



## **Collaborative modelling and concurrent scientific data analysis:**

### **Application case in space plasma environment with the Keridwen/SPIS- GEO Integrated Modelling Environment**

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## **Introduction**

- New challenges in numerical modelling
- Integrated Modelling Environments

## **Keridwen 2**

- Overview
- Domains of application
- A modular system
- Underlying technologies

## **Cassandra, shared visions**

- Cassandra 2.5
- Experimental cloud service
- A lightweight approach

## **Application case: SPIS**

- Overview
- A complex modelling process
- Geometry and CAD editor
- CAD interoperability
- Mesh editor
- Properties and groups settings
- Simulation control and live monitoring
- Data mining and post-processing
- Automatic reporting

## **Conclusion and perspectives**

# Introduction

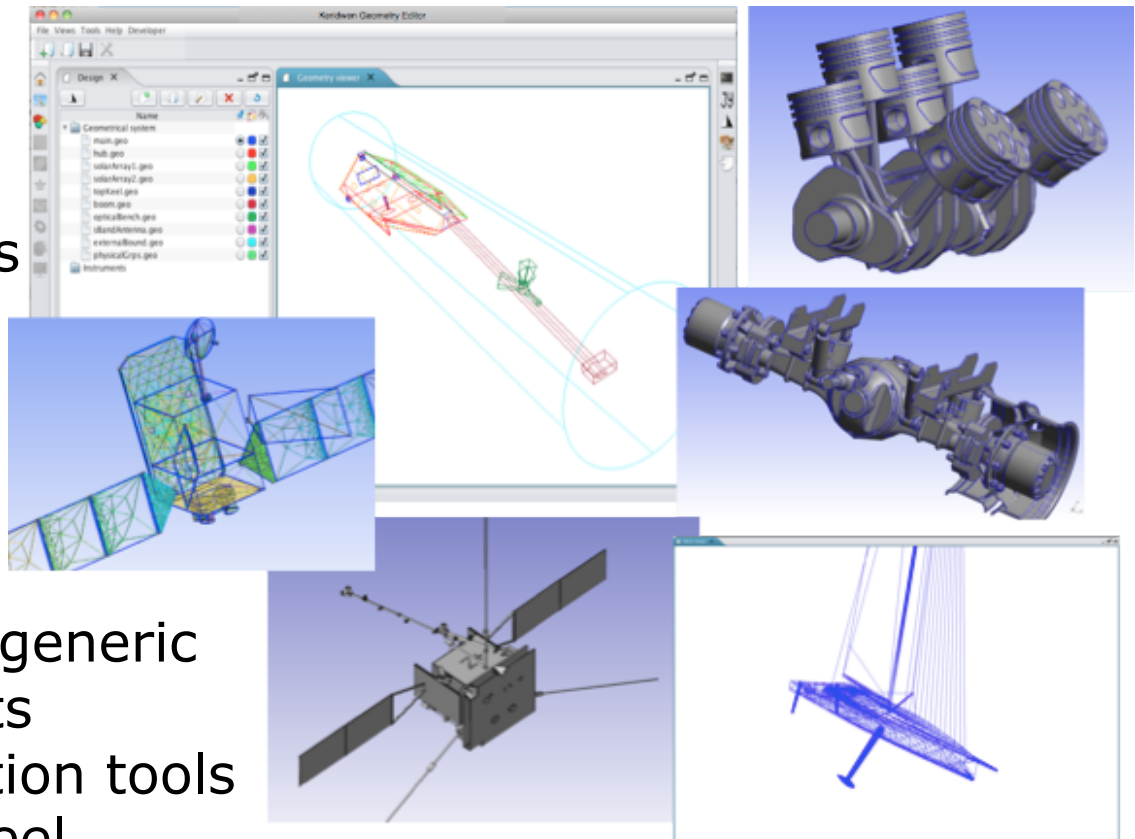
## **New challenges in numerical modelling**

Modelled systems are more and more complex and large

- Multi-physics / multi-scales / multi-models
  - ⇒ Require a large spectrum of expertise, often geographically spread
  - ⇒ Interoperability and integration into existing information systems
- Large systems highly demanding in terms of resources
  - ⇒ Parallel and/or distributed computations
  - ⇒ Remote control of the simulation loop(s) and live monitoring
- Complex to configure and model (3D geometry, properties attributions, numerical parameters settings)
  - ⇒ Need for simplified modelling process to reduce the learning curve and guide the users along the modelling chain
- Large amount of rich output data to process
  - ⇒ Necessity to share over the Web rich and complex data
  - ⇒ Necessity of a robust traceability of the input/results

## Integrated Modelling Environments

- Provide tools common to most simulation environments
  - Possibility to integrate various numerical kernels
  - File formats converters
  - Distributed capabilities
  - Simulation monitoring and control
  - Tailored modelling chains
  - Sharing capabilities
  - Traceability and reporting



## Objectives

- Simplify the integration of generic features in tailored contexts
- Easier to build new simulation tools without reinventing the wheel

# **Keridwen 2**

## **Integrated Modelling Environment**

**Keridwen** is an open-source modular toolbox gathering, through interoperable software modules, a structured set of key functions of the scientific software and to address the whole modelling process.

**Keridwen** provides numerous generic modules like:

- Pre-processing, simulation control, post-processing
- CAD editors and 3D visualisation tools
- Fully written in Java and multi-threaded
- Based on industry standard OSGi modules system
- Robustness, performances and reliability
- High interoperability with other modeling tools
- Ready for future distributed architecture
- Generic data persistency and I/O capabilities
- Open-source: public release in the coming weeks

**Keridwen** aims to facilitate the conception and the development of tailored scientific applications, simulation software or data analysis tools.

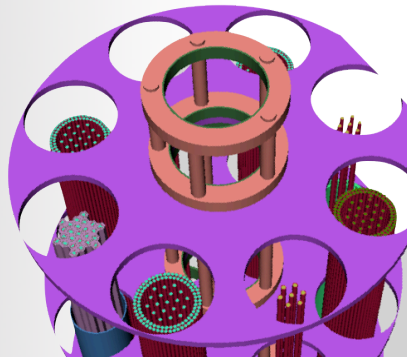
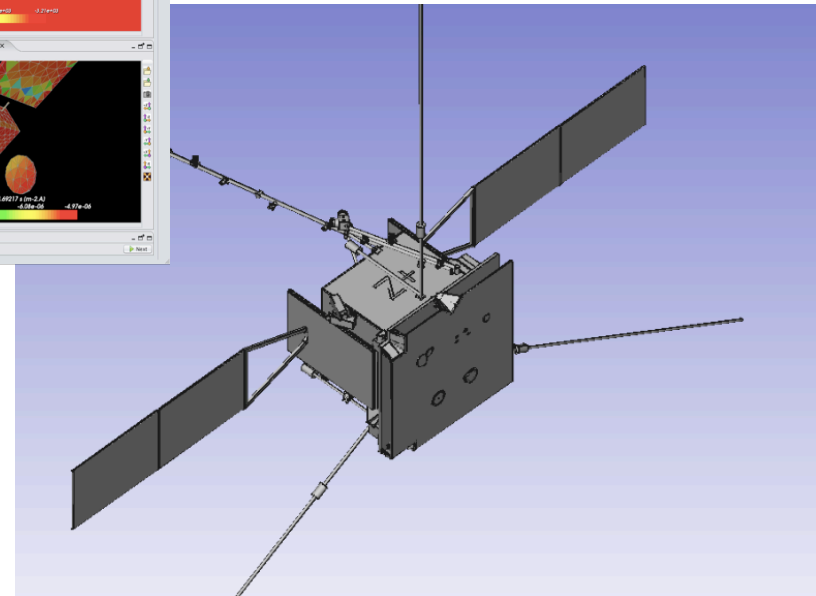
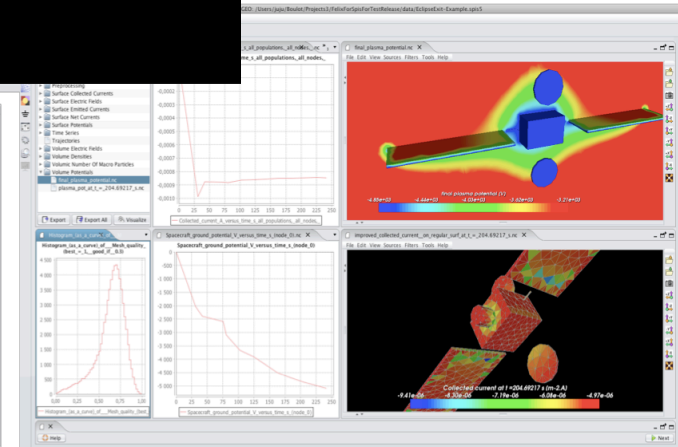
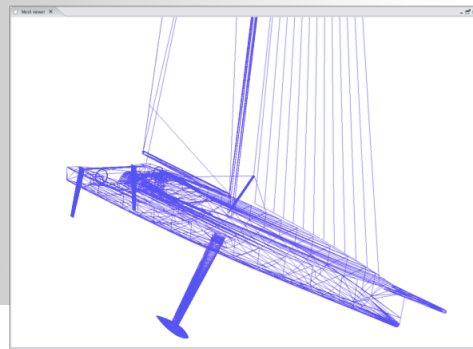
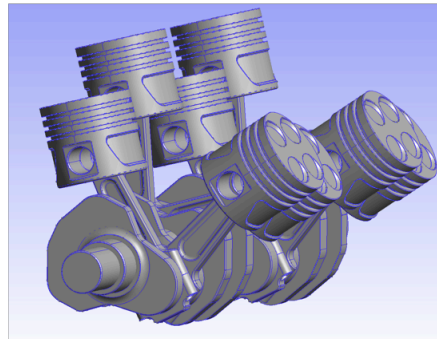
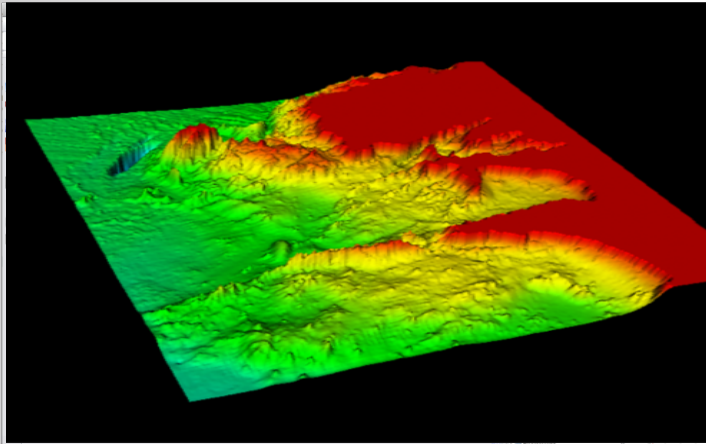
The best basis to easily build the adapted  
Integrated Modelling Environment (IME) solutions

**KERIDWEN**  
INTEGRATED MODELLING ENVIRONMENT



## A wide scope of applications

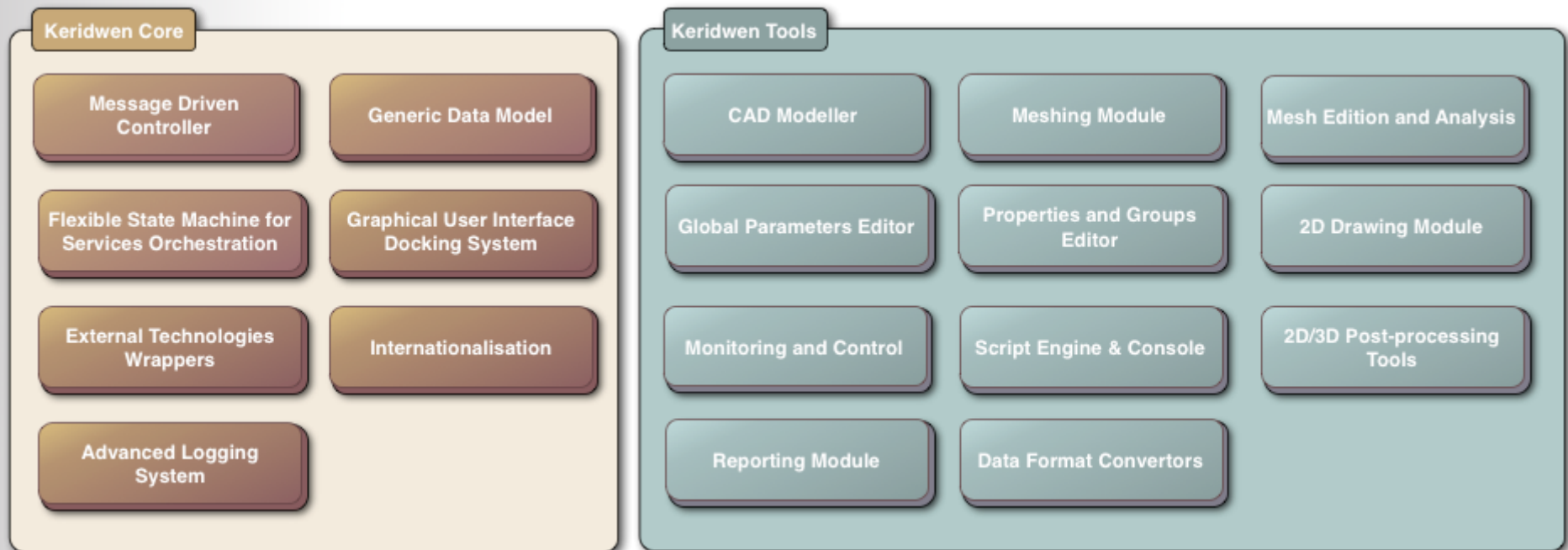
- Space environment
- Radio protection
- Mechanics and CFD
- GIS
- Electronic circuit design



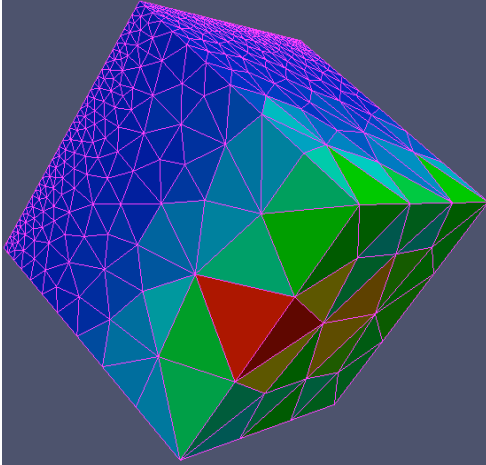


## A modular system

- OSGi and normalised modules to easily build dedicated and adapted solutions
- Low level as well as top level functional modules
- Set a generic tools (mesher, viewer, auto-reporting, properties settings...)



# Keridwen 2



## Underlying technologies

- Gmsh mesher
- VTK
- JFreeChart, 2D plotting library
- Open Cascade
- Penelope mesh library
  - Unstructured 3D meshing (tetrahedra)
  - Data fields (scalars, vectors, objects)
  - Mesh and data fields operators (splitting, mapping...)
  - Rich I/O capabilities: GMSH, XML, NetCDF, VTK...
- Frida, generic properties handling library
  - Handling of "Properties" being applied on CAD models, meshes or logical systems
  - Provide rich properties editions and mapping tools
- Cassandra, scientific 3D viewer and postprocessing tool

*Penelope's Mesh Library*



*Frida, the painter*

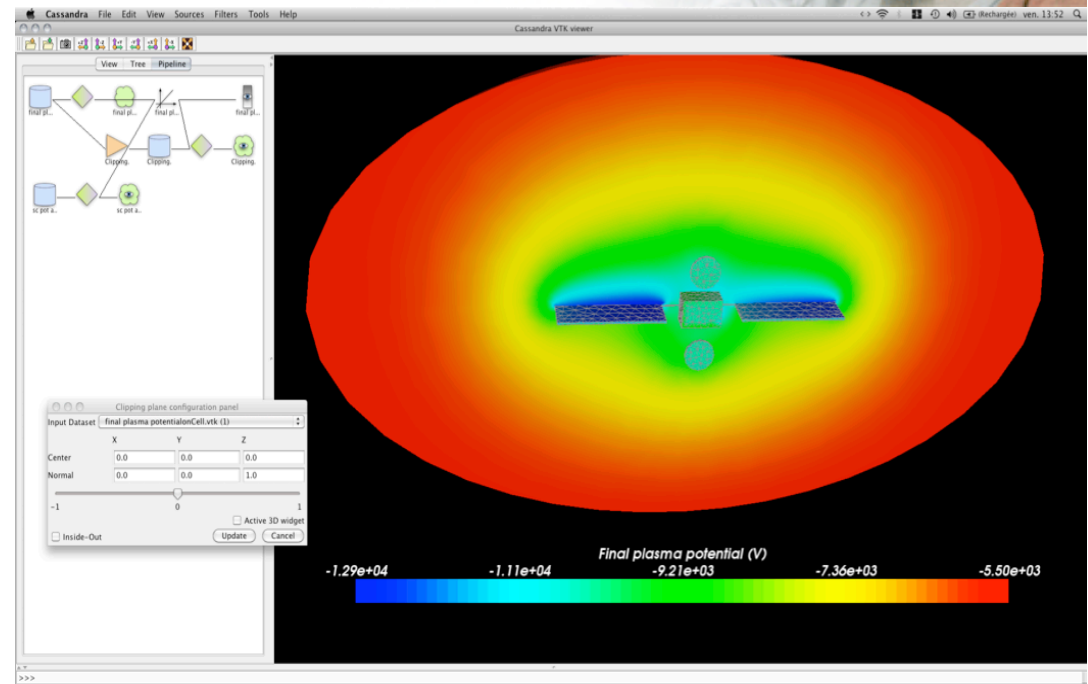
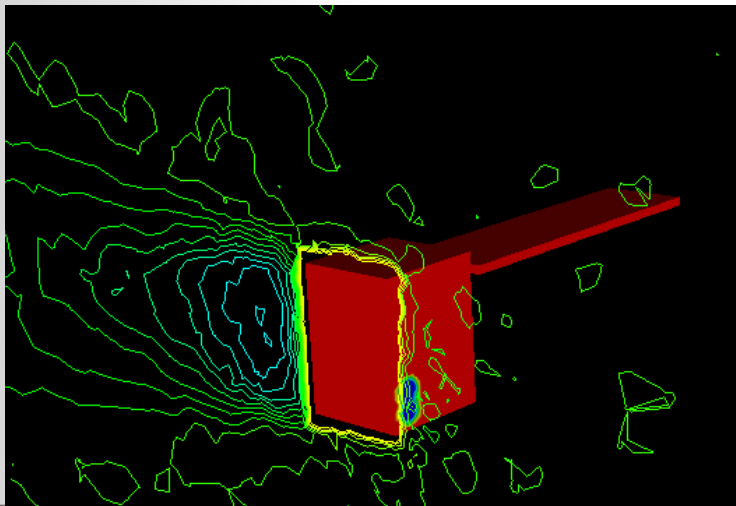


# Cassandra

## Shared visions

## Cassandra 2.5, 3D Scientific Data Viewer

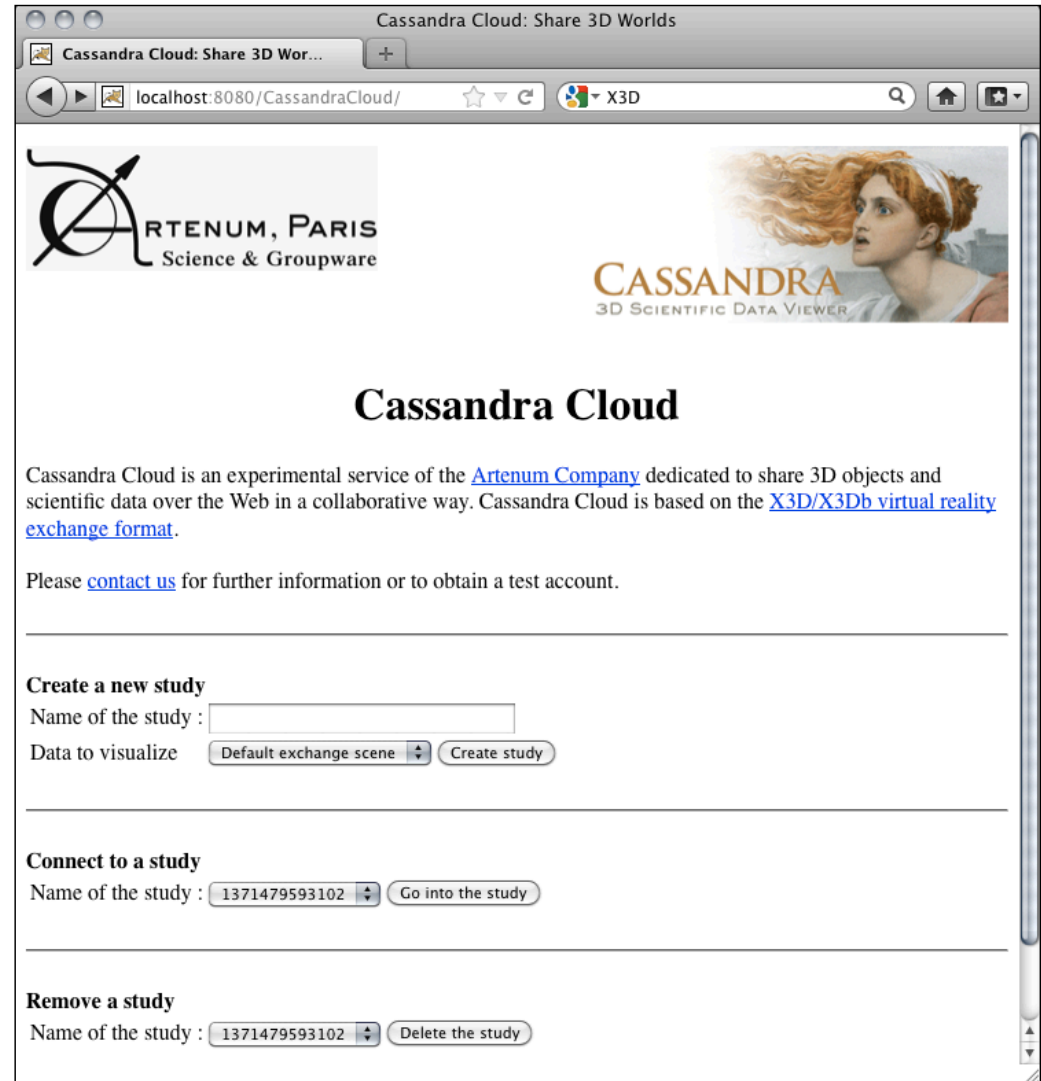
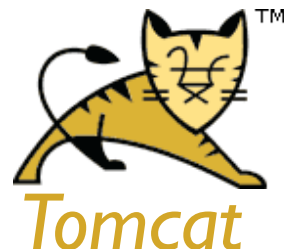
- Graphic visualisation pipeline editor for complex and tailored post-processing
- Simpler to use (improved LAF, 3D widgets)
- Based on Java and VTK
- Open-source
- Large set of filters
- Rich data conversion capabilities
- CAD import capabilities (STEP, Iges, Brep...)
- Collaborative capabilities with Cassandra Cloud



<http://www.artenum.com/EN/Products-Cassandra.html>

## Cassandra Cloud Service

- Experimental Web service
- Share over the Web
  - Processed 3D scientific data
  - CAD models
  - Meshes
- Interactive collaboration
- Data exchange based on X3Db files
- Fine integration into Keridwen (through Cassandra) to share:
  - CAD models
  - Mesh quality evaluation
  - Local properties settings
  - Simulation 3D post-processing



Cassandra Cloud: Share 3D Worlds

localhost:8080/CassandraCloud/ X3D

ARTENUM, PARIS  
Science & Groupware

CASSANDRA  
3D SCIENTIFIC DATA VIEWER

### Cassandra Cloud

Cassandra Cloud is an experimental service of the [Artenum Company](#) dedicated to share 3D objects and scientific data over the Web in a collaborative way. Cassandra Cloud is based on the [X3D/X3Db virtual reality exchange format](#).

Please [contact us](#) for further information or to obtain a test account.

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**Create a new study**  
Name of the study :   
Data to visualize

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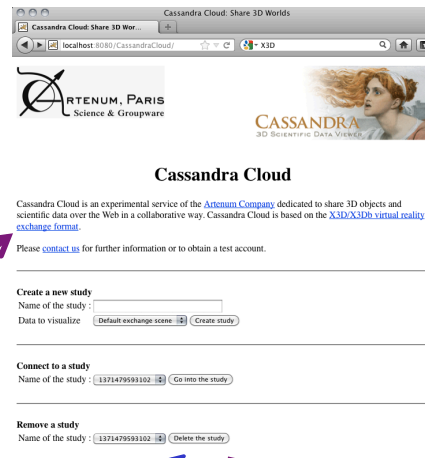
**Connect to a study**  
Name of the study :

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**Remove a study**  
Name of the study :

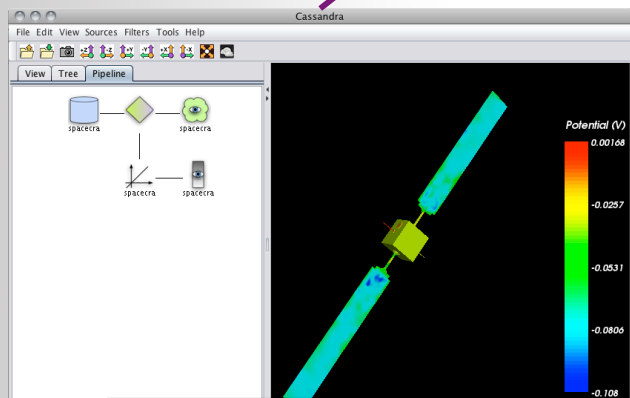
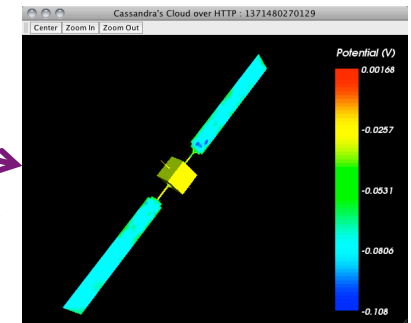
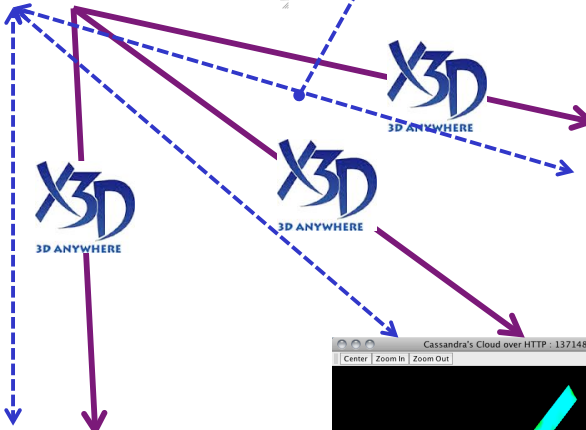
## Cassandra Cloud Service

- Data fields and CAD models
- Publication in X3Db format
- Share actions and points of view through Comet based notifications
- Based on ShareX3D (S. Jourdain, Web3D 2009)

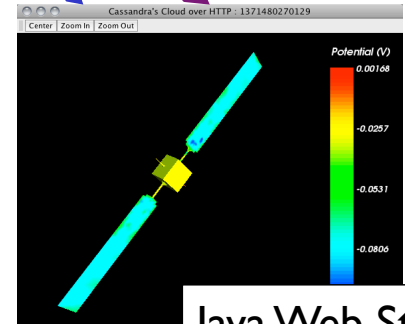
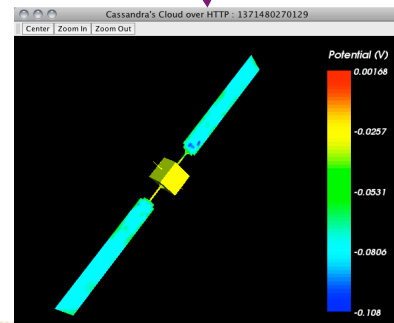


Light weight sharing server

Comet based notifications



Cassandra based client & scientific data analysis tool



Java Web Start & XJ3D light visualisation client

The image displays the Cassandra application interface with several key components highlighted:

- Data processing with Cassandra:** A pipeline diagram in the top-left pane shows a sequence of 'spacecra' components connected by arrows, representing a data flow process.
- Session management:** A 'Cassandra Cloud: 1371479593102' window shows server details (Address: `http://localhost:8080/CassandraCloud`), attendees (wallace@artenum.com, groomit@artenum.com, garfield@artenum.com), and session controls like 'Upload to Cloud' and 'Create shared se'.
- Invitation by e-mail:** An email invitation window titled 'Sujet: Invitation to Cassandra Cloud's session: 1371480270129' provides a link to access the shared 3D scene: `http://localhost:8080/CassandraCloud/V3D.jsp?scene=dynamic&etude=137`.
- Sharing of the view:** Three overlapping windows show a 3D visualization of a satellite-like structure with a color-coded 'Potential (V)' scale. The scale ranges from -0.108 (blue) to 0.0016 (red), with intermediate values at -0.0806, -0.0531, and -0.0257.

## A lightweight approach

- Server side successfully runs on light Raspberry Pi based solution
  - ARM based
  - 256Mo RAM
  - ADSL internet connection
- Why such tests?
  - Check the relevance of the whole approach
    - X3Db based data exchange
    - Band-width & latency
    - Server needed resources
  - Explore possibilities of simple and intranet exchange points
    - Easy to install
    - Easy to use
    - Low cost and low consumption





# Application Case

## The SPIS Project

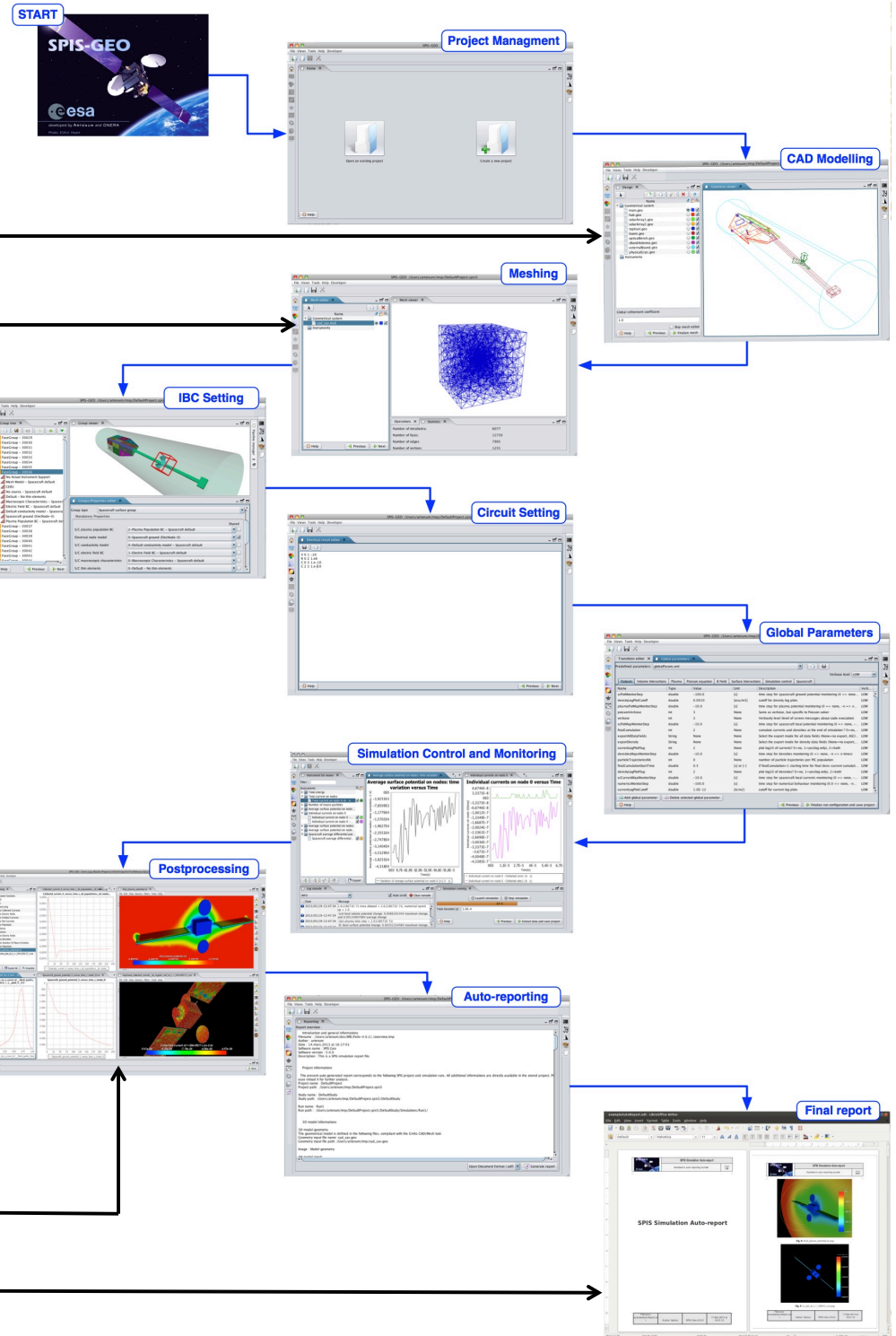
## Overview

- Spacecraft Plasma Interactions Software
- Funded by ESA and CNES
- 9 major releases since 2003
- More than 6 500 downloads
- New SPIS generation
  - SPIS-GEO
  - SPIS-Science
  - AISEPS for plasma propulsion
  - SPIS Dust
- <http://dev.spis.org>
- More than 800 registered members (and around 2 new registrations a week)
- About 20 active contributors (including SMEs, major industrial actors and academics)

## SPIS-GEO project

- International consortium:
  - Artenum
  - ONERA
  - Astrium
  - OHB-Sweden
- Objectives:
  - Simplified user interface
  - Support of standard file formats (STEP, NetCDF, VTK, XML, etc.)
  - Improved robustness and overall quality

⇒ **Full redevelopment based on Keridwen 2**



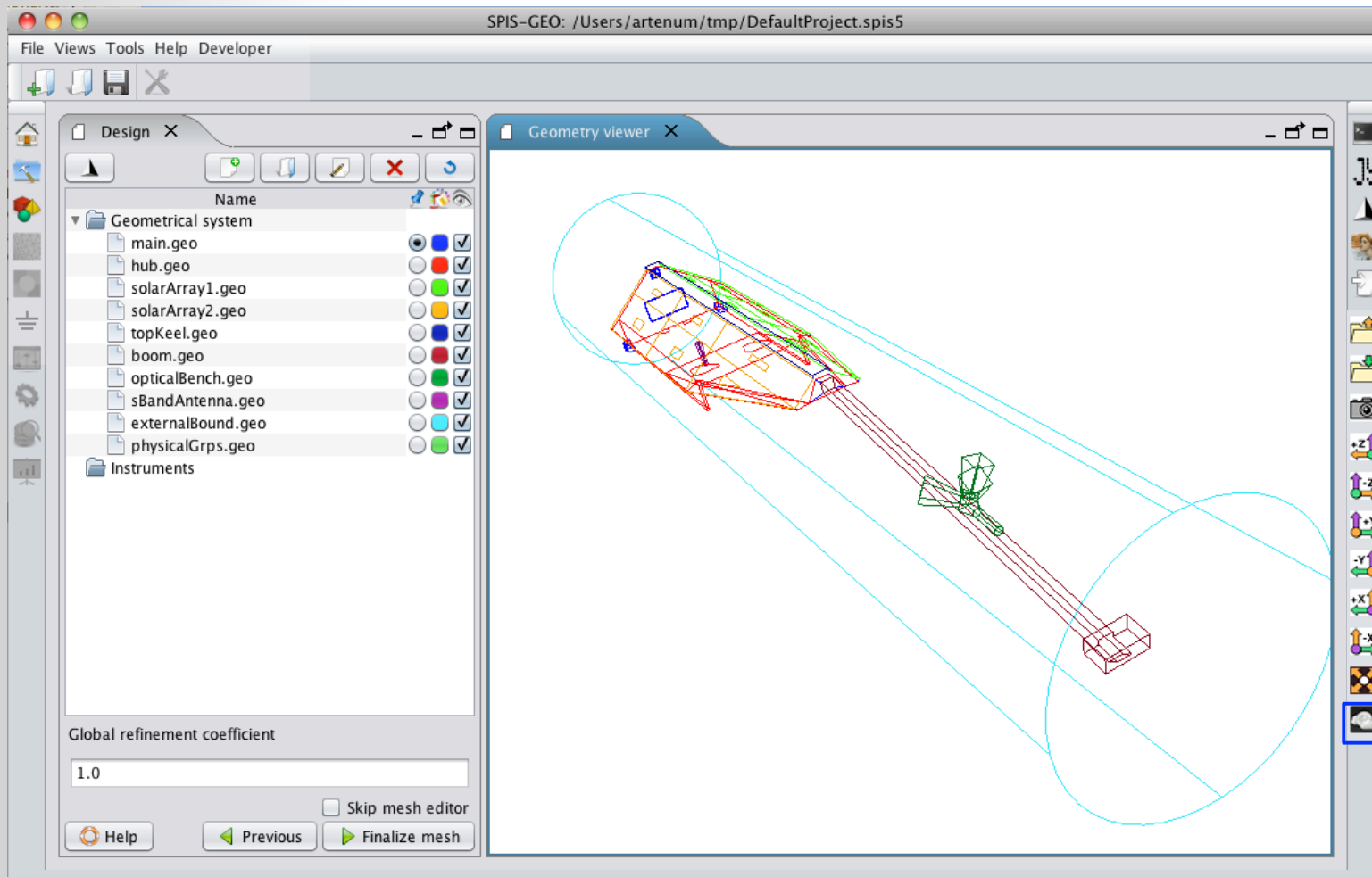
## A complex and rich modelling process

- A long path to follow:
  - From the system definition to the post-processing
  - Control the simulation (monitoring)
  - Simplify the reporting and data traceability
- Data may have to be shared at various steps:

## **Data may have to be shared over a network at several points along the modelling process**

- Whole project persistency scheme:
  - Saving on a central server
  - Should allow a remote access (files paths defined as URIs)
  - Should allow a distributed persistency scheme
- Centralised material database
- Share and/or visualise CAD models
  - Visualisation
  - Concurrent design
  - Centralised CAD sub-systems
- Share and/or visualise Initial and Boundary Conditions settings
- Share and/or visualise produced result data
- Share and centralised simulation reports

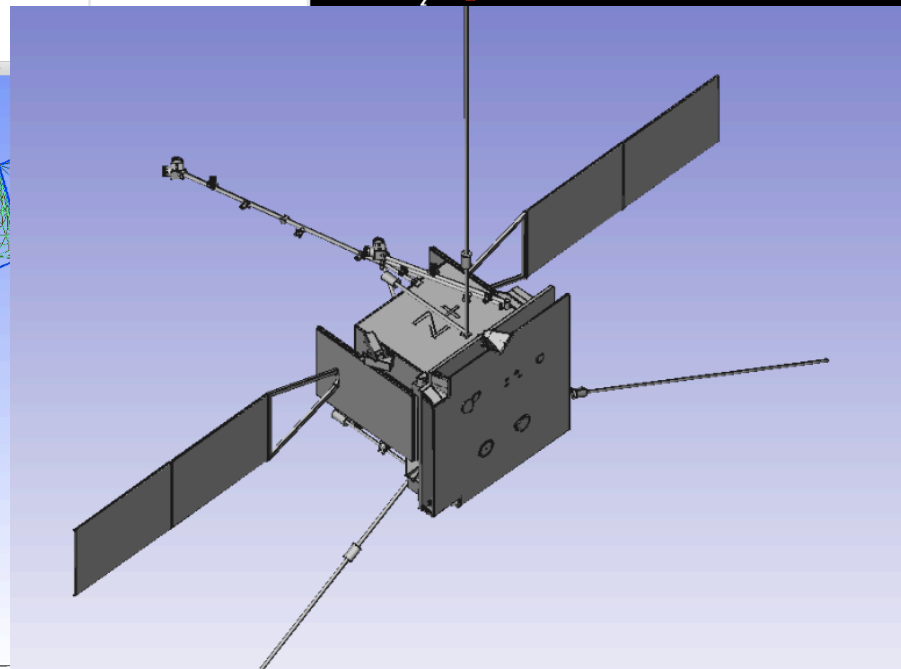
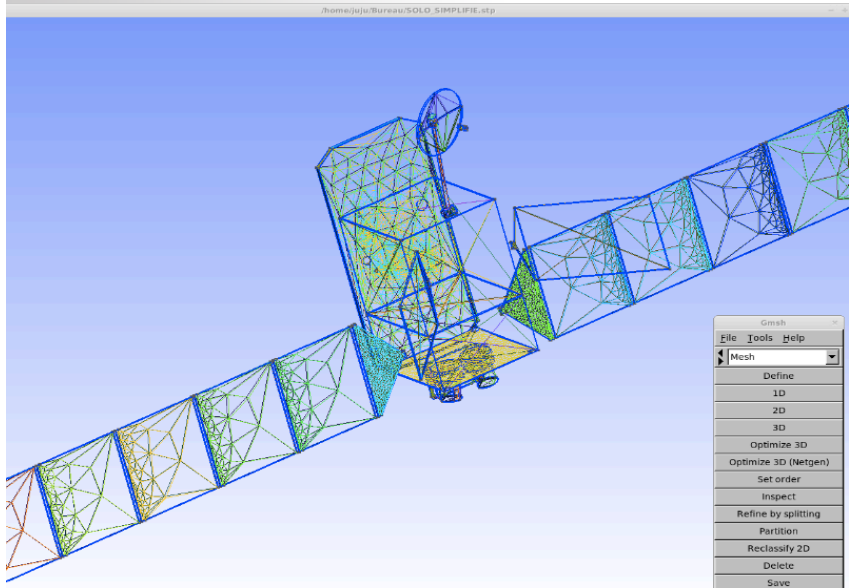
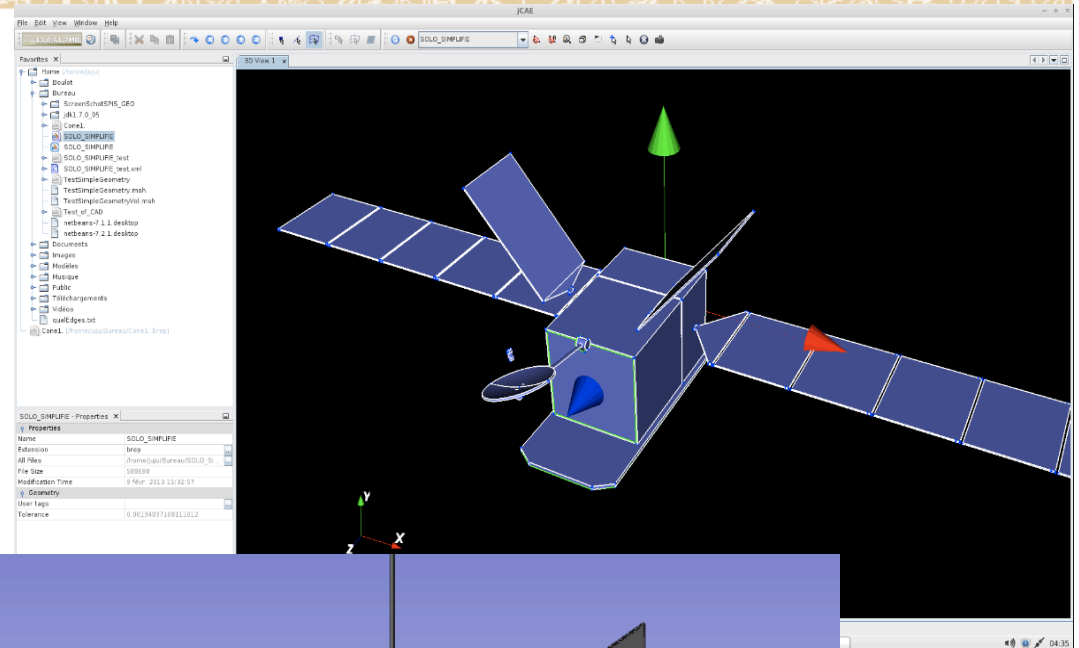
## Geometry and CAD editor



Sharing with  
Cassandra  
Cloud

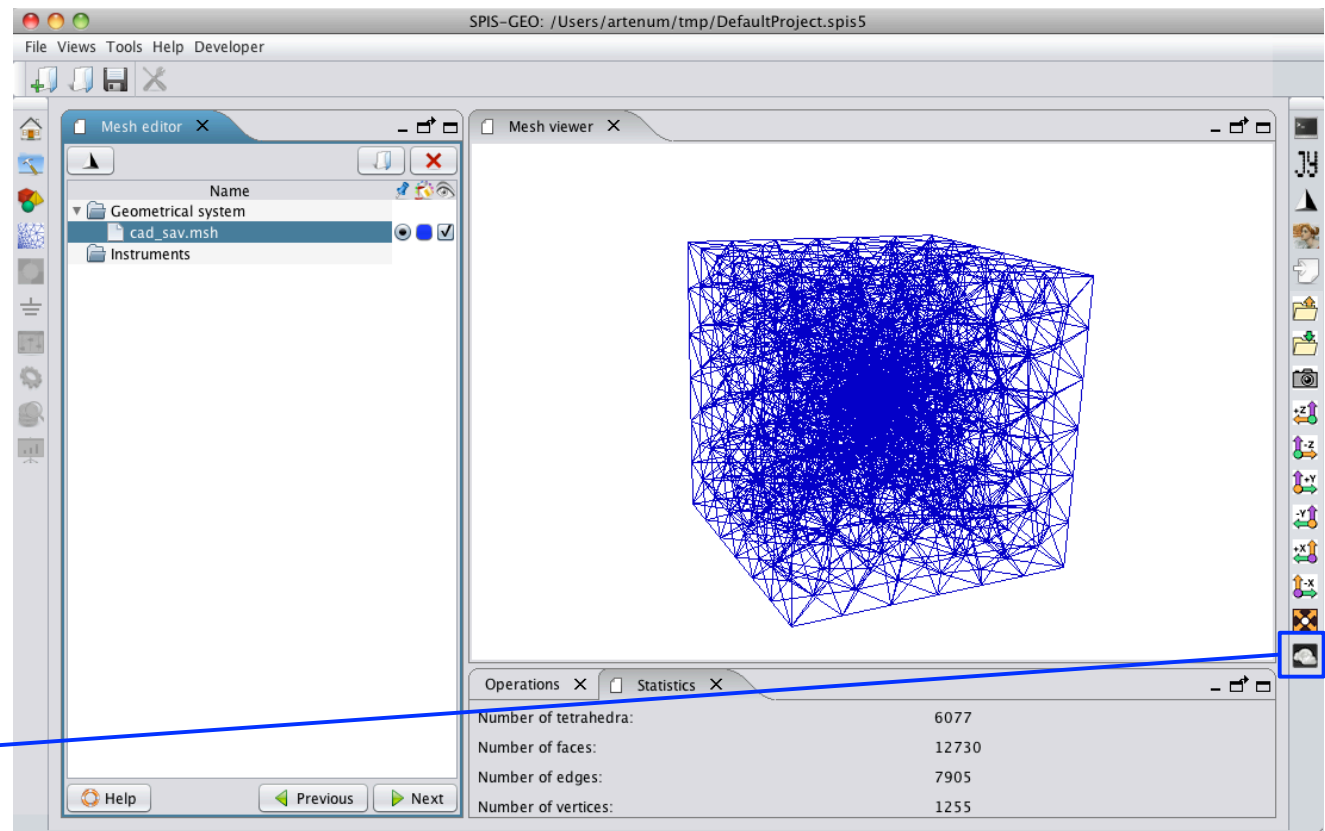
## CAD Interoperability

- STEP importer through Gmsh (OpenCascade based)
- Tessellated geometries importer (Penelope)
- Interfacing with external CAD tools (e.g. JCAE, FreeCAD, CATIA...)



## User interface overview – Mesh editor

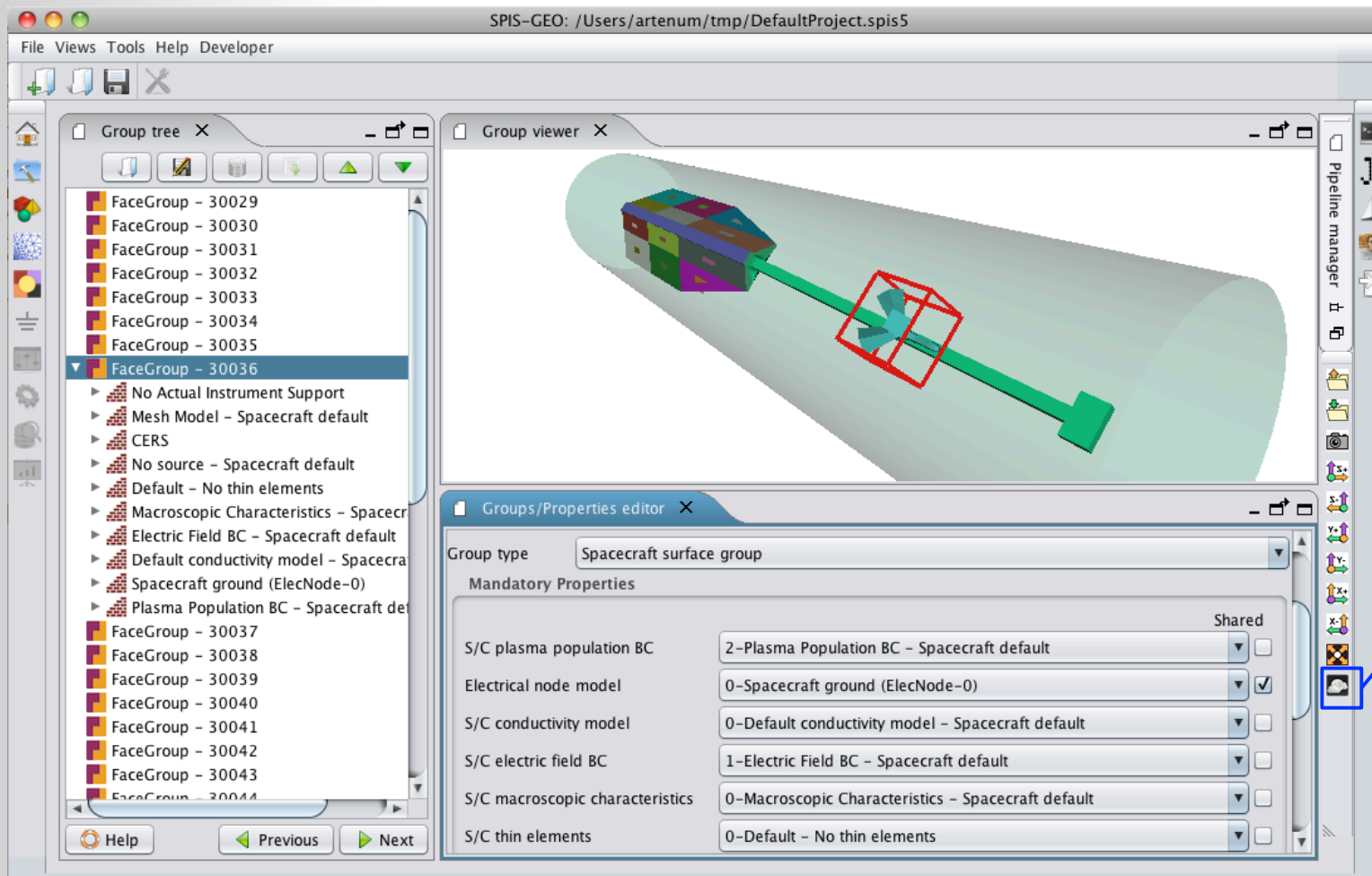
- Mesh statistics
- Possibility to directly import existing mesh files in various formats (gmsch, STL, UNV...)
- Mesh operations mechanisms: currently, one operator provided to change the orientation of mesh faces (used for 2D thin elements)
- Mesh statistics information



Sharing with  
Cassandra Cloud

## Properties and Groups editor

- Simplified edition of the group properties allocation and edition
- Based on the Frida library

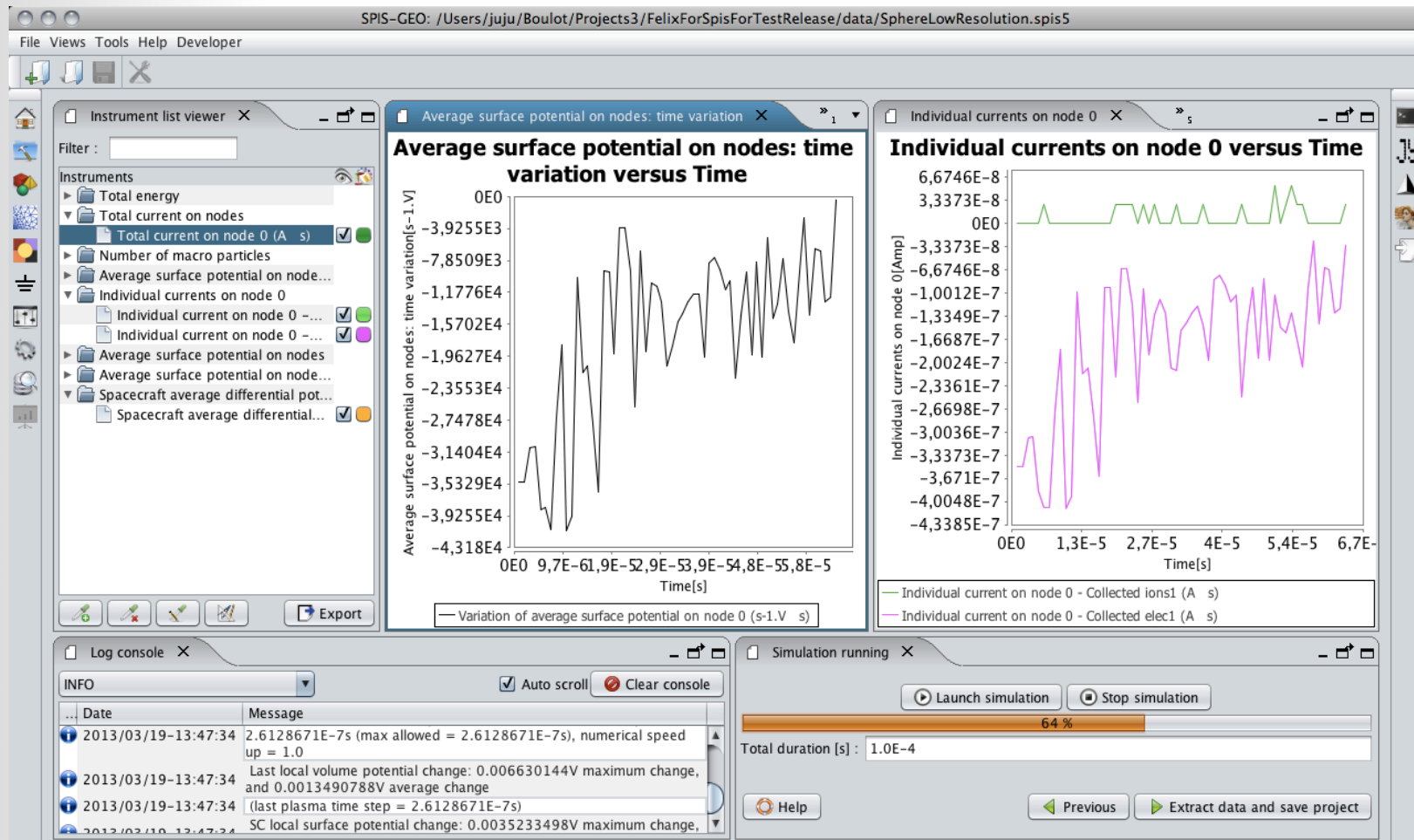


Sharing with  
Cassandra  
Cloud



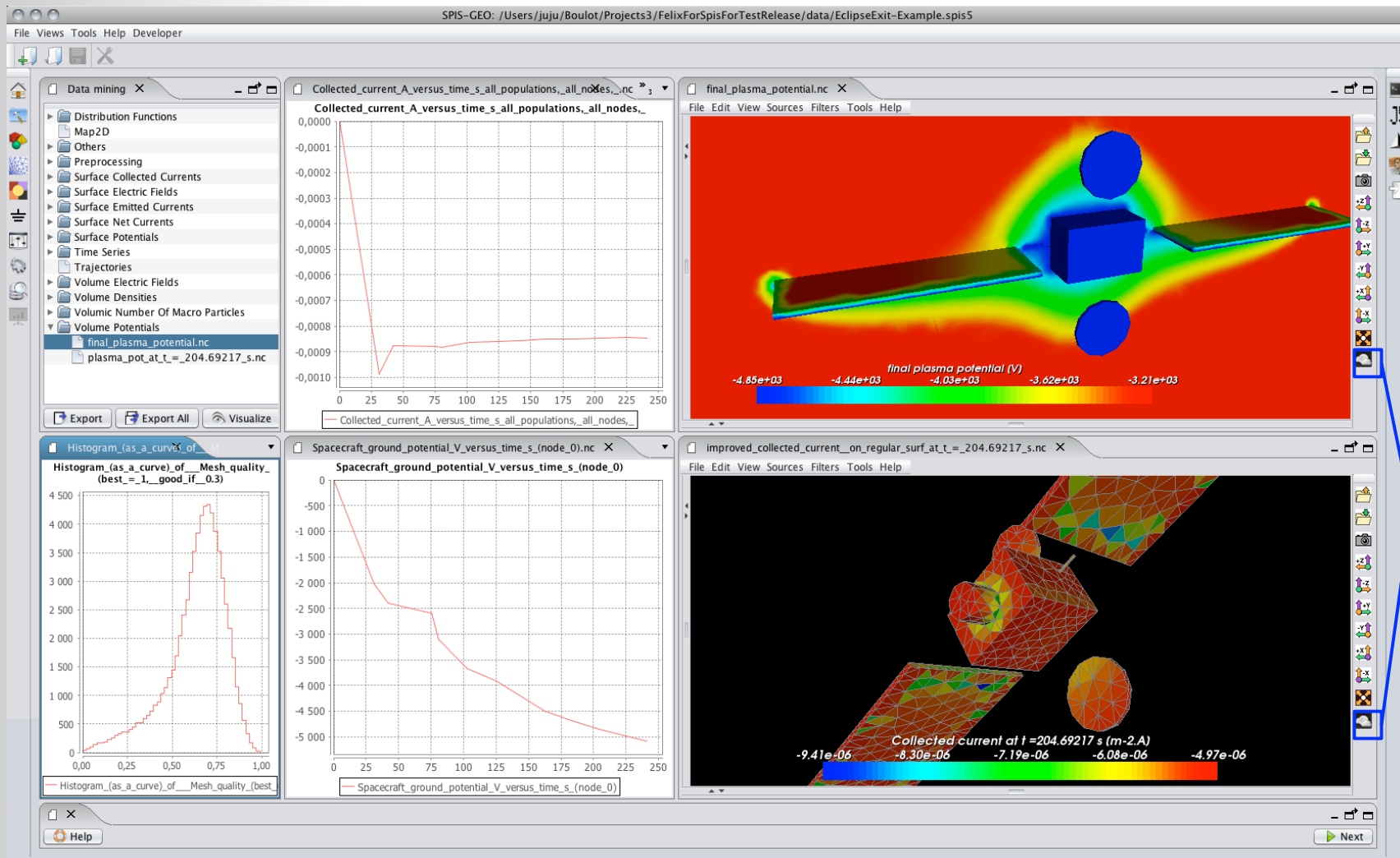
## User interface overview – Simulation control & monitoring

- Simulation control: start / pause / stop
- Real-time monitoring: displays key parameters of the simulation



## Post-processing

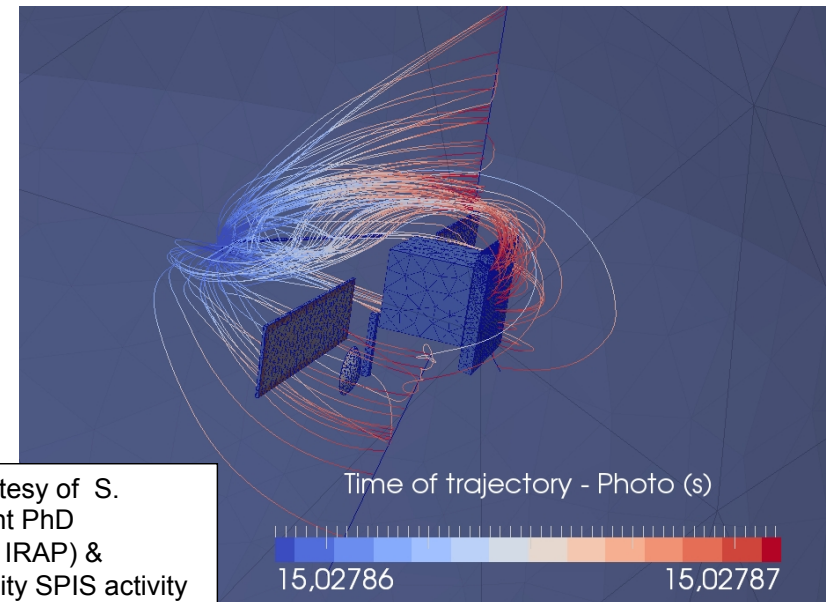
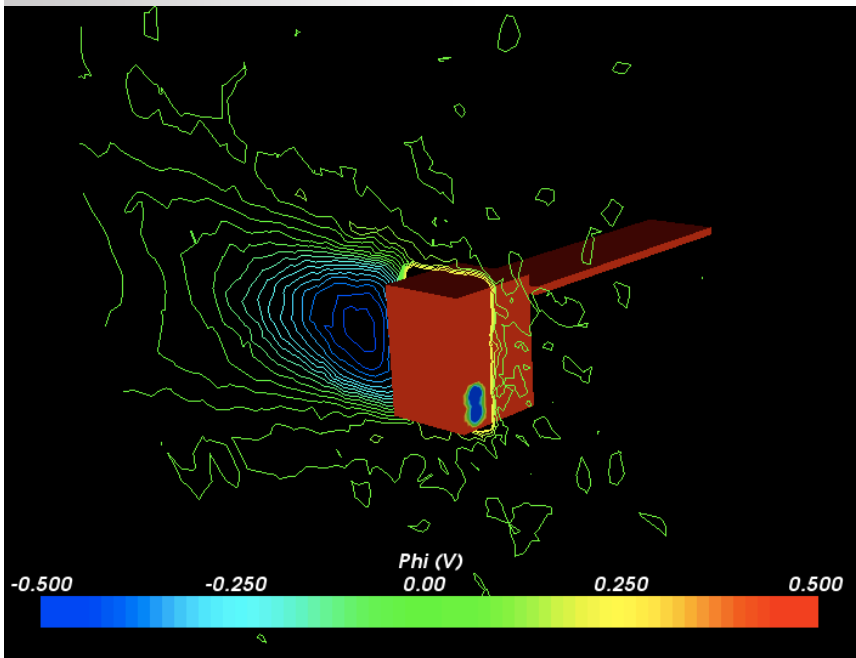
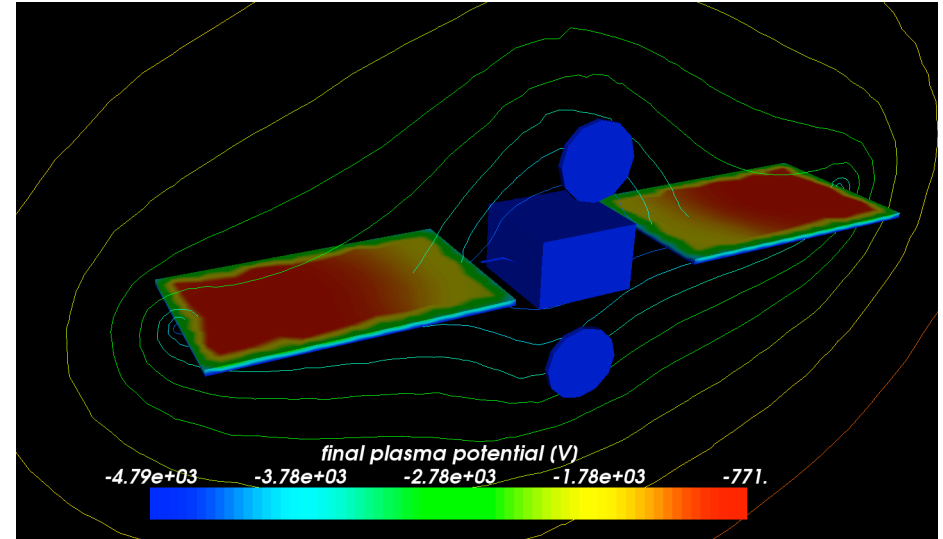
- Rich 2D/3D post-processing tools



Sharing  
with  
Cassandra  
Cloud

## 3D Post-processing

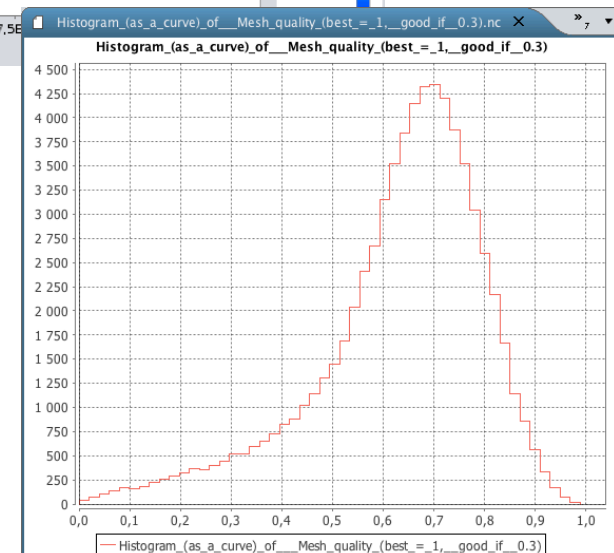
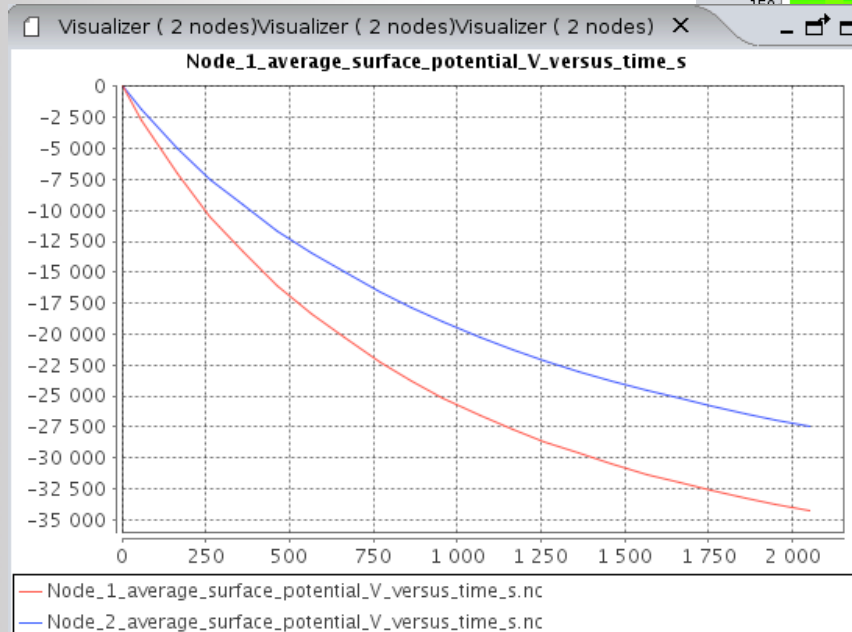
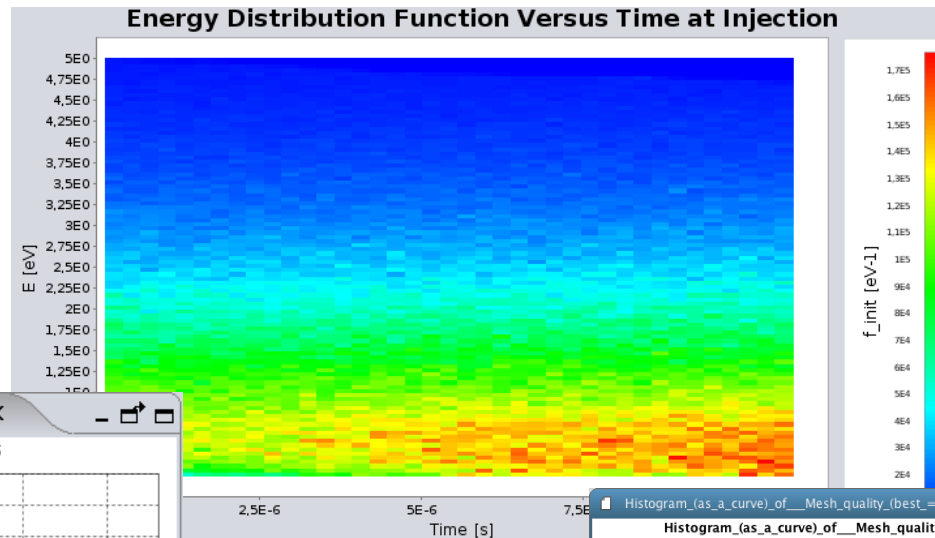
- Multi-data analysis and filtering
- Rich post-processing pipeline
- Sharing over the Web with Cassandra Cloud Service



With courtesy of S. Guillemant PhD (ONERA, IRAP) & ESA activity SPIS activity

## 2D Post-processing

- Rich 2D post-processing capabilities, based on JFreeChart 2D plotting functions
  - times series
  - histograms



# Auto-reporting

- Automatically generated OpenOffice reports

The screenshot displays the SPIS-GEO software interface. On the left, a 'Reporting' window shows a 'Report overview' with the following details:

- Introduction and general informations**
  - Filename : /Users/artenum/dev/IME/Felix-4.0.2/.overview.tmp
  - Author : artenum
  - Date : 14.mars.2013 at 16:17:01
  - Software name : SPIS Geo
  - Software version : 5.0.0
  - Description : This is a SPIS simulation report file.
- Project informations**
  - The present auto generated report corresponds to the following SPIS project: DefaultProject
  - Project name : DefaultProject
  - Project path : /Users/artenum/tmp/DefaultProject.spis5
  - Study name : DefaultStudy
  - Study path : /Users/artenum/tmp/DefaultProject.spis5/DefaultStudy
  - Run name : Run1
  - Run path : /Users/artenum/tmp/DefaultProject.spis5/DefaultStudy/Simulation
- 3D model informations**
  - 3D model geometry**
    - The geometrical model is defined in the following files, compliant with the Cesium Geometry input file name: cad\_sav.geo
    - Geometry input file path : /Users/artenum/tmp/cad\_sav.geo
  - Image : Model geometry**
  - 3D model mesh**

The main window shows a LibreOffice Writer document titled 'exampleAutoReport.odt'. The report content includes:

- Title:** SPIS Simulation Auto-report
- Author:** Keridwen's auto-reporting bundle
- Section 6. Outputs:**
  - The outputs of the simulation run, including time series for simulation duration and 2D/3D map data. Images may have been resized during report generation, full size versions are still stored in project.
- Figure 6:** Spacecraft ground potential V versus time s (node 0). A line graph showing potential (V) on the y-axis (ranging from -7.000 to 0.250) and time (s) on the x-axis (ranging from 0 to 2000). The potential starts at 0, drops to a minimum of approximately -6.5V at 1000s, and then rises back towards 0.
- Figure 8:** final\_plasma\_potential.nc.png. A 3D visualization of a spacecraft with a color-coded plasma potential field around it.
- Figure 9:** sc\_pot\_at\_t=2000.0\_s.nc.png. A 3D visualization of a spacecraft with a color-coded potential field at t=2000.0s.

At the bottom of the report, a metadata table is present:

Filename: exampleAutoReport.odt	Author: fabrice	SPIS Geo v5.0.0	17.Mar.2013 at 16:01:10
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# Conclusion and perspectives

- New modelled systems, new needs in the modelling process
- As an IME solution, **Keridwen** aims to address them
  - Lightweight and modular solution
  - Adaptable
  - Based on industrial standards
- Need of data sharing and visualisation over the Web appears at several levels along the modelling chain
- The **Cassandra Cloud** service, based on X3D, has demonstrated the possibility to exchange data/visualisation in an efficient way.
- **Keridwen** and **Cassandra Cloud** have been successfully tested on a real-life use case **SPIS**.
  
- Other applications currently under investigation
  - Remote HPC: simple data extraction and visualisation
  - Remote non-regression test suite: simple data extraction and visualisation
- Cassandra Cloud is still experimental and should be further improved/tested

# More info

[contact@artenum.com](mailto:contact@artenum.com)

<http://www.keridwen.org>