**Application cases of space modelling software based on the open-source Integrated Modelling Environment Keridwen**

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**Introduction:** Modelling complex systems needs several steps, from pre-processing – to define studied systems – to post-processing – to analysis results. Multi-physics or multi-scales simulations improve such complexity. Integrated Modelling Environments (IME) aims to reduce this complexity by offering adapted and homogeneous tools to users.

Last released in September 2017, Keridwen is an open-source set of tools – developed in Java/OSGi – that aims to help the creation of tailored IME. Beyond decreasing tailored application developing time, sharing common tools improves software quality and helps maintenance and evolution along.

**Keridwen generic functions:**

1. **Define 3D geometric description**
   Keridwen CAD modules aims to help the user to define its geometry, from scratch or by using conversion from industrial geometry formats. Depending on the modelled physic, needs in terms of geometry are different. From precise geometry to more abstract representations, Keridwen aims to handle them through its various editors.

   Some 3D model may need a precise mesh description. Keridwen can produce such meshes using the Gmsh software or can directly import them into the framework.

2. **Apply properties on geometry**
   Keridwen group editor allows creating generic properties and attributing them to geometric descriptions. Such properties can represent:
   - Initial and/or Boundary Conditions
   - Material properties
   - Local parameters

   Such properties can then be attributed to different sub-systems or the whole system.

3. **Define simulation parameters**
   Define the various global simulation parameters using generic editors or dedicated graphical user interfaces to guide more precisely the user. Both approaches rely on the Keridwen global parameter format that simplifies loading and saving such parameters to and from the disk.

4. **Follow numerical kernel evolution**
   Dynamic control of on-going simulation main characteristics via $f(x,y,z)$ type plots and $F(x,y)\rightarrow z$ type 2D map visualisation.

   It is possible to update those visualisations following the simulation evolution, depending on the simulation kernel capabilities.

5. **Extract data from simulation results**
   Keridwen features advanced post-processing 2D/3D functions:
   - 2D plots data visualisation
   - 3D plots data visualisation and post-processing (operations such as clipping, cutting plane, obtain values along an axis, etc.)
   - Large export possibilities (NetCDF, XML, CSV, VTK, X3D, etc.)

6. **Space applications based on Keridwen:**

   **Modelling spacecraft charging:** **SPI5**
   Initiated by ESA and CNES, developed by ONERA and Artenum and maintained by the SPINE community, SPI5 (for Spacecraft Plasma Interaction System) aims to model interactions between spacecraft and surrounding plasma, and more particularly spacecraft charging. The SPI5-NUM numerical core is an electrostatic 3D PIC model mainly developed by ONERA.

   **Modelling radiation effects:** **MoORa**
   Initiated and developed by Artenum, MoORa, for Modelling Of Radiations Effects aims to provide a integrated solution to drive radiations effects analysis end-to-end.
   MoORa simulation relies on ESA tool GRAS, a fully operational 3D Monte-Carlo radiation effects analysis tool based on GEANT4.

   **Modelling multipactor effect in Iris : IRIS-SEY**
   Funded by CNES, the French agency, and developed by Artenum, IRIS-SEY models the multipactor effect in irises inside RF components and wave-guides. IRIS-SEY consists of a Java 2D model integrated into a dedicated IME.

**Conclusion:** Keridwen has been successfully used to create several complex system modelling software (SPI5, Edge, MoORa, IRIS-SEY, ...). Keridwen being used by several tools, its components are more and more validated by their various uses in tailored applications. The last released version (2.0.20 in September 2017) of Keridwen covers a wide range of space applications. The various space applications of Keridwen has shown the relevance of Keridwen, and of the IME concept more generally. But Keridwen is not limited to space-related thematics and can be extended to various scientific domains: for example, Keridwen has already been used in robotics.