Managing Semantic Big Data for Intelligence

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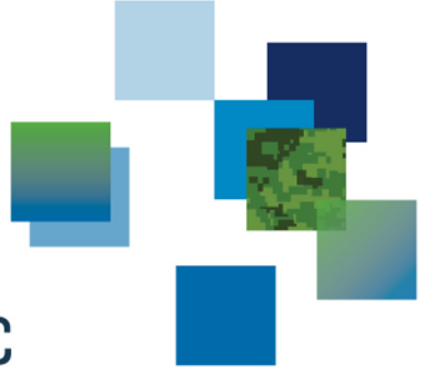

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Outline

- Intelligence context
- Information management and integration challenges
- Proposed approach and architecture
- Ontology support
- Enabling technologies
- Future work and conclusions

The problem : Data Variety, Volume, Velocity …

Intelligence is about data: Collection, Processing, Discovery, Retrieval, Exploitation, Analysis, Dissemination

- Increase of sensor data volume (terabytes – petabytes – exabytes)
- Heterogeneity: multiple data formats and standards, mix of structured and unstructured
- Need to quickly acquire and process intelligence information
- Agility is required to be able to incorporate new data sources

Support to data exploitation

- Each piece of data represents some part of a situation
- Intelligence data contain entities that must be understood and correlated

Context and objectives

Military Intelligence context

- Increasing amount of data/information stored in stove-piped systems
- Multi-sources: SIGINT, IMINT/GeoINT, HUMINT, OSINT, etc.
- Various formats: sensor data, multimedia (text, images, audio, video)
  - Hard/soft, structured/unstructured
- Information overload

Objectives

→ Develop a Multi-Intelligence Data Integration System (MIDIS)

→ Build on prior R&D work

Domain ontologies, annotation, fact extraction, etc.

→ Leverage Semantic and Big Data technologies

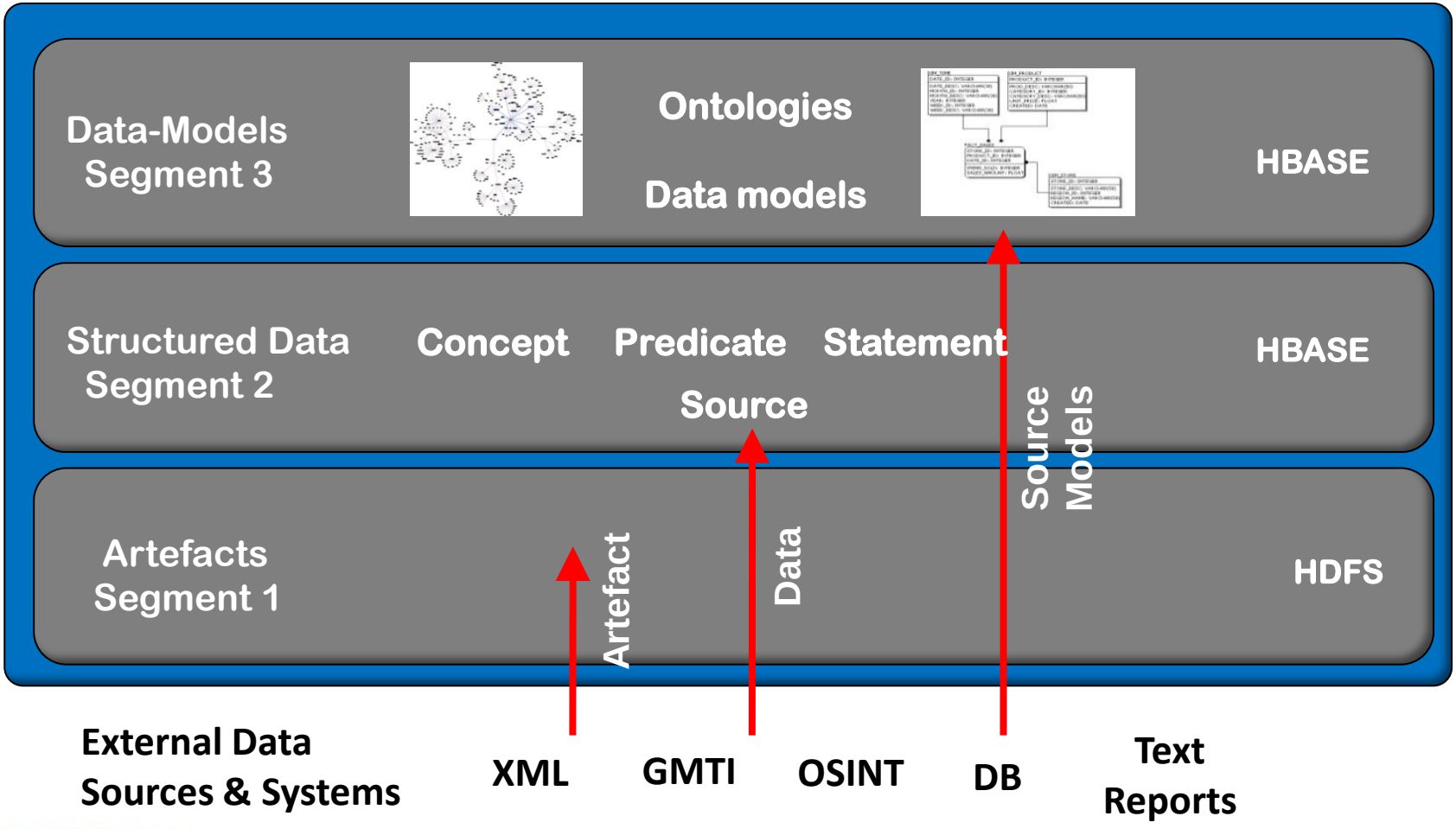
→ Better support intelligence analysts in fusion & analytical tasks

Approach

- Underlying concepts
  - Dataspace: incorporation of large heterogeneous data
    - co-existence approach (Franklin, Halevy)
  - Unified data representation and integration framework (Yoakum-Stover) exploiting ontologies for semantic enrichment (Salmen, Malyuta, Smith)

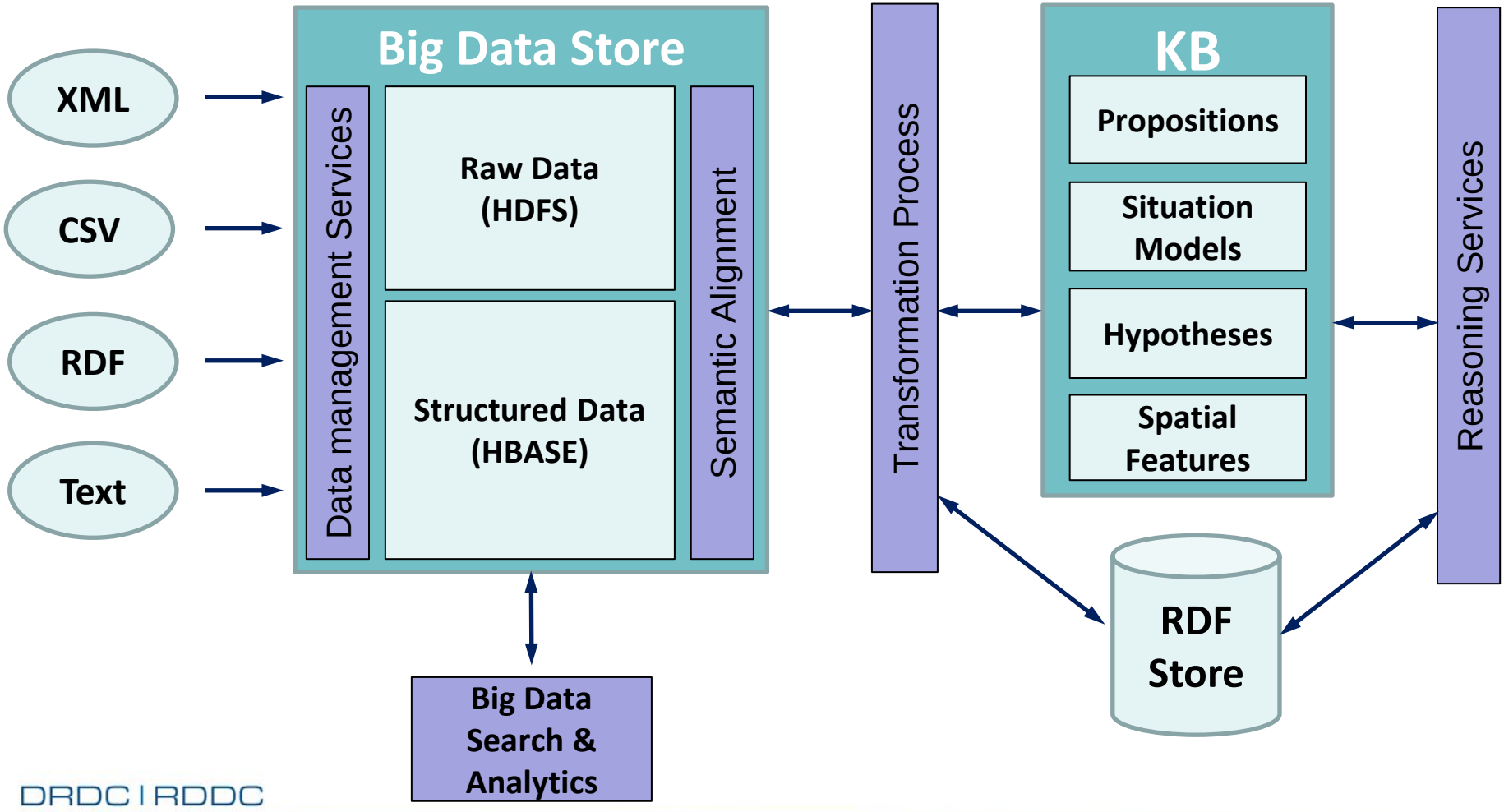
- Data flow and processes for data integration
  - Data ingestion mechanism from heterogeneous data sources
  - Semantic enrichment, alignment (data source model, domain ontologies)
  - Ontology support (incremental ontology development)
  - Unified query mechanism

Unified Data Space layered architecture

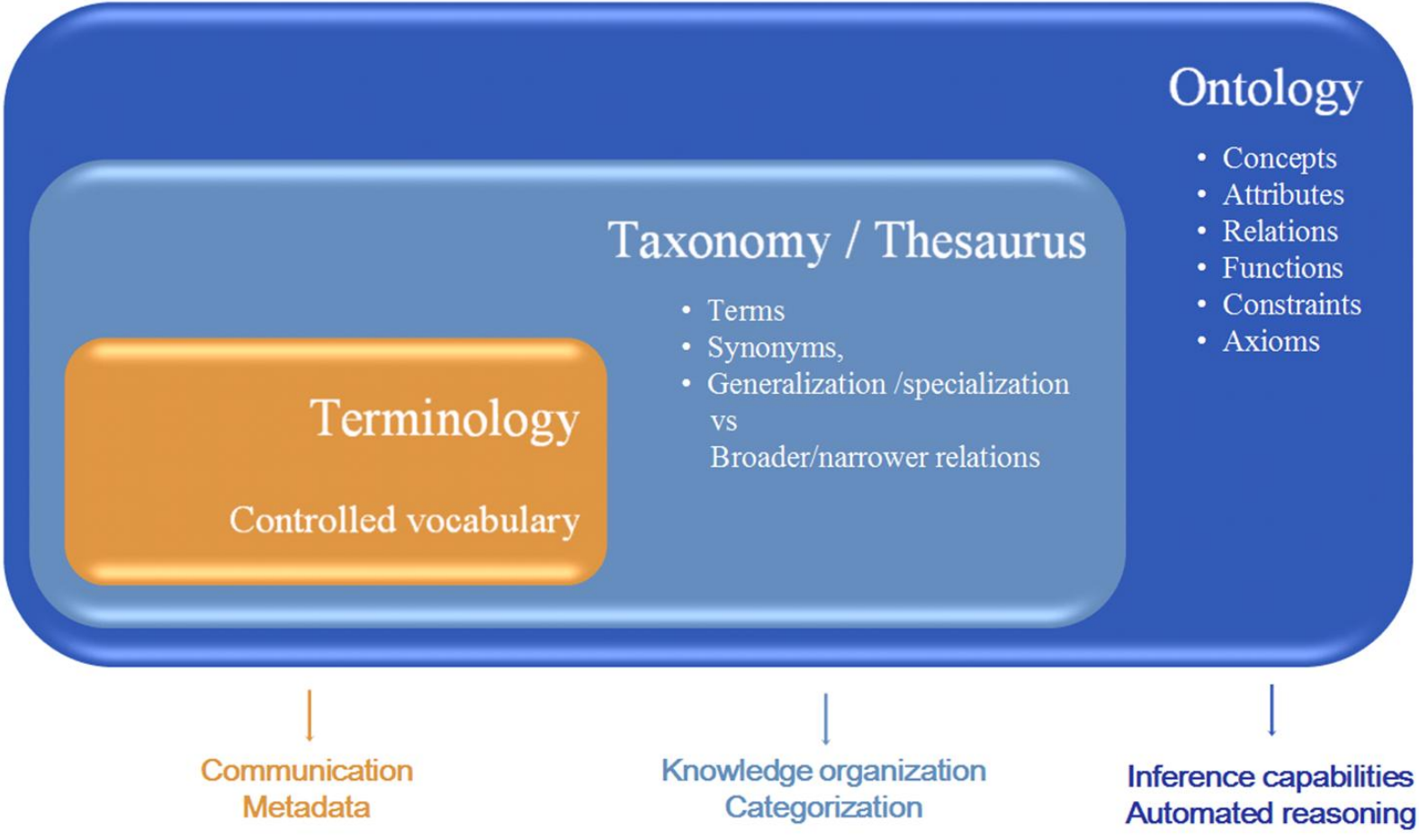


(Adapted from Yoakum-Stover, 2012)

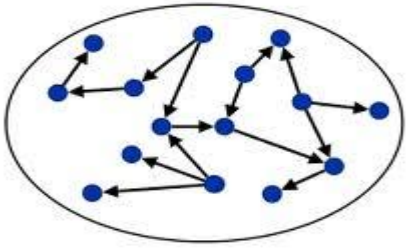
Intelligence Data Integration and Analysis



Ontology support



Intelligence ontology(ies)

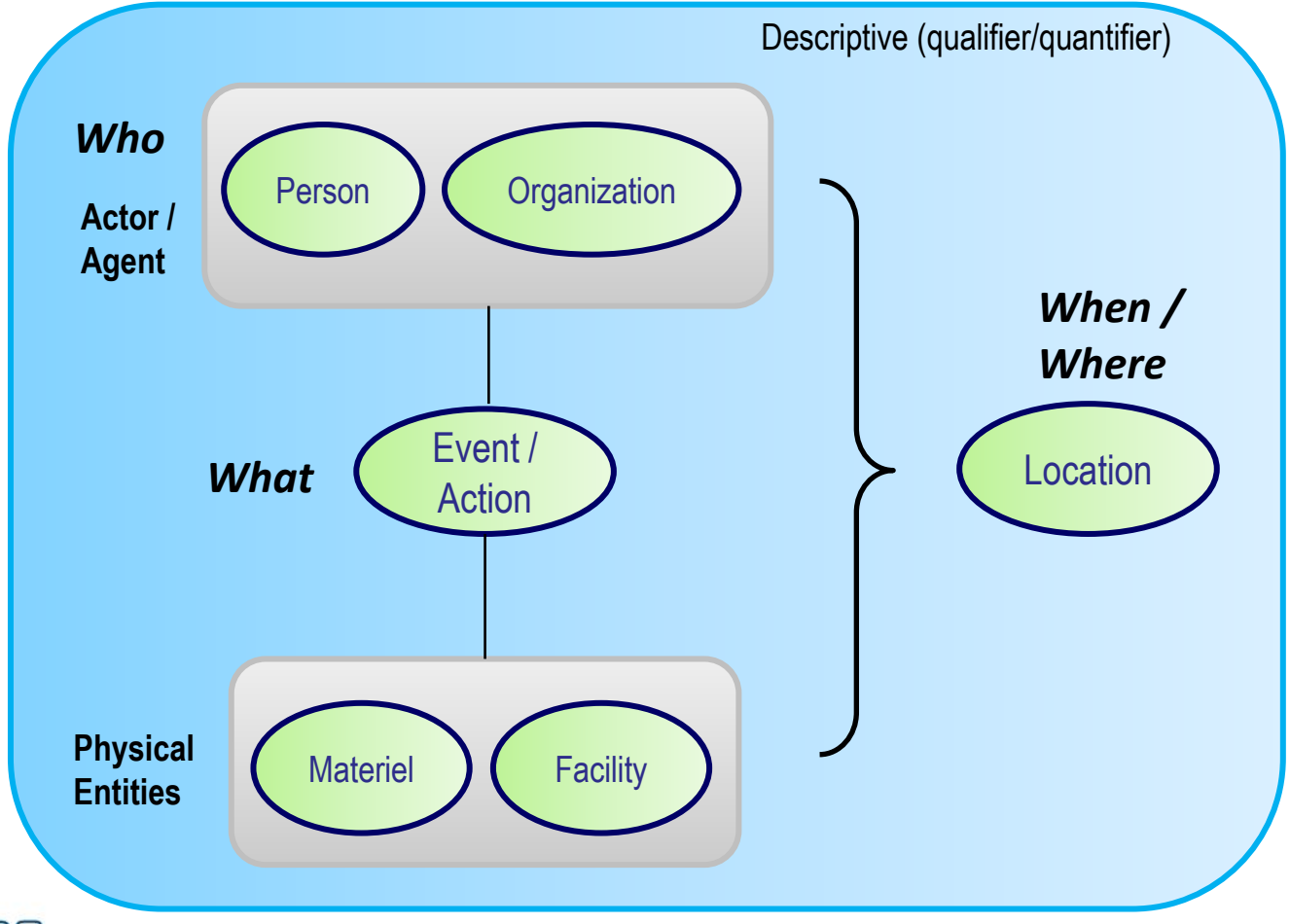


- Role
  - Formal reference model for the intelligence domain
  - Semantic enrichment, annotation, integration / mapping
  - Reasoning / inferencing
- Requirements: expressiveness, flexibility, modularity
- Development: reuse, incremental extensions
- Scope - domains
  - Intelligence high-level concepts
    - Physical entities, people/groups, event/activities, feature, information, etc.
  - Domain specific models
    - Threat assessment
    - Human geography
    - Terrorism

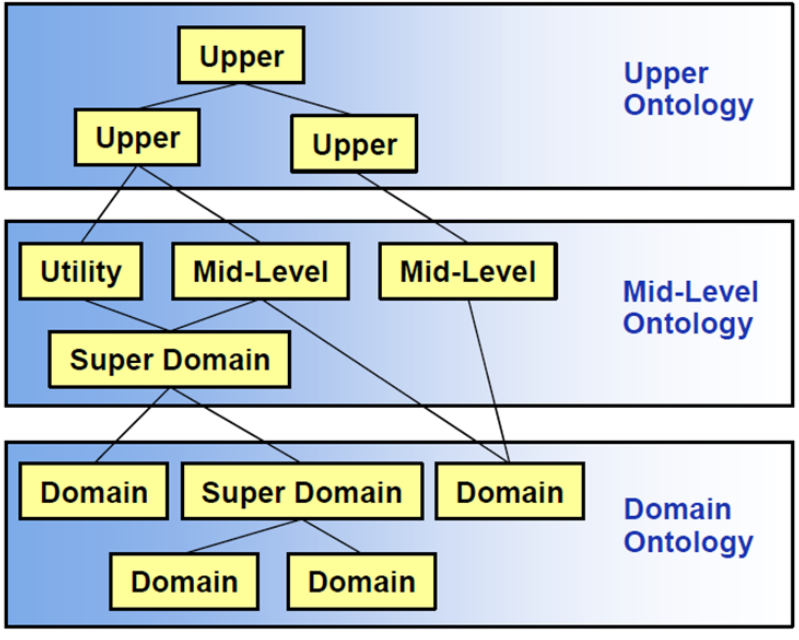
Semantic enrichment & alignment with ontologies

- Aim
  - Data annotation and alignment according to ontologies to address data source semantic heterogeneity
  - Facilitate unified querying of heterogeneous data
  - Facilitate heterogeneous data correlation and fusion
- Strategy
  - Annotation of structured data sources
    - Establish mapping: Data source term – reference ontology term
  - Annotation of unstructured data sources
    - Original source is annotated using terms of ontologies
    - Extraction of metadata, facts and statements (structured data)
- Benefits
  - Better support of intelligence analysts in the production of intelligence

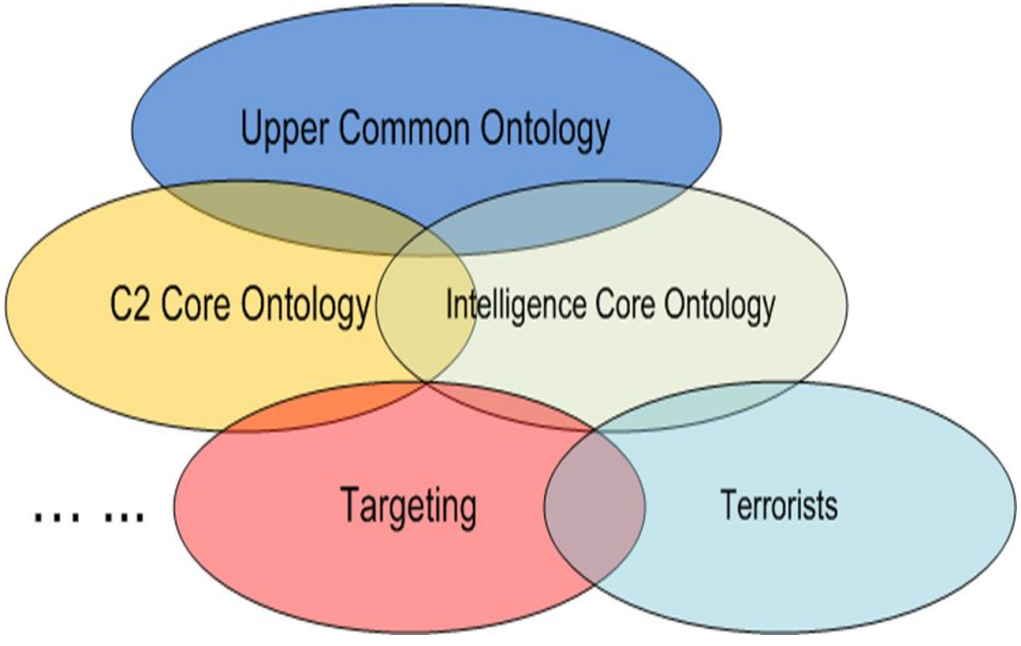
Domain of interest – Key high-level concepts



Ontology development - Modularity



(Source Pulvermacher et al, Mitre, 2004)



(Source : Barry Smith - NCOR)

Upper-level constructs

Continuants			Occurrents	
Physical Artifact	Agent	Dependent Entity	Information Artifact	Process Event / Action
Equipment Infrastructure Facility Vehicle Weapon Geospatial Site	Person Organisation Group	Quality Function Property Role	Plan Product Report Info Reqt …	Military Event Social Event Terrorist Event … Planning Process Operation Task

Leveraging Semantic and Big Data Technologies

- Semantic Technologies
  - OWL Ontologies, RDF triples, mapping
- Big Data Technologies:
  - Apache Hadoop Framework (Cloudera) – HDFS / HBase
  - Indexing and query mechanisms
    - HDFS, HBase (e.g. Impala)
    - Index tables (permutations of triple patterns) - Sparql query
  - Data Analytics (e.g. Mahout)
    - Data clustering, filtering, profiling
- Integration within a SOA-based Intelligence S&T Integration Platform

Conclusions and future work

- Incremental, flexible approach to data integration
  - Agility, modularity, extensibility
  - Enhanced support to intelligence analysis: data query, correlation, fusion, reasoning
  - Enabler to evolve from single Int production to Multi-Int
- Ontology support
  - Combination of top-down, bottom-up, and horizontal development of ontologies
- Big Data technologies
  - Benefit from distributed processing (volume)
  - Unstructured data (HDFS) – Structured data (HBase) processing
  - Emerging, still immature
- To be investigated further:
  - Data analytics
  - Additional data management services, e.g. Entity resolution
  - Data uncertainty

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