

The VIRTUAL SOLAR-TERRESTRIAL OBSERVATORY

Peter Fox¹ (pfox@ucar.edu), Don Middleton², Stan Solomon¹, Deborah McGuinness³, Jose Garcia¹, Luca Cinquini², Patrick West¹, James Benedict³, Tony Darnell¹ (HAO/NCAR) (2SCD/NCAR) (3McGuinness Associates)

ASSOCIATIONS: Earth System Grid, Community Data Portal, CEDAR, NSF/NMI

SPONSORS: National Science Foundation/CISE/Shared Cyberinfrastructure Initiative

FURTHER READING: <http://vsto.hao.ucar.edu/> and watch for <http://www.vsto.org>

GLOSSARY:

SWEET - Semantic Web for Earth and Environmental Terminology, sweet.jpl.nasa.gov

SPDML - Space Physics Data Markup Language, sd-www.jhuapl.edu/SPDML

CEDAR - Coupled Energetics and Dynamics of Atmospheric Regions, cedarweb.hao.ucar.edu

CISM - Center for Integrated Space-Weather Modeling, www.bu.edu/cism

ACOS - Advanced Coronal Observing System, mlso.hao.ucar.edu

UC1: Plot the observed/measured Neutral Temperature (Parameter) looking in the vertical direction for Millstone Hill Fabry-Perot Interferometer (Instrument) from January 2000 to August 2000 (Temporal Domain) as a time series.

Precondition: portal application is authorized to access the backend data extraction and plotting service

- User signs in to portal application (or otherwise accesses application with or without authenticating)
- User goes through a series of views to select (in order) the desired observatory, instrument, record-type (kind of data), parameter, start and stop dates, and the plot type (should this be inferred?). At each step, the user selection determines the range of available options in the subsequent steps. NB, an alternate path is selection of start and stop dates, then instrument, etc.
- The application validates the user request: first it verifies that the user is authorized to access the specific kind of data, then it verifies the logical correctness of the request, i.e. that Millstone Hill is an observatory that operates a type of instrument that measures neutral temperature (i.e. check that Millstone Hill <is-a> observatory and check that the range of the measures property on the Millstone Hill Fabry Perot Interferometer subsumes neutral temperature). Also, the application must verify that no necessary information is missing from the request.
- The application processes the user request to locate the physical storage of the data, returning for example a URL-like expression: find Millstone Hill FPI data of the correct type (operating mode; defined by CEDAR KINDAT since the instrument has two operating modes) in the given time range (Millstone Hill FPI <hasKindOfData> 1701 <intersects> TemporalDomain [January 2000, August 2000])
- The application plots the data in the specified plot type (a time series). This step involves extracting the data from records of one or more files, creating an aggregate array of data with independent variable time (of day or day-time depending on time range selected) and passing this to a procedure to create the resulting image.

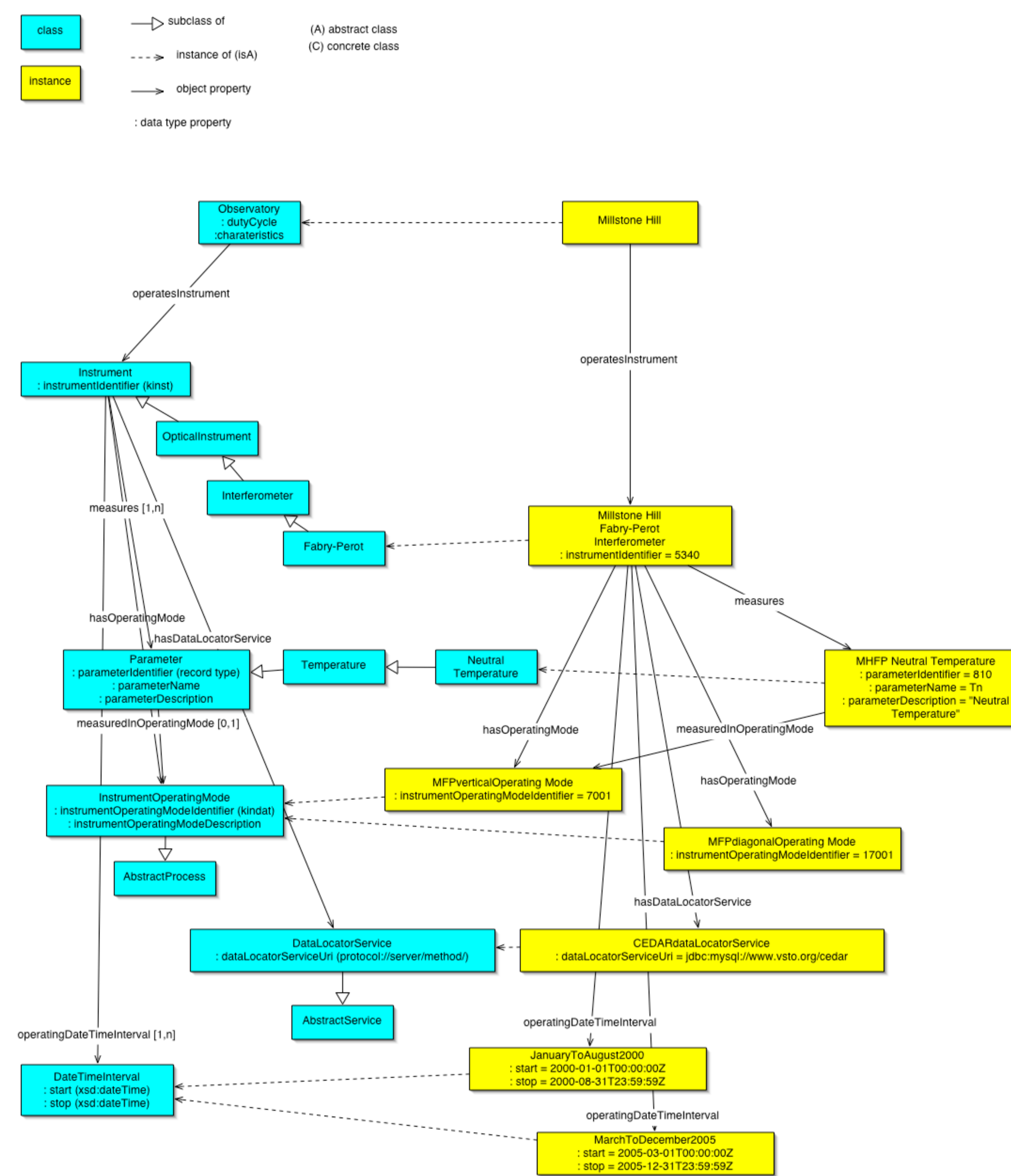
Virtual Observatory Concept

Goal - find the right balance of data/model holdings, portals and client software that a researchers can use without effort or interference as if all the materials were available on his/her local computer.

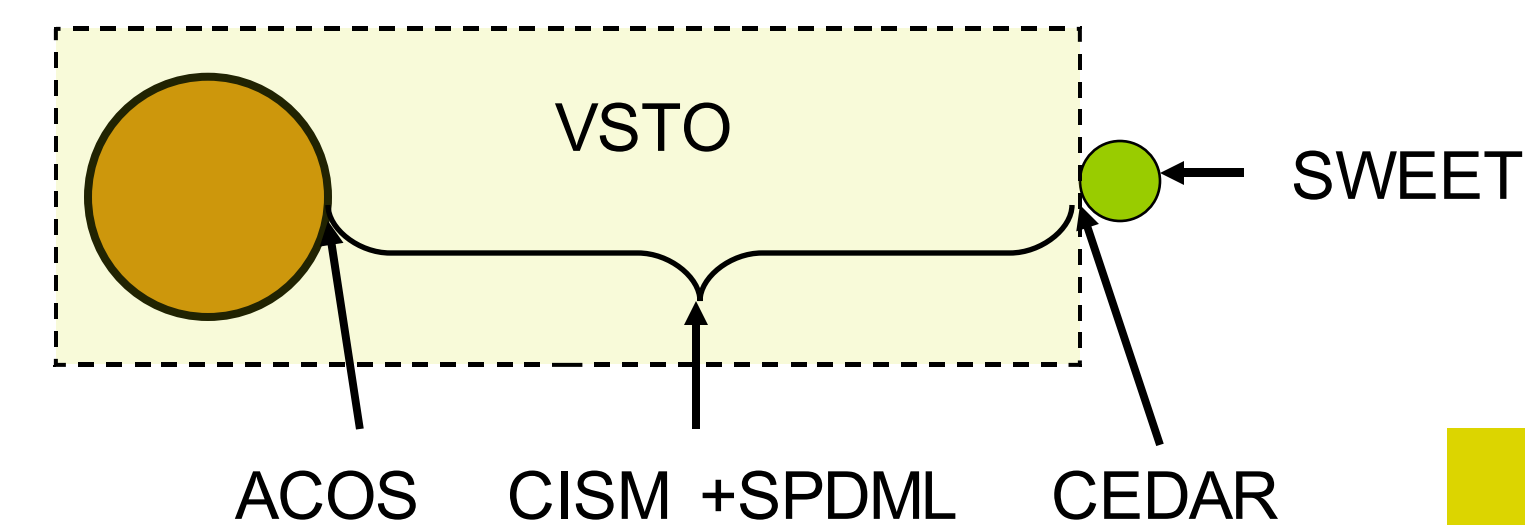
The prototype Virtual Solar-Terrestrial Observatory (VSTO) is a distributed, scalable education and research environment for searching, integrating, and analyzing observational, experimental and model databases in the fields of solar, solar-terrestrial and space physics (SSTSP). VSTO comprises a framework which provides virtual access to specific SSTSP data, model, tool and material archives containing items from a variety of space- and ground-based instruments and experiments, as well as individual and community modeling and software efforts bridging research and educational use. Too often users (and data providers) have to deal with the organizational structure of the data sets which varies significantly --- data may be stored at one site in a small number of large files while similar data may be stored at another site in a large number of relatively smaller files. There is an equally large problem with the range of metadata descriptions for the data. Users often only want subsets of the data and struggle with getting it efficiently.

Datasets alone are not sufficient to build a virtual observatory. The VSTO addresses the interface problem to bring data to the users' tools, and to the tools within the VSTO, effectively and scalably. VSTO leverages the development of schema (e.g CEDAR, MLSO, Earth System Grid, SPDML) that adequately describe the syntax (name of a variable, its type, dimensions, etc. or the procedure name and argument list, etc.) and semantics (what the variable physically is, its units, etc. or what the procedure does and returns, etc.) of the datasets and tools.

Use-Case 1



Solar-Terrestrial System



Ontology Development

The Problem:

CEDAR - has 'flat' and overlapping listings of instruments (covers radars, optical, indices, models and more), parameters (same name, different scale factor or units, no formal specification of independent variables, etc.)

CEDAR: begin with flat listings of CEDAR parameters, instruments and develop a simple hierarchy

Where applicable: add to SWEET; Realms, Properties, Space, Time, etc.

Instances: contain the metadata

CEDAR/VSTO ontology: will map from SWEET

Build/evolve: using Use-case application

Radar
Incoherent Scatter
Ionospheric Doppler (aka HF)
Middle Atmosphere (aka MLT)
MST
MF
LF
Meteor Wind

Digisondes
Optical (hasBand, measuresTo, etc.)
Interferometers
Fabry-Perot
Michelson
IR
Doppler
Spectrometers
IR ((OH))
Airglow Imagers
All-Sky Cameras
Lidar
Spectrometers
Polarimeter
Hellograph
Photometers
Single-Channel
Multi-Channel

hasName:
alsoKnownAs:
isOperatedBy:
hasOperator:
isType:
isPartofProgram:
isFundedBy:
hasCoverage:
hasSensor:
hasOperatingFrequency:
hasOperation:
Start:
hasOperatingMode:
Measurement:
hasDataFrom:
hasDataTo:
hasLocation:
Address:
City/Town:
PostalCode:
Country:
Continent:
Latitude:
Magnetic:
Longitude:
Magnetic:
hasLocalTimeatZeroUT:

Excerpt from SunRealm.owl

```
<owl:Class rdf:ID="ActiveRegion">
  <rdfs:subClassOf rdf:resource="#MagneticRegionType"/>
  <rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty
      rdf:resource="http://sweet.jpl.nasa.gov/ontology/space.owl#isPartOf"/>
    <owl:allValuesFrom rdf:resource="#SunSurfaceLayer"/>
  </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty rdf:resource="#hasMagneticRegionType"/>
    <owl:allValuesFrom rdf:resource="#SunMagneticRegion"/>
  </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

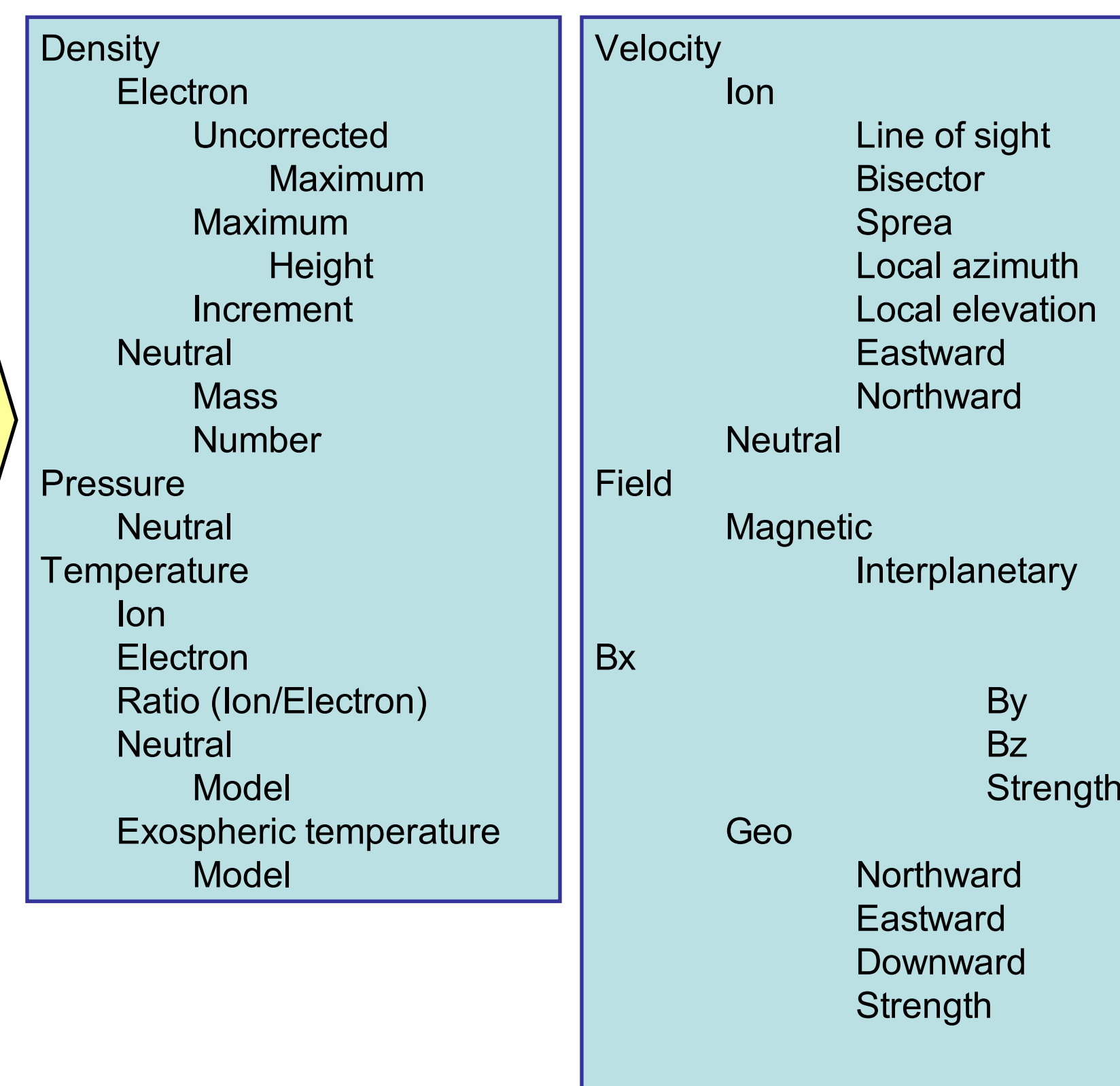
Excerpt from EarthRealm.owl

```
<owl:Class rdf:ID="Thermosphere">
  <rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty
      rdf:resource="#hasLowerBoundaryReferenceHeight"/>
    <owl:hasValue
      rdf:datatype="http://www.w3.org/2001/XMLSchema#double">
      85000</owl:hasValue>
  </owl:Restriction>
  </rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty
      rdf:resource="#hasUpperBoundaryReferenceHeight"/>
    <owl:hasValue
      rdf:datatype="http://www.w3.org/2001/XMLSchema#double">
      500000</owl:hasValue>
  </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf rdf:resource="#AtmosphereLayer"/>
</owl:Class>
```

Excerpt from Properties.owl

```
<owl:Class rdf:ID="BulkDensity">
  <rdfs:subClassOf rdf:resource="#Density"/>
</owl:Class>
<owl:Class rdf:ID="Density">
  <rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty
      rdf:resource="http://sweet.jpl.nasa.gov/ontology/numerics.owl#hasDefaultUnit"/>
    <owl:hasValue
      rdf:resource="http://sweet.jpl.nasa.gov/ontology/units.owl#kilogram_perMeterToPower3"/>
  </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf
    rdf:resource="#MassConcentrationRelatedQuantity"/>
</owl:Class>
```

Parameter classes



"Parameter" table (excerpt)

Code	Full Name	Scale	Units	Name
Time related parameters				
10	Year (Universal time)	1.0	yr	year
34	Time past 0000 UT	1.E-03	hour	uth
36	Time past 0000 UT	10.0	sec	uts
Geographic parameters				
110	Altitude (height)	1.0	km	gdalt
120	Range	1.0	km	range
130	Mean azimuth angle (0=N, 90=E)	1.E-02	deg	azm
140	Elevation angle (0=horizontal, 90=vertical)	1.E-02	deg	elm
194	Declination angle (GEI coordinates)	1.E-02	deg	dec
Basic ionospheric parameters				
510	Electron density	1.E+09	m ⁻³	ne
550	Ion temperature	1.0	K	ti
552	Ion temperature	0.1	K	tip1
560	Electron temperature	1.0	K	te
Neutral atmosphere parameters				
800	Line of sight neutral velocity (away: >0)	1.0	m/s	vnlv
810	Neutral temperature	1.0	K	tn
Vector field parameters				
1410	Direction 1 neutral wind (eastward)	1.0	m/s	vne
1420	Direction 2 neutral wind (northward)	1.0	m/s	vnn
1610	Direction 1 electric field (eastward)	1.E-05	V/m	ee
Spectral parameters				
2400	Wavelength	0.1	nm	waveln

"Instrument" table (excerpt)

INSTRUMENT	CODE	ABBR	LAT	LONG	ALT
Jicamarca Peru I.S. Radar	10	JRO	-11.95	283.12	0.520
Arecibo P.R. I.S. Radar	20	ARO	18.35	293.25	0.0
Millstone Hill I.S. Radar	30	MLH	42.62	288.51	0.146
EISCAT I.S. Radar	70	EIS	69.58	19.22	0.087
Ground-Based Indices:					
Geophysical NGDC: AE	211	AEI	N/A	N/A	N/A
Geophysical NGDC: Dst	212	DST			
Model Outputs:					
NCAR TGCM/TIGCM Model	310	GCM	N/A	N/A	N/A
AMIE Model	311	ARE	N/A	N/A	N/A
HF Radars:					
Halley Antarctica HF Radar	820	HHF	-75.5	333.4	
MST Radars:					
Arecibo P.R. MST Radar	1040	ARM	18.35	293.25	0.0
Poker Flat Alaska MST Radar	1140	PKR	65.13	-147.46	
LF and MF Radars:					
Scott Base Antarctica MF Radar	1210	SBF	-77.85	166.75	
Poker Flat Alaska MF Radar	1375	RPK	65.13	-147.5	0.208
Passive Optical Instruments:					
Davis Antarctica Spectrometer	3010	DVS	-68.48	77.97	0.025
Arecibo P.R. Fabry-Perot	5160	AFP	18.345	293.25	0.0
LIDARS:					
USU ALO Rayleigh LIDAR	6330	USL	41.74	-111.81	1,466
USU Mesospheric Temp Mapper CCD Imager	7191	MTM	N/A		