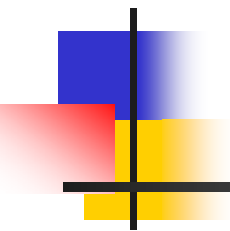


Ontologies for Environmental Systems



Rob Raskin
NASA/Jet Propulsion Laboratory

Dec 11, 2008



What is an Ontology and why is it Useful?

- Captures common sense (shared) knowledge in a form that can be used (and reused) by computers (and humans)
- Enables resources (data, web pages, documents, people) to be associated with (mapped to) the stored knowledge
- Expandable to accommodate growing knowledge



Data to Knowledge



Basic Elements
Services
Storage
Volume
Density

Bytes
Save
File
High
Low

Numbers
Database

Visualize
Models
Infer
GIS

Facts
Understand
Ontology
Low
High
Predict
Mind

Syntax

Semantics

Semantic Understanding is Difficult!



Variable t: temperature

Variable t: time

Data quality= 5

Data quality= 3

Surface wind: measured 3 m above surface

Surface wind: measured at surface

Semantic Understanding is Difficult! (more)



“not a nobody”

“ain’t nobody”

“yeah, right”

Let’s eat, Grandma.

Let’s eat Grandma.

Time flies like an arrow.

Fruit flies like a pie.

“Mission accomplished. Major combat operations in Iraq have ended”

-Pres. Bush, 2003

**Low-Profile
Rice Has
Bush’s Ear**

LA Times headline



Application: Intelligent Search for Data

- Consults knowledge base to find alternative meanings
 - Clustered by: synonyms, parent, children
- Enables discovery of resources without exact keyword match
- Semantic understanding is crucial
- Common search engines (Google) use these capabilities only minimally, at present

Use Case: Global Warming Query



Find data which demonstrates global warming at high latitudes during summertime and plot warming rate.

- Extract information from the use-case - encode knowledge
- Translate this into a complete query for data - inference and integration of data from instruments, indices and models

“Global warming”= Trend of increasing temperature over large spatial scales

“High latitude”= Latitudes > 60 degrees

“Summertime”= June-Aug (NH) and Jan-Mar (SH)

“Find data”= Locate datasets using catalogs, then access and read it

“Plot warming rate”= Display temperature vs time



Application: Intelligent Search for Data (more)

- Noesis ontology-aided search tool
 - <http://noesis.itsc.uah.edu>
- Provides access to:
 - Data
 - Journal articles
 - Web pages
 - Experts (people)



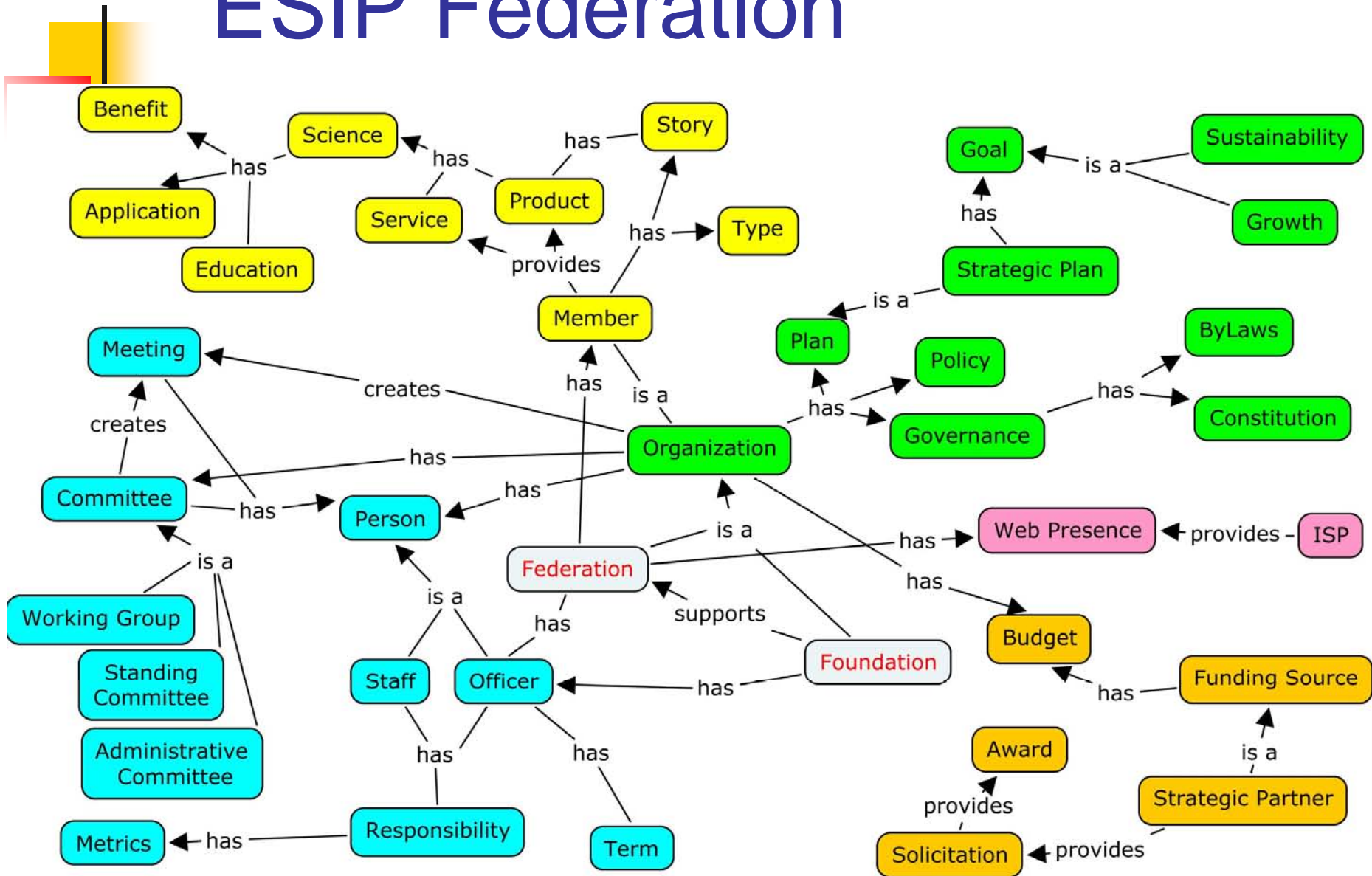
Knowledge Base of Facts as Triples

Subject-Verb-Object representation

- Flood is a WeatherPhenomena
- GeoTIFF is a FileFormat
- Soil Type is a PhysicalProperty
- Pacific Ocean is a Ocean

- Ocean has substance Water
- Sensor measures Temperature

Ontology of an Organization: ESIP Federation





Ontology Languages: RDF and OWL

- W3C has adopted XML-based standard ontology languages
 - Resource Description Formulation (RDF)
 - Ontology Web Language (OWL)
- Languages predefine specific tags
 - RDF: Class, subclass, property, subproperty, ...
 - OWL: Extends RDF to predefine further tags such as cardinality
 - Three flavors of OWL (Lite, DL, and Full)
- Use of standard languages make it easy to extend (specialize) work of others



Semantic Web for Earth and Environmental Terminology (SWEET)

- Concept space written in OWL
- Initial focus to assist search for data resources
 - Funded by NASA
- Later focus to serve as community standard
- Enables *scalable classification* of Earth system science concepts

Fragment of SWEET

3DLayer

subClassOf

PlanetaryLayer

partOf

Atmosphere

primarySubstance
="air"

partOf

AtmosphereLayer

subClassOf

subClassOf

sameAs=

"Lower
Atmosphere"

Troposphere

Stratosphere

upperBoundary
=50 km

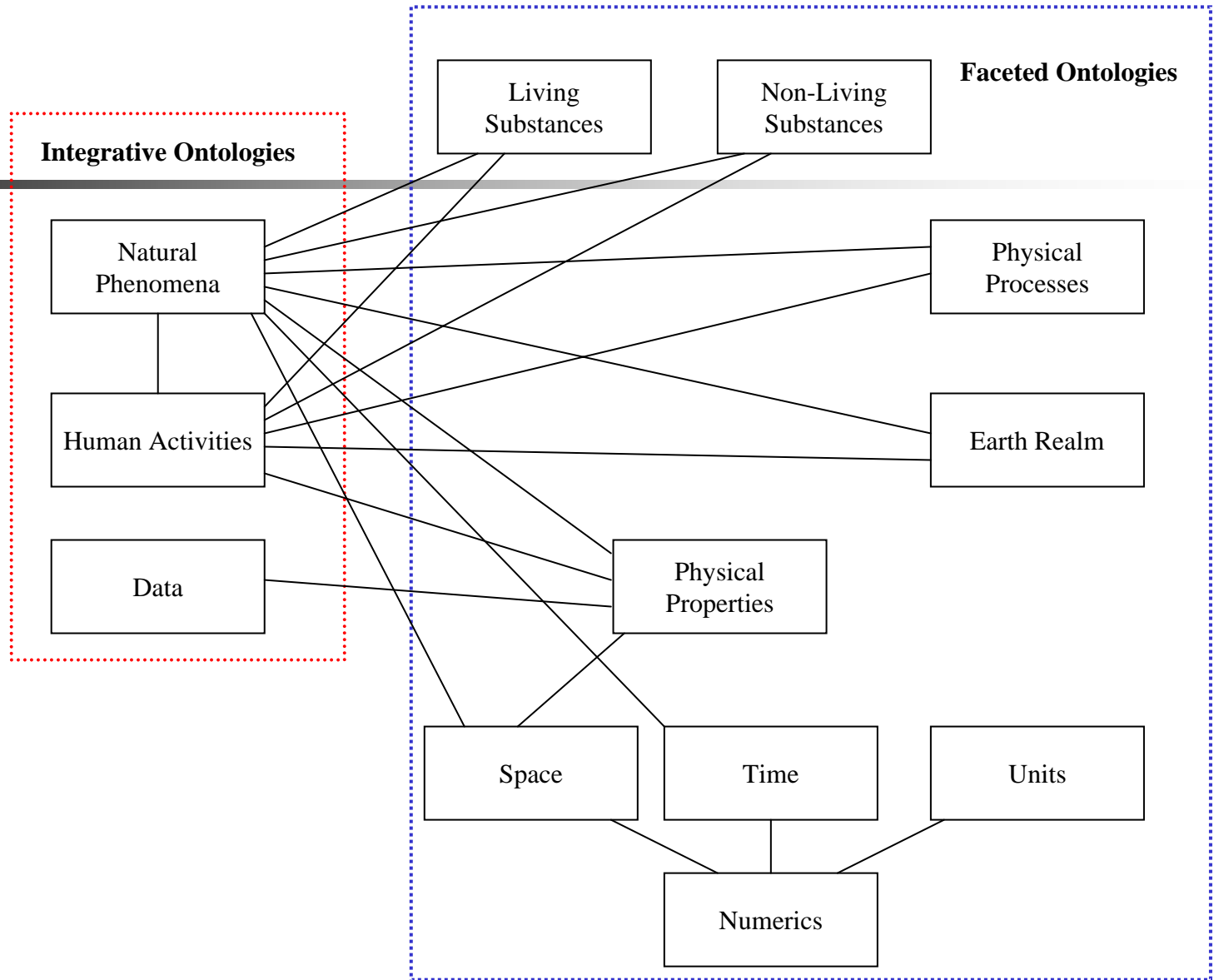
lowerBoundary
=15 km

isUpperBoundaryOf

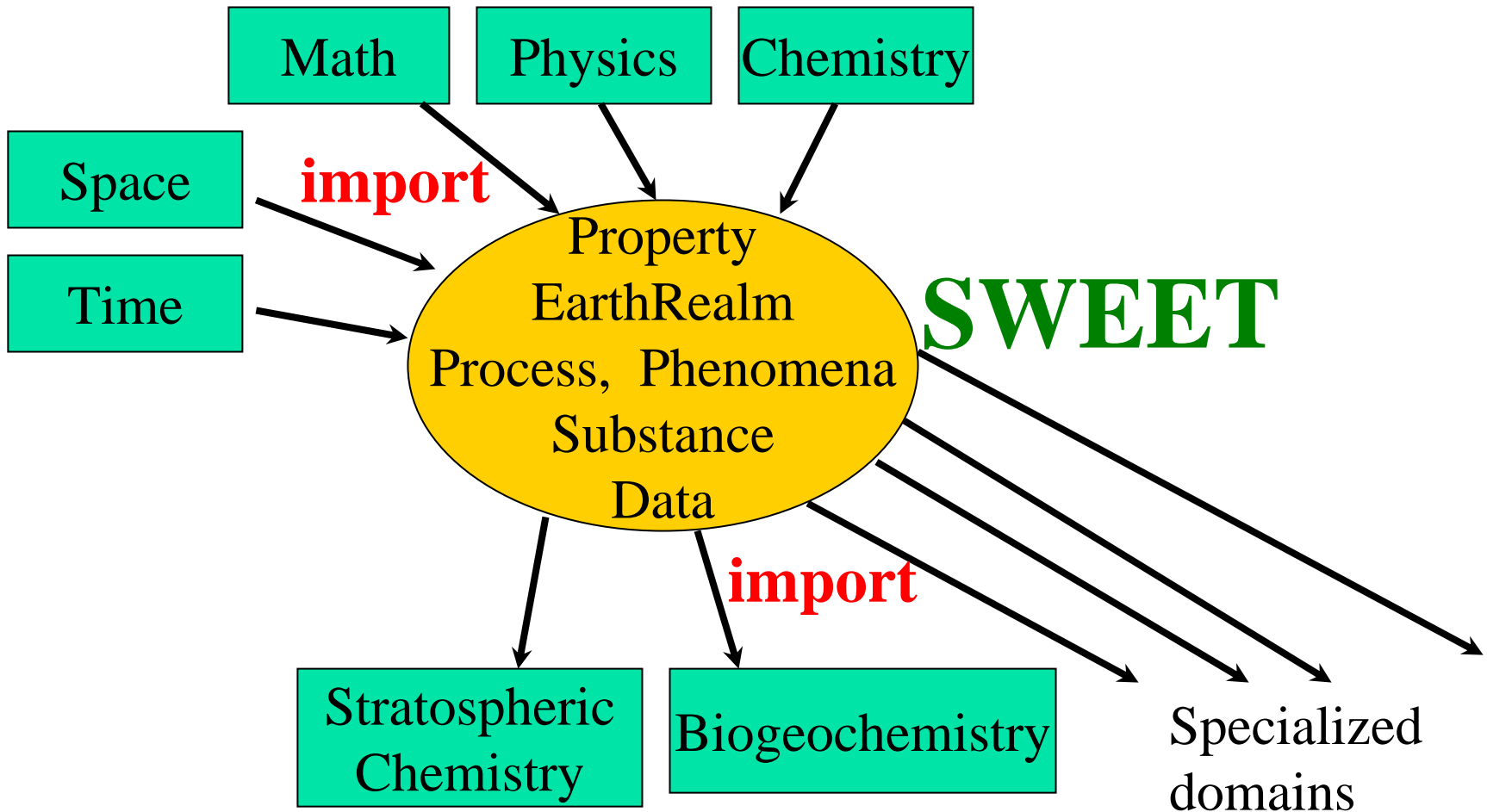
isLowerBoundaryOf

Tropopause

SWEET 1.0 Ontologies



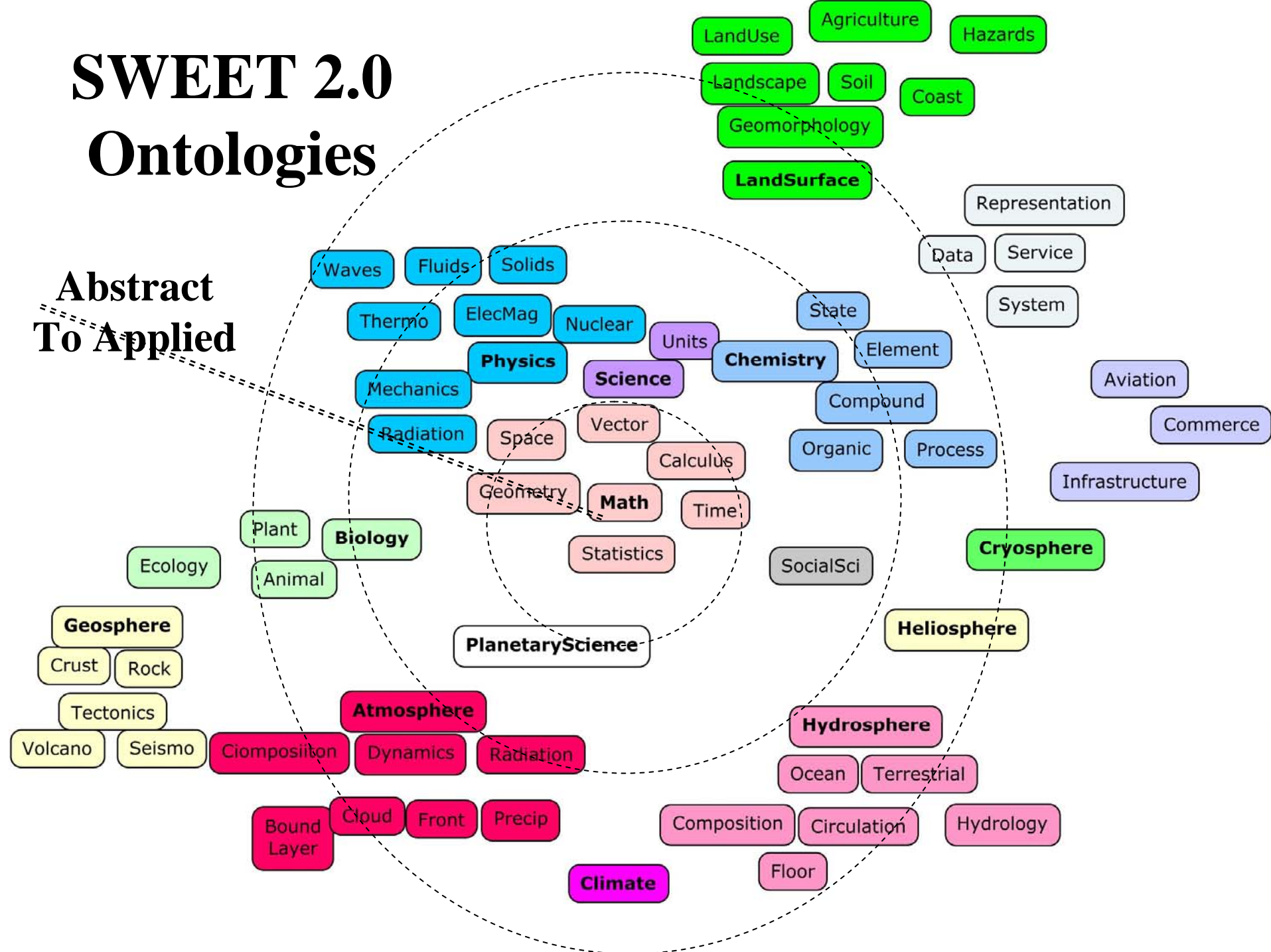
SWEET as an Upper Level Earth System Science Ontology



SWEET 2.0

Ontologies

Abstract
To Applied





Characteristic Level of Abstractions for Scalability

- Each concept has a characteristic level of abstraction
 - How theoretical is it?
- If more than one characteristic level... repeat it
 - Words are commonly defined in dictionaries with multiple meanings



SWEET Data Ontology

- Dataset characteristics
 - Format, data model, dimensions, ...
- Provenance
 - Source, processing history, ...
- Parameters
 - Scale factors, offsets, ...
- Data services
 - Subsetting, reprojection, ...
- Quality measures
- Special values
 - Missing, land, sea, ice, ...



Web Services Ontology

- OWL-S
 - Enables semantic descriptions of Web service inputs and outputs
 - Provides binding to actual implementation of Web service



Best Practices

- Keep ontologies small, modular
 - Be careful that “Owl:Import” imports everything
 - Use higher level ontologies where possible
- Identify hierarchy of concept spaces
 - Model schemas
 - Try to keep dependencies unidirectional
- Gain community buy-in
 - Involve respected leaders



Planetary Ontologies

A web site for sharing ontologies in the Earth and Space Sciences

Purpose and Scope

- To facilitate the use, re-use, development, evolution, alignment and merging of ontologies by a community of best-practices in the broad fields of Earth and Space Sciences.
- To enable collaborative use and discussion of ontologies by practitioners.

Ontology Collaboration

- [Ontologies](#)
- [RSS Feed for ontology changes](#)
- [Wiki](#)
- [Mailing List](#)

Links

- [SESDI \(Semantically-Enabled Science Data Integration\)](#)
- [SWEET \(Semantic Web for Earth and Environmental Terminology\)](#)
- [GEON \(Geosciences Network\)](#)
- [VSTO \(Virtual Solar-Terrestrial Observatory\)](#)
- [NOESIS \(Earth and Atmospheric Science Smart Search\)](#)
- [MMI \(Marine Metadata Initiative\)](#)
 - [VINE \(Vocabulary Integration Environment Tool\)](#)

Private

- [SWEET mailing list](#)



Additional Ontology Properties

- Synonym support (multiple terms with same meaning)
 - label available to indicate preferred term for each community
- Homonym support (multiple meanings of same term)
 - separate namespaces (President:Bush vs Plant:Bush)



Ontology Development Tools: CMAP

- Free, downloadable tool for knowledge representation and ontology development
- Visual language with input/export to OWL
 - Supports subset of OWL language
- <http://cmap.ihmc.us/coe>



Other Ontology Editors

- Public Domain
 - SWOOP
 - Mindswap Lab (UMBC)
 - <http://www.mindswap.org/2004/SWOOP>
 - Protégé
 - Stanford
 - <http://protege.stanford.edu>
- Commercial
 - Cerebra Construct
 - <http://cerebra.com>
 - TopBraid Composer
 - <http://www.topquadrant.com/topbraid/composer>



Terminology

- **Ontology**
 - An explicit formal specification of how to represent the objects, concepts and other entities that are assumed to exist in some area of interest and the relationships that hold among them.
- **Semantic Web**
 - An extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation, www.semanticweb.org
- **Semantic Grid**
 - Semantic services to use the resources of many computers connected by a network to solve large scale computational problems
- **Provenance**
 - origin or source from which something comes, and the history of subsequent owners, sense of place and time of manufacture, production or discovery, documented in detail sufficient to allow reproducibility.
- **Languages**
 - OWL - Web Ontology Language
 - RDF - Resource Description Framework
 - OWL-S/SWSL - Web Services
 - WSMO/WSML - Web Services
 - SWRL - Semantic Web Rule Language
 - PML - Proof Markup Language
 - ODM/MOF - Ontology Definition Metamodel/Meta Object Facility (OMG)
 - Editors: Protégé, SWOOP, Medius, SWeDE
- **Reasoning Tools**
 - Pellet, Racer, Medius KBS, FACT++, fuzzyDL, KAON2, MSPASS, QuOnto
- **Query Languages**
 - SPARQL, XQUERY, SeRQL, OWL-QL, RDFQuery
- **Other Tools for Semantic Web**
 - Search: SWOOGLE swoogle.umbc.edu
 - Collaboration: www.planetont.org
 - Other: Jena, SeSAME/SAIL, Mulgara, Eclipse, KOWARI
 - Semantic wiki: OntoWiki, SemanticMediaWiki



Resources

- SWEET
 - <http://sweet.jpl.nasa.gov>
- Ontology development/sharing site
 - <http://PlanetOnt.org>
- Noesis (search tool)
 - <http://noesis.itsc.uah.edu>
- SESDI
 - <http://sesdi.hao.ucar.edu>