Orbital Debris
Ontology, Terminology & Knowledge Modeling

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PROBLEMS: limited orbital data sharing, no standard vocabularies, how to classify & characterize debris, policy & legal questions, knowledge discovery from data, …

GOALS: apply knowledge-based and formal ontological analysis to address problems for improved safety of flight and knowledge growth. Develop formal models to represent our space domain knowledge, data, entities. Apply AI & semantic tech.

I. Develop accurate **terminologies & definitions** global community can agree on. Identify commonalities & problems among existing terms & definitions.

II. Develop computable ontological **classifications** for orbital debris (& related entities).

III. **Develop ontologies** to capture orbital debris domain knowledge for data providers
Domain reference ontology (e.g. ODO, OO, etc.), Ontologies to model instances, etc.

IV. Help **resolve policy & legal questions** (e.g., gaps in definitions, standards, etc.)

V. Address **philosophical questions** in astrodynamics (phi of science, of physics)

VI. Collaboratively apply the Ontologies: industry, university projects, etc.
To space object catalogs, visualizations, web-based applications, AI, etc.

RATIONALE: by developing accurate terminologies, taxonomies, & knowledge models we create means to either (a) bridge information systems within & among orgs., or (b) individual orgs. can use to better manage their content.

- **Improve Data Management**: data-sharing (= better SSA), search & retrieval, automated reasoning, semantic interoperability, decision support. Various resources can use same model for information integration and machine reasoning.

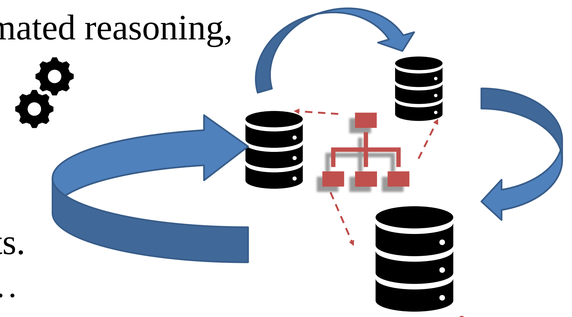
METHODS

- Iterative and revisionary approach. Collaborative potential → Community-input.
- Research → Concept Dev. → Terminology Dev. → Ontology Dev. → Apply data sources → Use tech (e.g., ML) → Verification → Revision
- Formal, philosophical & ontological analysis, Logics, Editor tools,

Ontological/Semantic Rigor: *Categories* (e.g., Mission-related, Payload, Rocket Body Debris, Inactive Spacecraft), *Properties* of Orbital Debris (attitude, (un)controlled, shape, albedo), *Relationships*, *Rules*, *Logical axioms*

Terminologies – communication, common understanding, search
Taxonomies – structured terminologies that tag content

Ontologies – knowledge model w/ formally-defined taxonomies. Help manage enterprise data. Annotate data. Machine & human readable *semantic layer*. Query Data. Automated reasoning,



Knowledge Modeling – representing knowledge in computational systems & AI agents. AI, Semantic Web, Linked Data, …

Knowledge-based systems often use ontologies. e.g., enterprise knowledge graphs. Machine-learning can be improved with ontologies

Ontologies to be completed:

- ODO – The Orbital Debris Ontology
- OO – The Orbitology Ontology
- Celestial Orbit Ontology (Class taxonomy of orbits)
- Spacecraft Ontology (Types, parts, systems)
- SSAO – The SSA Ontology
- OSEDO – The Orbital Space Environment Domain Ontology
- STMO – The Space Traffic Management Ontology
- Case-study ontology: An ontology for the Union of Concerned Scientists Satellite Database (see reference [7] in paper)

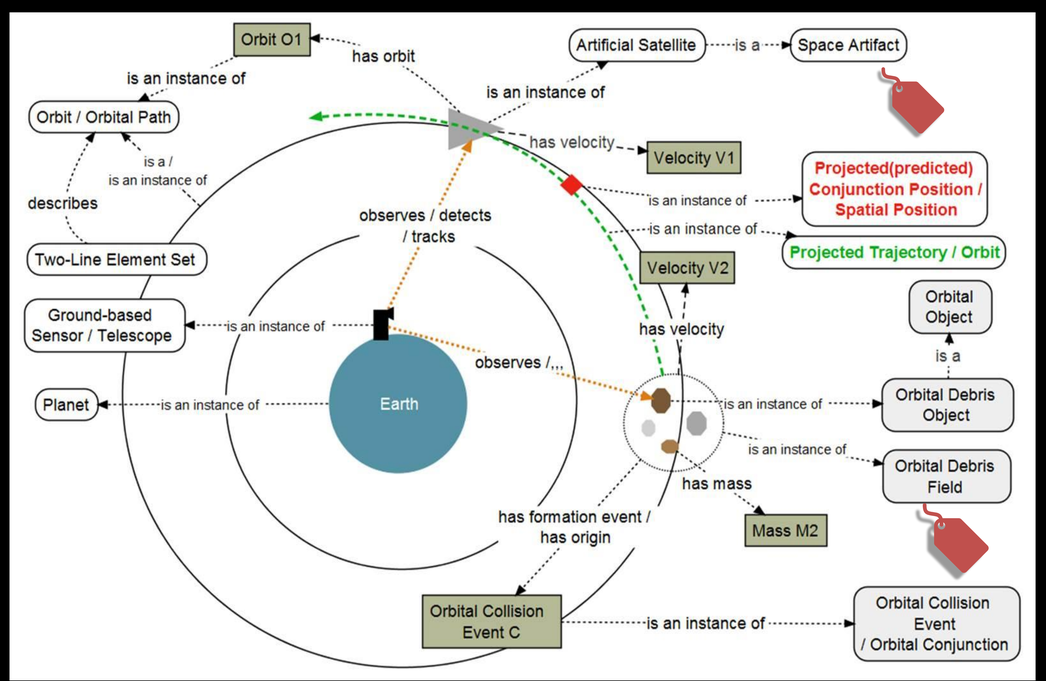


Diagram from "Orbital Debris Ontology" presented at CODER Nov 2016.

FEATURES: Modular architecture, high-level concepts for universality, unique identifiers, logics, formal definitions consistent w/domain knowledge, supports FAIR data.

EFFORTS TO DATE: 10 publications. Presentations. Preliminary ontology files. Collaborations. AIAA committee work. **Website**: https:/purl.org/space-ontology

Sample (full list on Google scholar of [(1)])

- *An Ontological Architecture for Orbital Debris Data* (2015) Rovetto. Earth Science Informatics.
- *Preliminaries of a Space Situational Awareness Ontology* (2016) Rovetto, & Kelso.
- *An Ontology-Oriented Orrery*, O'Neil & Rovetto (Forthcoming TBD, NASA Technical pub).

DESIDERATA

- *Funding*, Sponsorship, A studentship or work opportunity (for corresponding author [(1)])
- *Partners.* Ideally interdisciplinary team environment.
- *Applications & Data* – ideas & opportunities to develop & apply the ontologies
- *Community input* & interest.

Please contact Robert Rovetto[(1)] with opportunities or general interest.

Thank you.

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