Metadata formalism for the description of spacecraft-environment interaction data and models

Toward a meta-model for the description, archiving and retrieval of the material, environment and interaction data and models

Sébastien HESS

ONERA

THE FRENCH AEROSPACE LAB

Context and outline

Spacecraft-Environment Interaction topic:

- covers a large number of intricated phenomena: charging, radiation, material, contamination, environment

- supported by a large number of models, fed by a larger number of experimental data

- up to day mostly qualitative and dissociated studies *(« Is there a risk of ESD for some kind of glass covering a surface on a more or less metallic spacecraft structure? »)*

- but studies more and more quantitative and intricated *(« How much power will I lose due to contamination by erosion products due to the recollection of CEX ions from an electric thruster plume on a spacecraft which potential depends on the RIC of a particular dielectric due to energetic particles? »)*

To answer such a question *(more or less the one that SPIS-EP is required to answer)* …

Context and outline

« How much power will I lose due to contamination by erosion products due to the recollection of CEX ions from an electric thruster plume on a spacecraft which potential depends on the RIC of a particular dielectric due to energetic particles? »

To answer such a question *(more or less the one that SPIS-EP is required to answer)* :

- need precise environment and material data to be quantitative:
    - covers different fields of physics, different parameters
    - need to extract them from different experimental setups and publications
    - need to retrieve, select and gather them in datasets relevant for a given model
    - keep track of the datasets (version, caveats,….)

- need to select the right models and parameters
    - need a description of the models (content, task, Inputs/Outputs,…)
    - need to match available data and models
    - need to keep track of the models and data used in a simulation
    - need to archive the results in a manner that allow an easy use and retrieval

Context and outline

- Describe, Archive and Retrieve

SPASE: space physics standard for environment and models

ChaMISEn: derived from SPASE for material measurement databases

- Data extraction and Application

SPASE description of SPIS (, Comova,..)

Build SPIS material dataset from measurement using SPASE and ChaMiSEn

- Keep track of material datasets and models

ISO 15836 header, implemented in SPIS v6.0RC

Describe, Archive and Retrieve

SPASE: space physics standard for environment and models

ChaMISEn: derived from SPASE for material measurement databases

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Describe, Archive and Retrieve: Environment

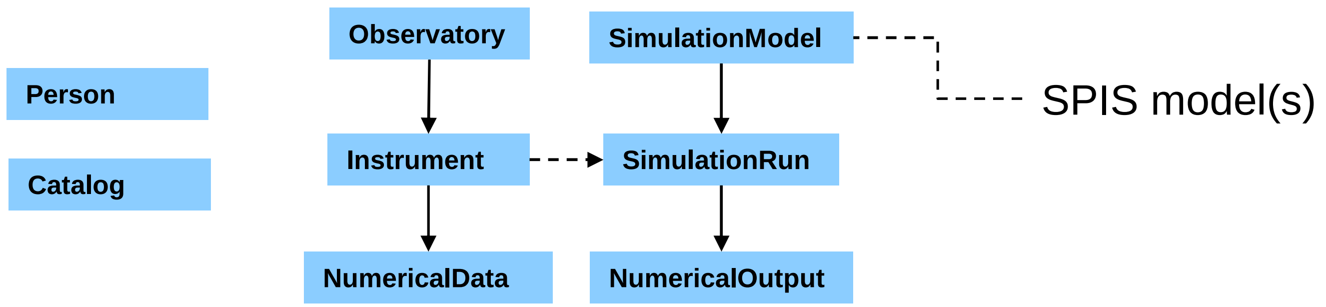
SPASE is a datamodel used as a worldwide standard for spacecraft environment measurements *(standard of US NASA/NOAA/NSF, ESA, JAXA, CNES/CDPP, Australia,… space weather/planetary environment databases).*

Object databases: each resource is described with a fixed structure, each field name and keyword are defined in a dictionary.

Dictionary size: large enough to be exhaustive, small enough to allow for efficient automated treatments by computers.

Resources: one type per type of content on which a search could be made
example: one may search for a particular dataset (NumericalData), or want to retrieve a model (SimulationModel)

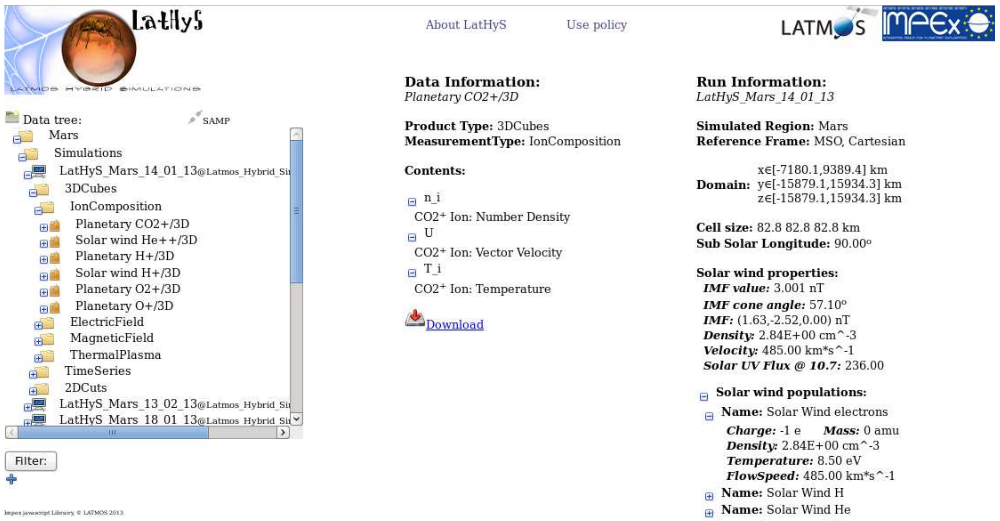
Each resources have: - a header that gives a brief overview of it *(~ISO 15836)*
- fields on which searches are made *(strong formalism, everything in dictionary)*
- descriptive fields for human end-user *(less formalized)*

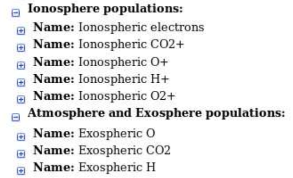


Simplified overview of the SPASE resources

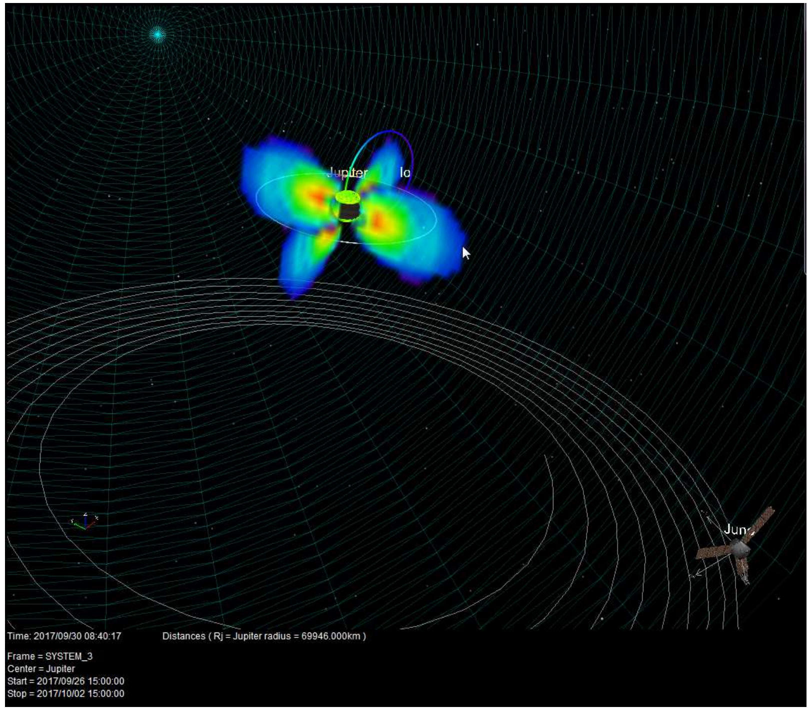
Today SPASE is the only standard datamodel for simulation codes in space physics.

Simulation extension developed in a EU FP7 program and now used worldwide
Current implementation in the US CCMC center *(~SPENVIS)*.





CNRS/LATMOS simulation database
All data displayed belong to a strict dictionary and can used for automated search.
Done at no cost: the simulation code directly provides the data and metadata following the standards



ONERA-Salammbô simulation of Jupiter belts
SPASE-compliant description allows to use a large librairy of tools to process the data (here CNES/CDPP 3DView)

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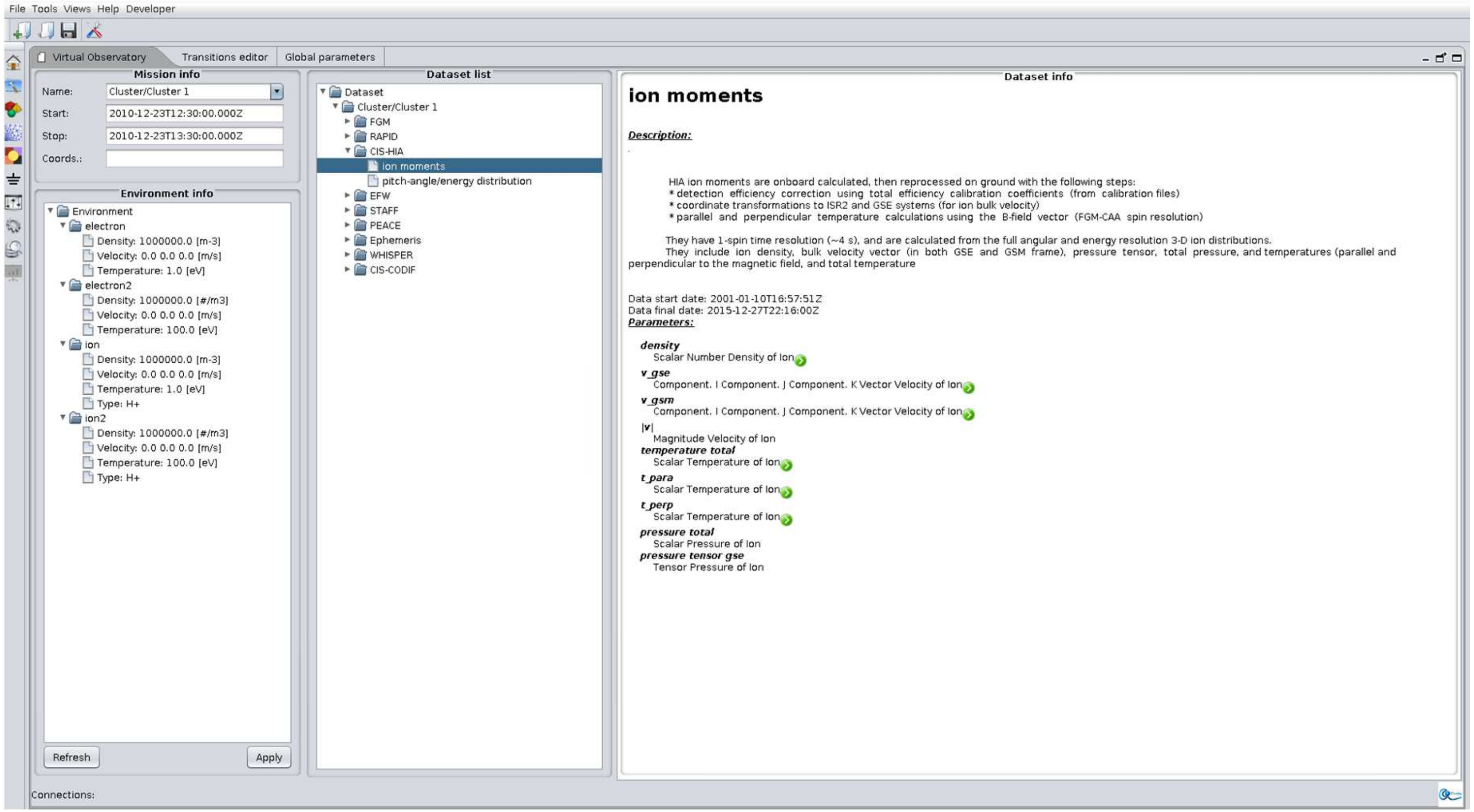
Experimental prototype of environment import in SPIS. Test with the CNES/CDPP/AMDA database

Allows to get ambiant populations densities, temperature, velocities from distant databases and use in SPIS *(time dependent)*



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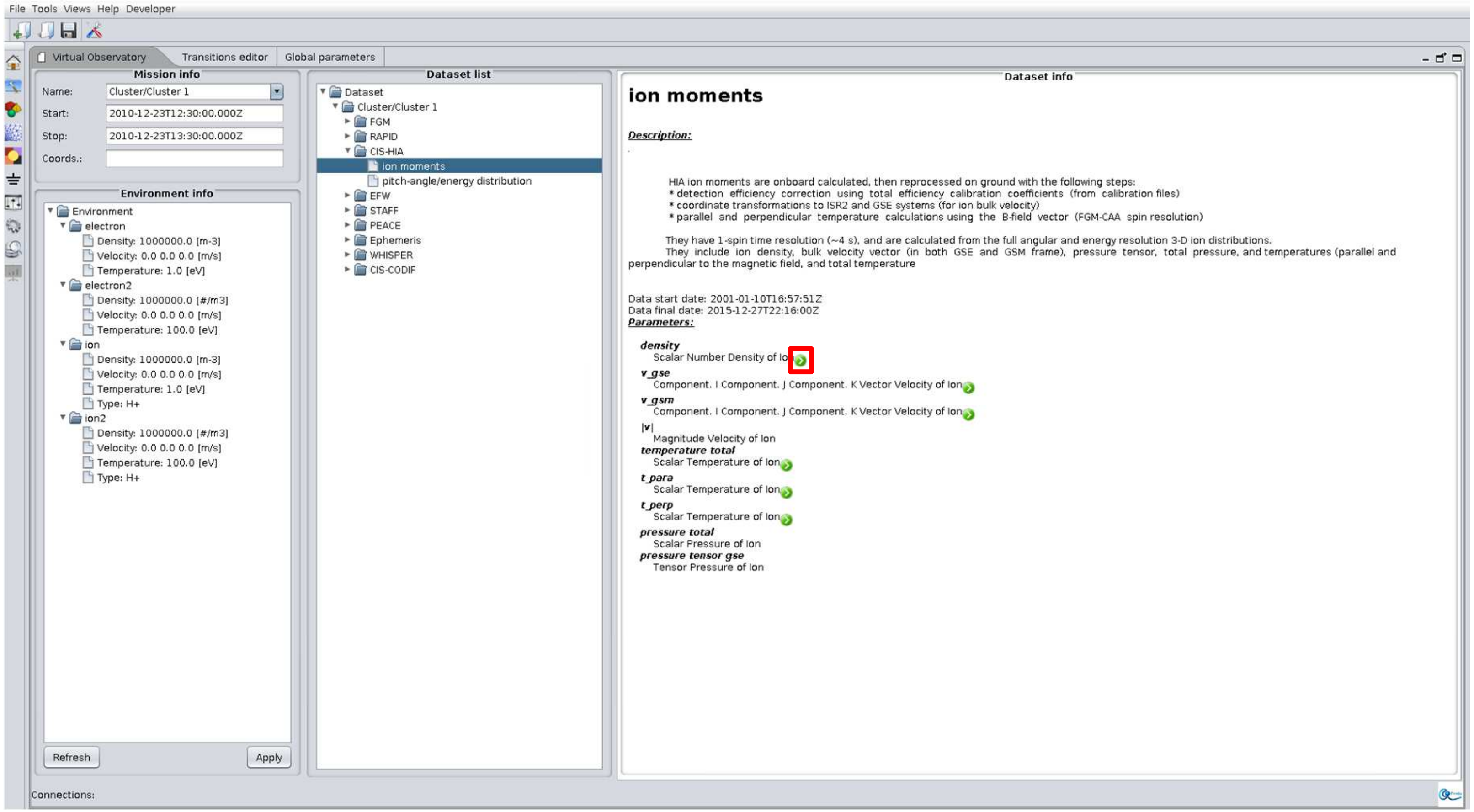

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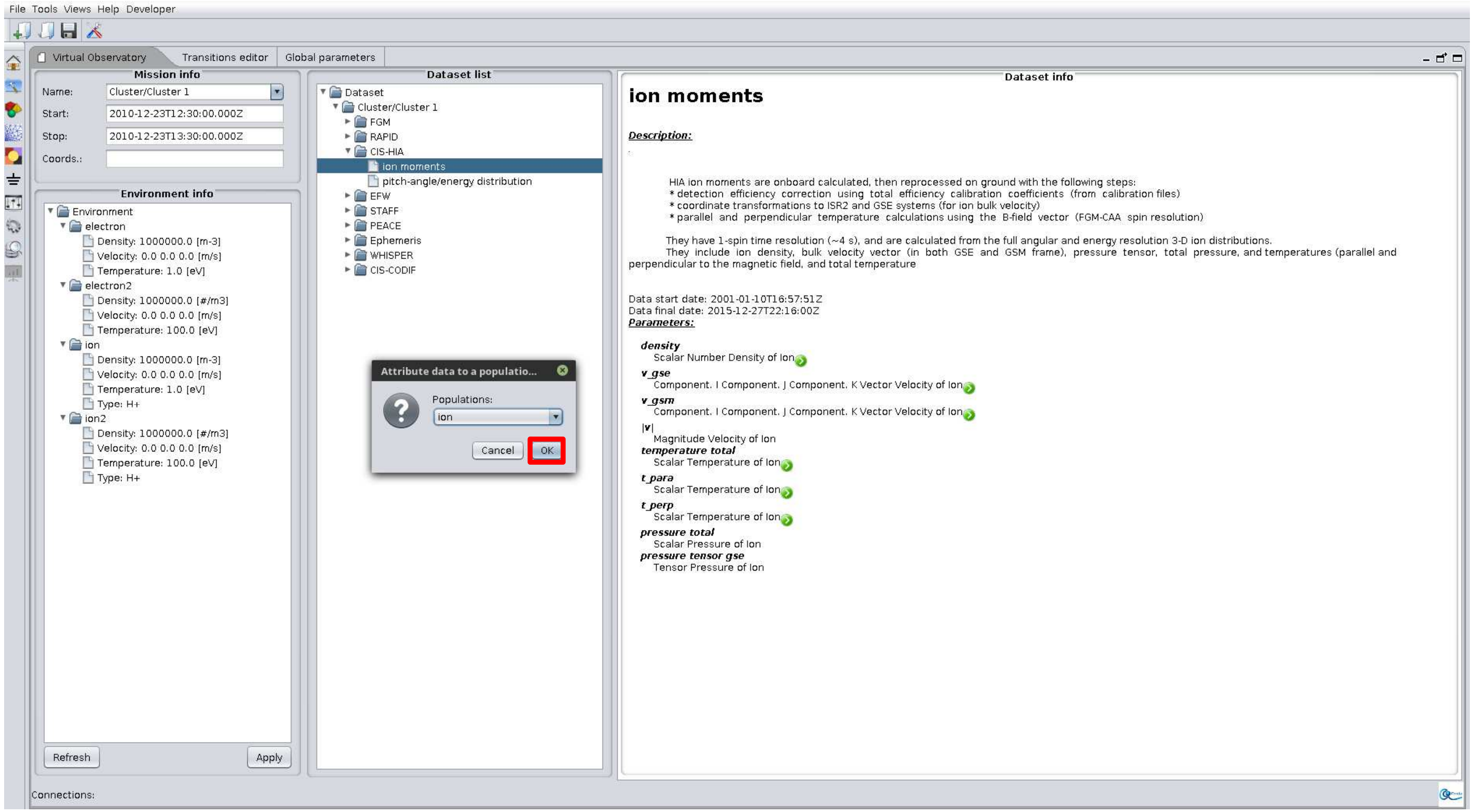

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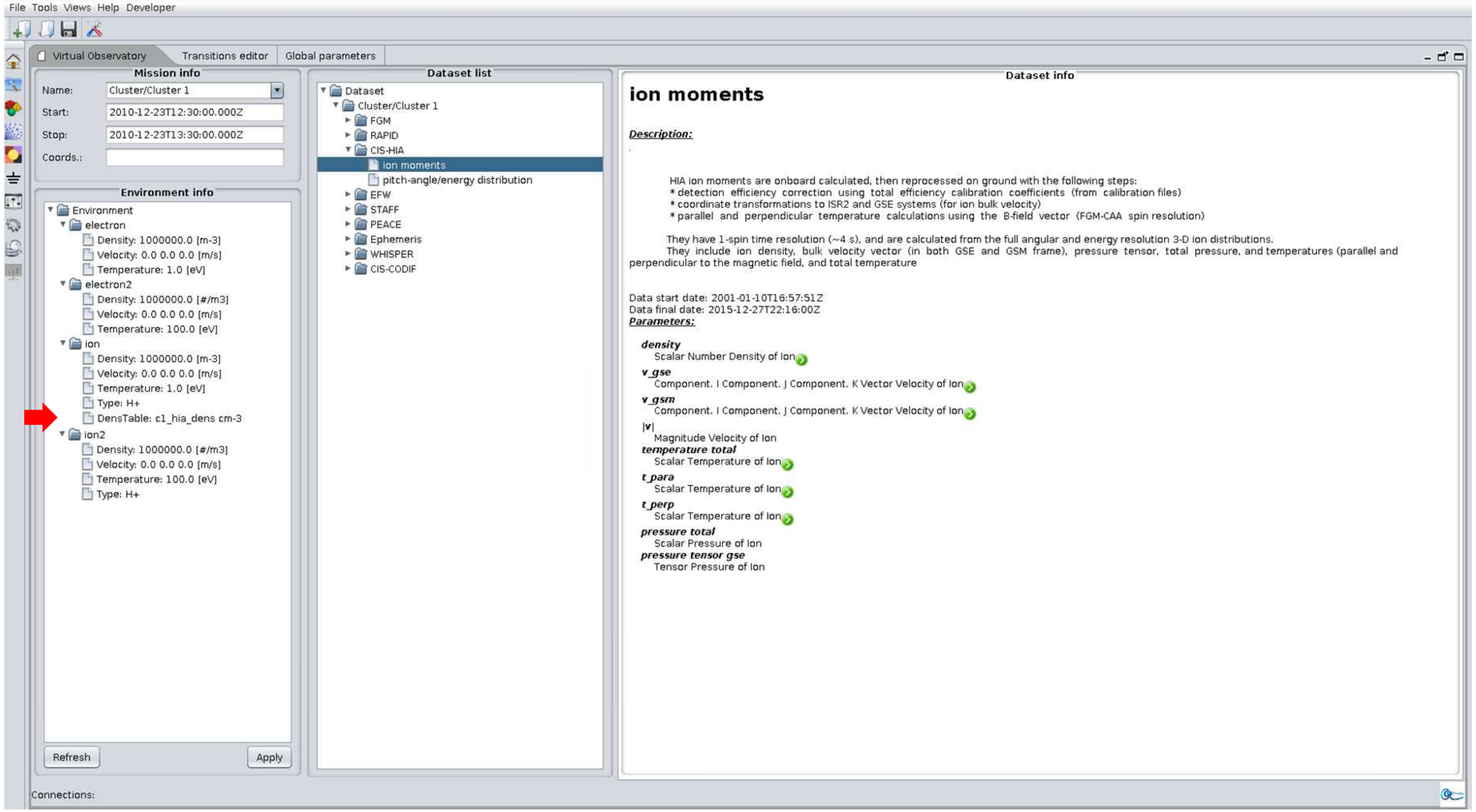

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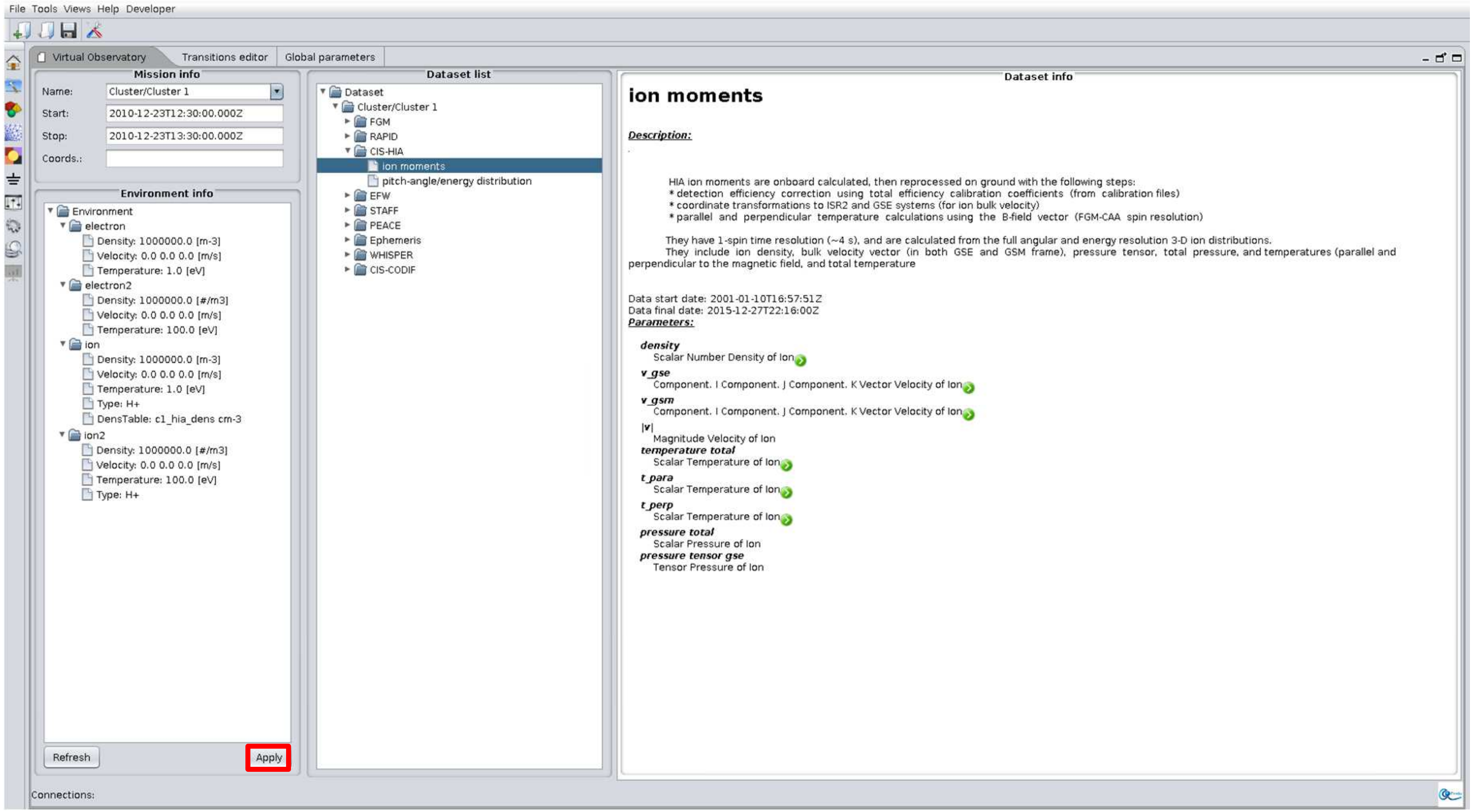

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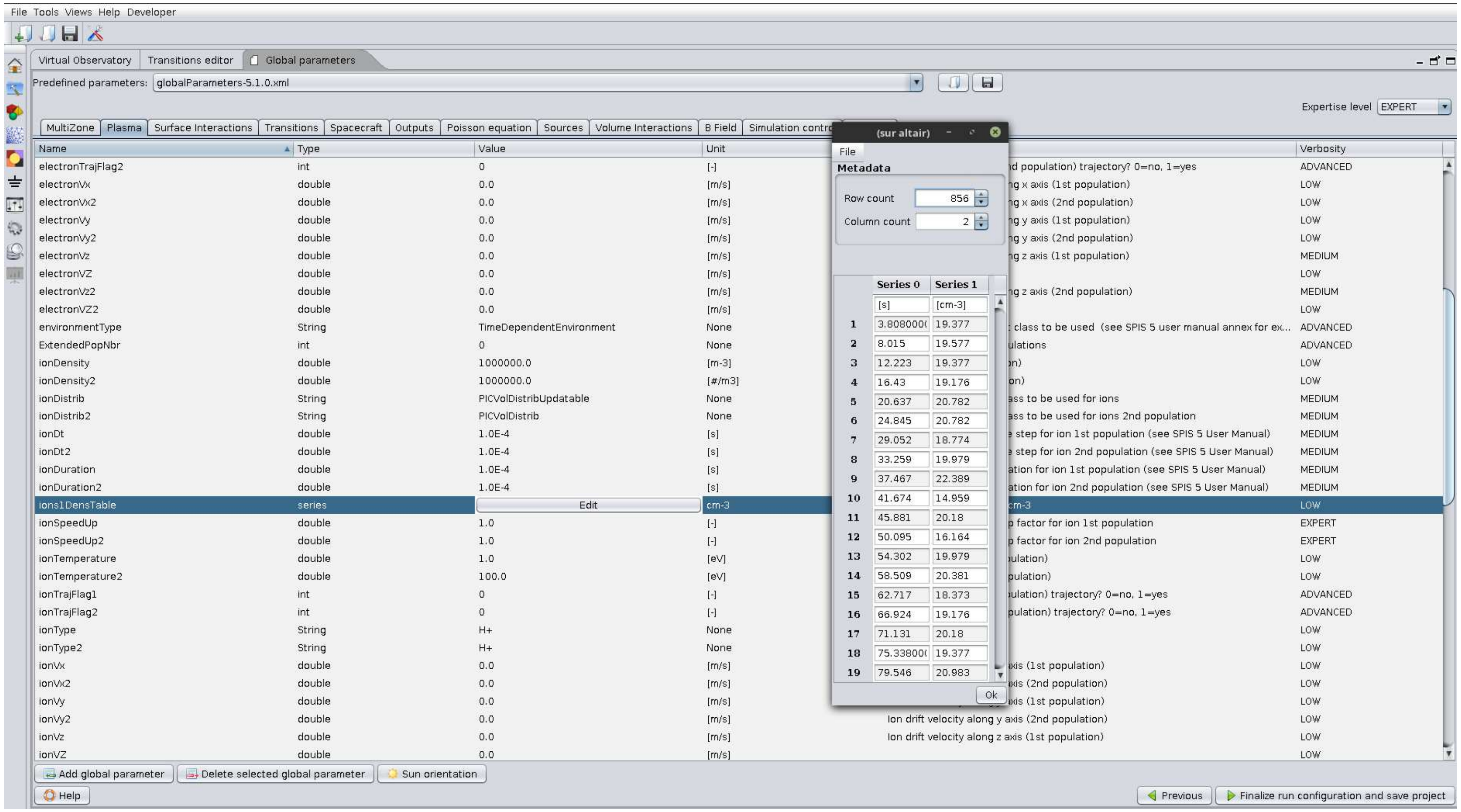

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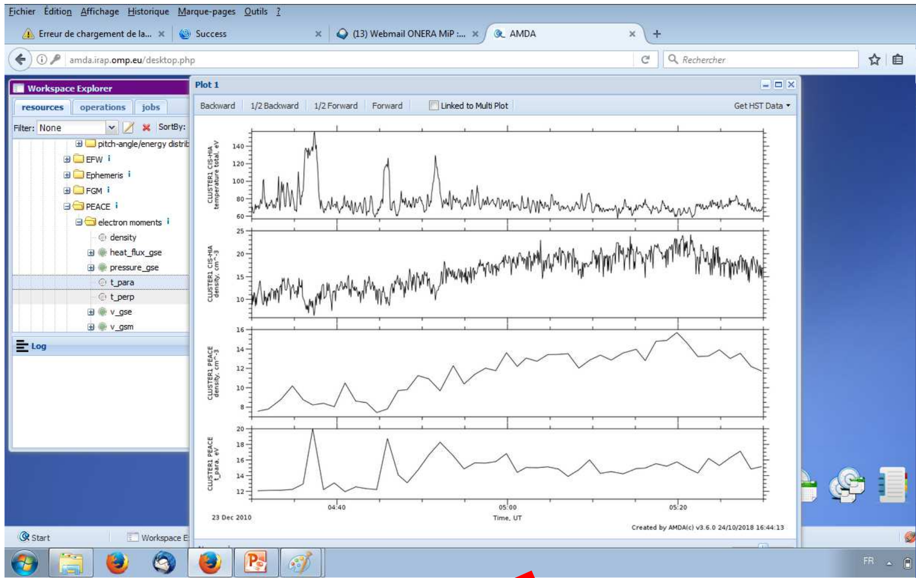
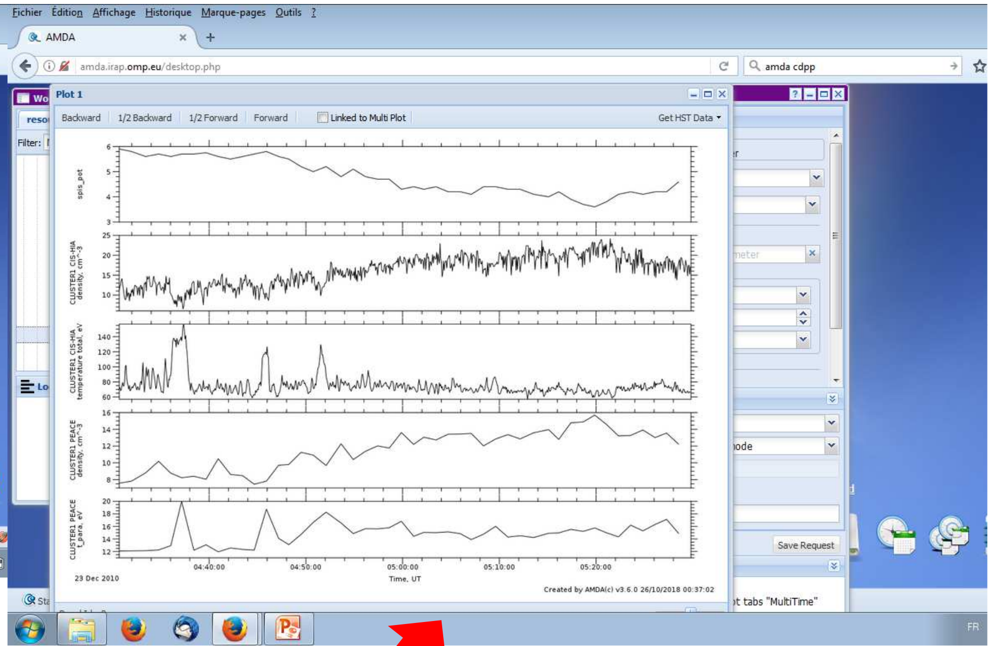
Describe, Archive and Retrieve: Environment export from SPIS





Import In SPIS

Run simulation, with data saved in VOTable format

Export it back to compatible tools such as AMDA

Visualize data and compare it to other sources

Describe, Archive and Retrieve: Materials (ChaMISEn)

Characterization of Material Interactions with Space Environments *(yes, the name came at the SCTC in Japan)*

Goal: describe and archive the material data relevant for the Spacecraft-Environment Interaction modelling.

Targeted user: institutes that perform and store the material measurements *(ONERA,…)*

Numerous data from experiments, models or simulations. Need to easily retrieve an experimental/model result.

It is necessary to keep track of the datasets, but also of the relevant experimental setups and methods, models and simulation parameters used to obtain them.

Datamodel built on SPASE:
- do not need to spend millions € to reinvent the wheel
- allows to re-use most of the tools developed for SPASE (including DB management) at little cost.
- ease the data extraction toward Spacecraft interaction models *(ONERA prototype, Artenum's MaMA,…)*

Only two major differences with SPASE:
- the dictionary (obviously)
- the material description

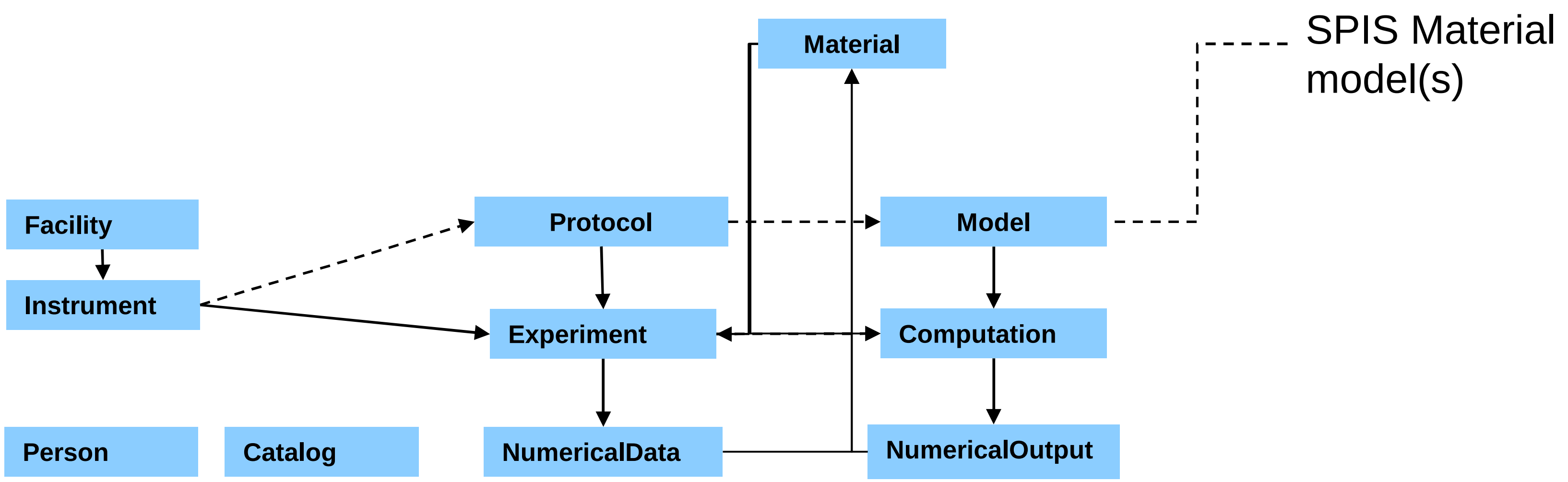
Only a few minor accommodations needed.

Describe, Archive and Retrieve: Materials (ChaMISEn)

Keep the SPASE philosophy of having different resources for :

methods	(experimental protocols, models)
practical works	(experiments, simulations)
outputs	(experimental or simulated data)

Separate resources for experiment and model

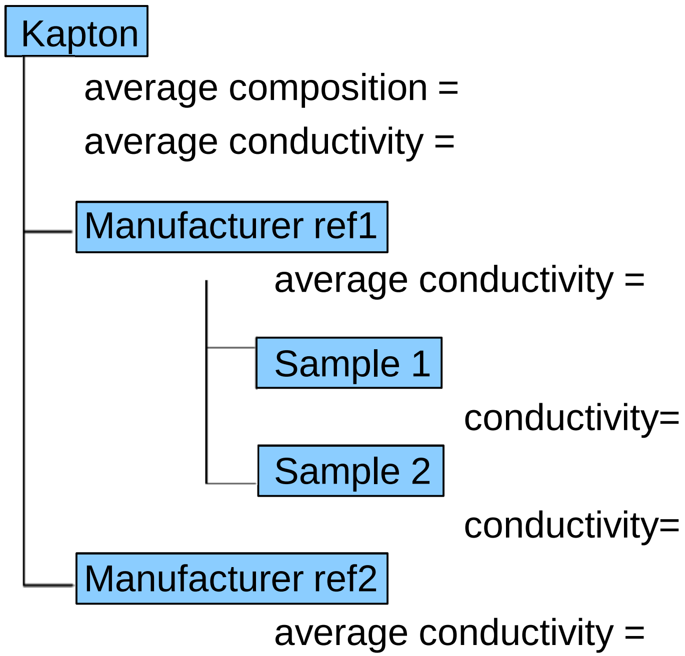


Simplified overview of the ChaMISEn resources

Describe, Archive and Retrieve: Materials (ChaMISEn)

Material Description:

May be differences between two samples of a « standard » material:



Solution:
«Material» resources can have a parent Material resource so that they can inherit the average characteristics, overriding those on which they have more precise values.

Materials referenced in a «Experiment» resource should be lower level, while models can reference more generic «Material» resources

Environment data available in exiting database under a standard formalism
Can be imported in SPIS, and SPIS data exported in the same formalism (experimental)
Similar formalism can be used for (raw) material data

Data extraction and Application

SPASE description of SPIS (, Comova,..)
Build SPIS material dataset from measurement using SPASE and ChaMiSEn

Data extraction and Application

In order to extract complete material dataset for a given tool:

- list the tools input parameters

  may be non-unique because different models are available

- list the available data :

  may be non-unique in two ways:

  different samples give different values

  different methods give different data (ex: SEEY)

- match the input parameters with the available data

  may result in several possibilities

- propose several options to the user.

- extracts the selected dataset, save it under the proper format.

Describe, Archive and Retrieve: SPIS Inputs description

SPIS model described as a SPASE SimulationModel resource, which provides a description of the code itself, a tracking of the version, a tracking of the funding project and agencies,….

The resource also provides the (documented) list of inputs and outputs in a well formalized format.

It takes the form of an XML file included in the SPIS-Core package, or in each plugin package.

Inputs described as a list of <Property> (defined in SPASE)

```
<Property>
    <Name> Plasma cycle Duration</Name>
    <Description>
        Duration of one cycle of the plasma solver.
        (automatic if 0: plasma dynamics is only integrated over
         a fraction 1/plasmaSpeedUp of actual physical time )
    </Description>
    <PropertyType>Float</PropertyType>
    <PropertyQuantity>Temporal</PropertyQuantity>
    <Units>s</Units>
    <PropertyLabel>plasmaDuration</PropertyLabel>
    <PropertyValue>0</PropertyValue>
    <ValidMin>0</ValidMin>
</Property>
```

Keywords from the SPASE dictionnary, ease searches (pointing to PropertyQuantity)

Provide default value and validity range (pointing to PropertyValue / ValidMin)

This provides all the necessary data to help configuring SPIS

Describe, Archive and Retrieve: SPIS Inputs description

Some input parameters can only have a limited number of values (enumeration)
Inputs whose values are part of an enumeration refers to a VOTable *(IVOA standard)*

```
<Property>
    <Name>Simulation Scenario Name</Name>
    <Description>
        Name of the simulation scenario model. Scenarios are defined
        to set-up the software for simulating particular phenomena
        that are sensibly different than the physics addressed by the
        standard version of SPIS
    </Description>
    <PropertyType>Enumeration</PropertyType>
    <PropertyQuantity>Other</PropertyQuantity>
    <Units/>
    <PropertyLabel>scenario</PropertyLabel>
    <PropertyValue>Scenario</PropertyValue>
    <PropertyTableUrl>jar:org-spis-num-bundles-spase!/spis/bundles/spase/resources/input_description_votable.xml?
resourceID=spase://ONERA/SimulationModel/SPIS_NUM_Core;tableID=scenario</PropertyTableUrl>
</Property>
```

The table enumerates the possibilities (name, type, value,…) and may give a reference for models

```
<TABLE name="scenario">
    <DESCRIPTION>Possible values for the fixedSimulationDtFlag Global Parameter</DESCRIPTION>
    <FIELD name="name"  ID="col1" ucd="meta.title"      datatype="char" unit=""/>
    <FIELD name="value" ID="col2" ucd="meta.main"       datatype="char" unit=""/>
    <FIELD name="type"  ID="col3" ucd="meta.code.class" datatype="char" unit=""/>
    <FIELD name="note"  ID="col4" ucd="meta.note"       datatype="char" unit=""/>
    <FIELD name="unit"  ID="col5" ucd="meta.unit"       datatype="char" unit=""/>
    <FIELD name="ref"   ID="col6" ucd="meta.ref"        datatype="char" unit=""/>
    <DATA>
        <TABLEDATA>
            <TR>
                <TD>Standard</TD>
                <TD>Scenario</TD>
                <TD>String</TD>
                <TD>Standard surface charging scenario</TD>
                <TD/>
                <TD/>
            </TR>
            <TR>
                <TD>Potential Sweep</TD>
                <TD>PotentialSweep</TD>
                <TD>ModelName</TD>
                <TD>Scenario simulating a potential sweep.</TD>
                <TD/>
                <TD>spase://ONERA/SimulationModel/SPIS/Scenario/PotentialSweep</TD>
            </TR>
        </TABLEDATA>
    </DATA>
</TABLE>
```

Some input parameters relate to names of models included in SPIS

Describe, Archive and Retrieve: SPIS Inputs description

Models in SPIS are also described by spase:SimulationModel and may have their own input list (allows to define the mandatory inputs for distributions, interactions,…)

Explicit relation to SPIS-NUM-Core:

“PartOf” : model within SPIS (distribution, interaction,…)

“DerivedFrom”: model extending SPIS (i.e. = plugins)

All plugins may have their own descriptor that is automatically read extending the SPIS input description automatically

```
<SimulationModel>
    <ResourceID>spase://ONERA/SimulationModel/SPIS/Scenario/PotentialSweep</ResourceID>
    <ResourceHeader>
        <ResourceName>SPIS Numerical Core</ResourceName>
        <ReleaseDate>2017-08-21T10:00:00.000</ReleaseDate>
        <Description>
            Spacecraft-Plasma Interaction Software (SPIS) scenario.
            Performs a potential sweep and supplies I-V characteristics
        </Description>
        <Contact>
            <PersonID>spase://ONERA/Person/JCMV</PersonID>
            <Role>GeneralContact</Role>
        </Contact>
        <InformationURL>
            <URL>http://dev.spis.org</URL>
        </InformationURL>
        <Association>
            <AssociationID>spase://ONERA/SimulationModel/SPIS_NUM_Core</AssociationID>
            <AssociationType>PartOf</AssociationType>
        </Association>
    </ResourceHeader>
    <Caveats>Some supplementary parameters possible, check the user manual</Caveats>
    <InputProperties>
        <Property>
            <Name>Number of steps (Potential Sweep)</Name>
            <Description>
                Number of steps in the potential sweep
            </Description>
            <PropertyType>Integer</PropertyType>
            <PropertyQuantity>Other</PropertyQuantity>
            <Units/>
            <PropertyLabel>scenarioParameter1</PropertyLabel>
            <PropertyValue>0</PropertyValue>
        </Property>
```

SPIS material model defined this way, but as a ChaMISEn model.

Data parsing, gathering, indexation and search tools implemented in a plugin by ONERA.
Development of SPIS-UI to take advantage of this package proposed for future activity to ESA.

Data extraction and Application

In order to extract complete material dataset for a given tool:

- list the tools input parameters

  may be non-unique because different models are available

→ read the SPASE/ ChaMISEn description of SPIS

- list the available data, may be non-unique in two ways:

  different samples give different values

  different methods give different data (ex: SEEY)

→ list all data by searching the SPIS input parameters in the ChaMISEn databases

- match the input parameters with the available data, result in several possibilities

- propose several options to the user.

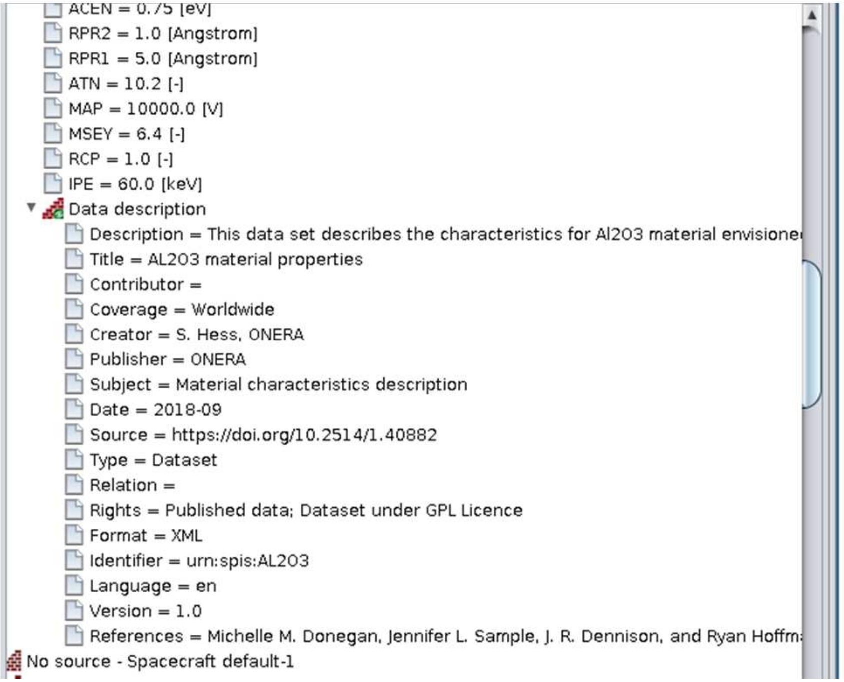
- extracts the selected dataset at the correct format, add a ISO 15836 header.

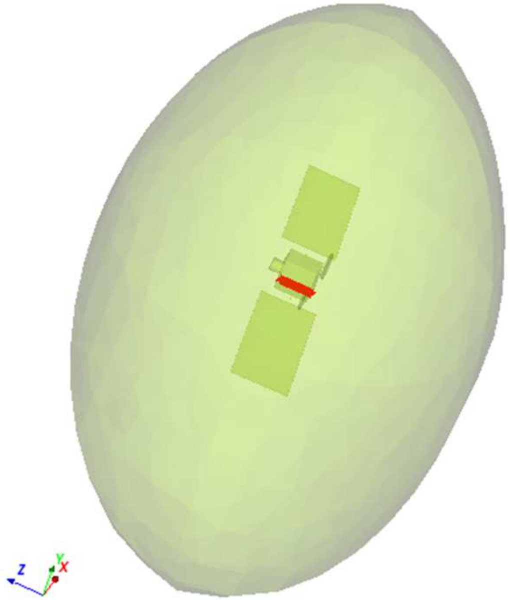
Keep track of material datasets and models

Metadata added to the material and device parameter sets in SPIS v6.0RC

CNES R&T activity performed by the ONERA

The metadata implemented are those of the Dublin Core (ISO 15836)





Allows to document the origin of the data!

Provide a unique identifier to the dataset.

Conclusion

Spacecraft-environment interaction software requires environment and material definitions.

Standards exist for space environment database that are well suited for our tools

They can be used to describe the spacecraft-environment interaction softwares in order to ease their documentation and their interface with databases.

The environment standards are generic an robust enough so that they can be adapted to material measurement databases at little cost.

This will help to make tools that export data from material measurement databases toward catalogs of material datasets to be used in softwares (Artenum's MAMA,…)

A first step was made under CNES funding with the addition of metadata to SPIS material and device (thruster, sola panels) datasets