service

Gridded Data


WellGEO RegRep Admin UI 4.8-SNAPSHOT
File View Tools Help
WELLFLEET
SOFTWARE CORPORATION
Seamless. Secure. Agile.
User ID*:
Password*:
Login
Taxonomies
Organizations
Search
Explore
Search
Match older versions
Federated Query Options:
Local Query
Select Query:
Find Data Set
Query Description:
Finds DataSets by ISO metadata, fields
Match on ANY Parameter:
Title:
Abstract:
keywords:
Classification:

Outline

- Background
- Semantic Interoperability Framework
  - NNEW Weather Ontology
  - Ontology/Vocabulary Alignment
  - Semantic Discovery in NextGen Network Enabled Weather (NNEW)
- **Summary**

Summary

- Future U.S. air transportation system (NextGen) requires large-scale integration of multiple systems
- Semantic services can do on-the-fly translation between information services
  - Early support for semantic functionality will save time and money in the future
- Lincoln is leveraging the semantic interoperability framework to lead FAA's effort to provide net-centric connectivity across organizations (DoD, Eurocontrol)

Summary

- Ontologies can be used in conjunction with other data modeling methods to enhance semantic interoperability of WXXM producers and consumers
  - Provides semantics for otherwise context-free data
  - Converges on and enforces mutually agreed-upon terminology
  - Enables reuse of domain knowledge
  - Allows for cross-implementation interoperability
- Ontology alignment can realize the dream of runtime discovery of services using different vocabularies
  - Utility of ontology alignment demonstrated in ebXML registry/repository OWL profile demonstration