

# AIRTHIUM

<https://airthium.com/>

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## Utilisations industrielles et interfaçage de FreeFEM

S. Garnotel, Airthium SAS

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## About us

Small enterprise – 12 team members

- 5 Ph. D., 2 in Applied Mathematics
- 3 Mechanical Engineers
- IT, Electronics, Management

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## About us

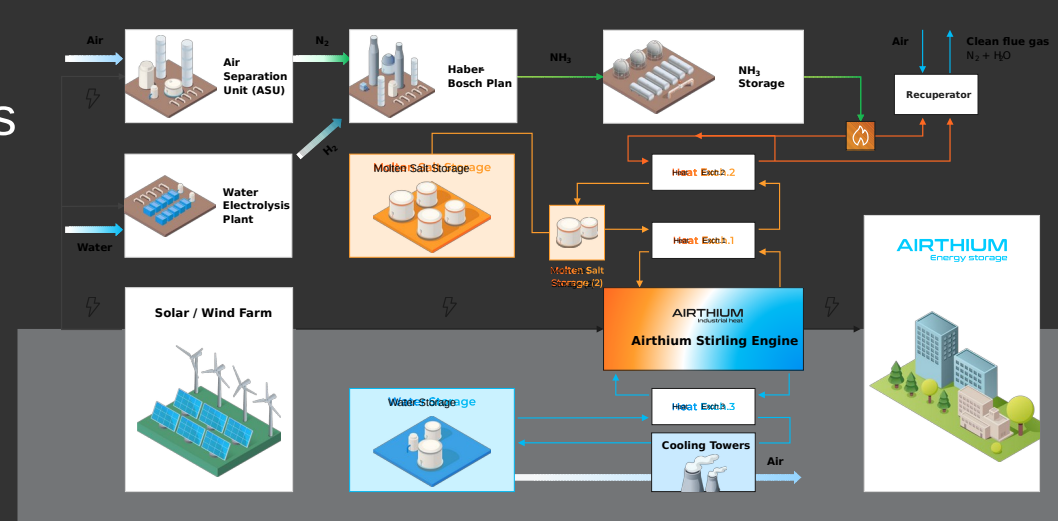
Small enterprise – 12 team members

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## Goal

High efficiency heat pump  
for seasonal energy storage

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Source: <https://airthium.com/>

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## About us

Small enterprise – 12 team members

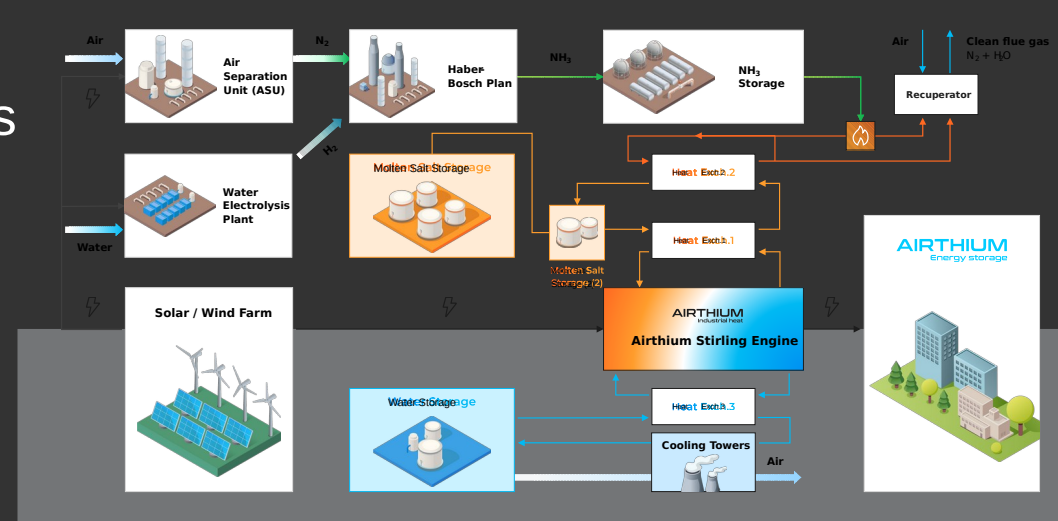
- 5 Ph. D., 2 in Applied Mathematics
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## Goal

High efficiency heat pump  
for seasonal energy storage

## ➔ Need of multiples physics simulations

1. Solid mechanics (linear elasticity, contact, ...)
2. Fluid mechanics (laminar, turbulent)
3. Couplings, ...



Source: <https://airthium.com/>

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## Framework choice

- Commercial simulation software, \$\$\$, black box
- Open source software, \$, customizable
  - FreeFEM

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## Problem

Mechanical Engineers does not know maths, programming, ...

Unable to write and/or modify a FreeFEM script! (without breaking all)

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## Framework choice

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## Problem

Mechanical Engineers does not know maths, programming, ...  
Unable to write and/or modify a FreeFEM script! (without breaking all)

## Solution

Build a FreeFEM graphical interface to allow engineers to parameterize, select the boundary conditions, run a simulation and post-process the results

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## Needs

- **Only click**
- **No code**
- Geometry integration from STEP, DXF (CAD software format)
- Automatic meshing
- Easy parameterize (material, physics parameters, mesh adaptation, solver parameters)
- Easy boundary conditions definition and selection
- Easy run (meshing + simulation)
- Post-processing (warp, stream lines, isolines, ...)



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## Framework

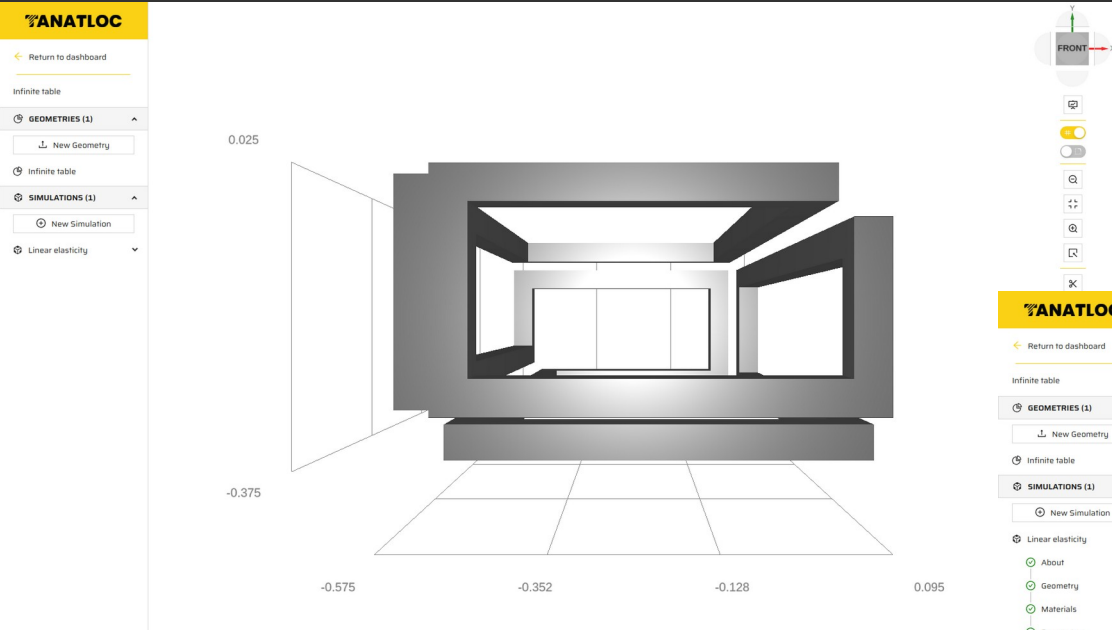
Web-based application (React (javascript) client, NodeJS server)

→ Cloud deployment, Cluster deployment, Electron app

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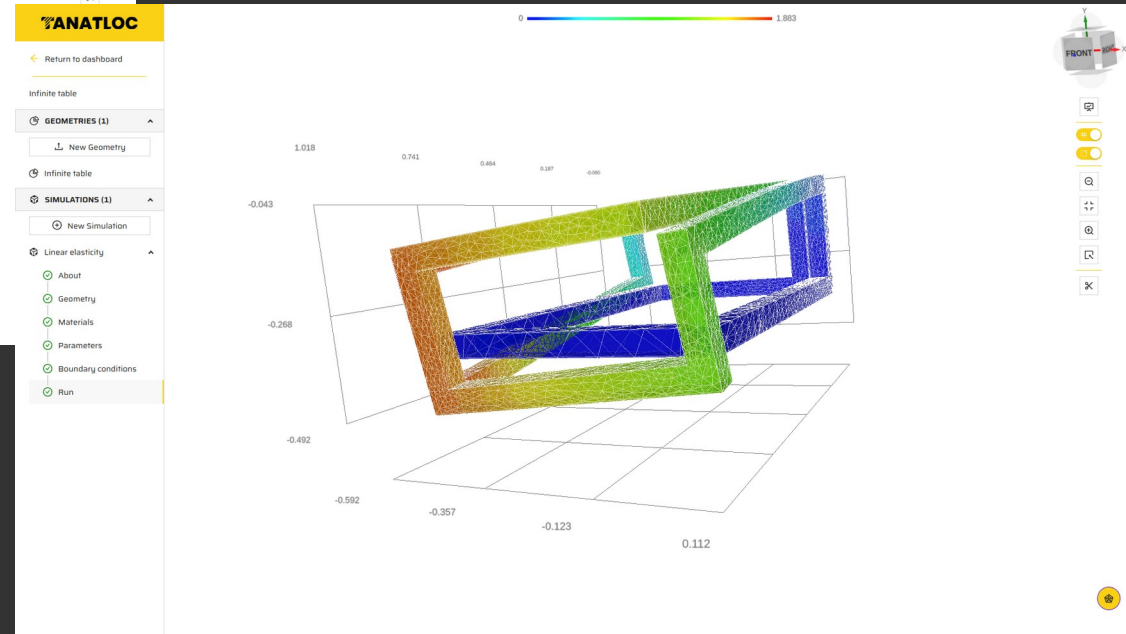
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# TANATLOC

by AIRTHIUM



<https://tanatloc.com/>  
Available soon

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## Geometry (+ mesh)

**ANATLOC**

**Geometry** X

Return to dashboard

Infinite table

**GEOMETRIES (1)** ^

New Geometry

Infinite table

**SIMULATIONS (1)** ^

New Simulation

**Linear elasticity** ^

- About
- Geometry**
- Materials
- Parameters
- Boundary conditions
- Run

When changing the simulation domain, you might lose your topological entity assignments

Select a simulation domain

Infinite table

**Mesh refinement**

Type

Automatic

Size

Normal

0.025

-0.375

-0.070

0.198

0.465

0.733

-0.128

-0.352

-0.575

0.095

1.000

FROM RIGHT

Navigation icons: Home, Settings, Search, Zoom, Rotate, Copy

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## Materials

Material ✕

Material: Stainless Steel 304

Rho

$kg, m^{-3}$  ⊙

E

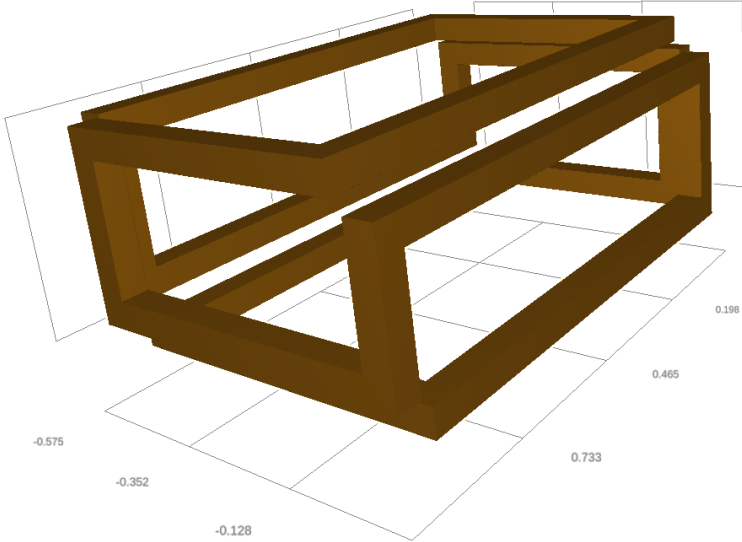
$Pa$  ⊙

Nu

$1$  ⊙

Filters

Solid 1



A 3D visualization of a rectangular frame structure, rendered in a dark brown color. The structure is positioned within a 3D coordinate system with axes labeled X, Y, and Z. The X-axis ranges from -0.575 to 1.000, the Y-axis from -0.375 to 0.025, and the Z-axis from -0.070 to 0.198. The frame consists of several interconnected beams forming a rectangular prism with a central vertical support. The background is a light gray grid.

0.025

-0.375

-0.070

0.198

-0.575


-0.352

-0.128

0.733

1.000

0.095



A vertical toolbar containing several icons for navigation and editing. From top to bottom: a 3D coordinate system icon with 'FRONT', 'RIGHT', and 'X' labels; a home icon; a yellow circle icon; a toggle switch; a magnifying glass icon; a double-headed arrow icon; a zoom-in icon; a zoom-out icon; and a close icon.

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## Parameters

### ANATLOC Parameters

Return to dashboard

GEOMETRIES (1)

New Geometry

Infinite table

SIMULATIONS (1)

New Simulation

Linear elasticity

- About
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Right hand side

External force (x)

0  $N \cdot m^{-3}$

External force (y)

-9.81  $N \cdot m^{-3}$

External force (z)

0  $N \cdot m^{-3}$

Advanced

Solver

System resolution

MUMPS

Mesh adaptation

Enabled

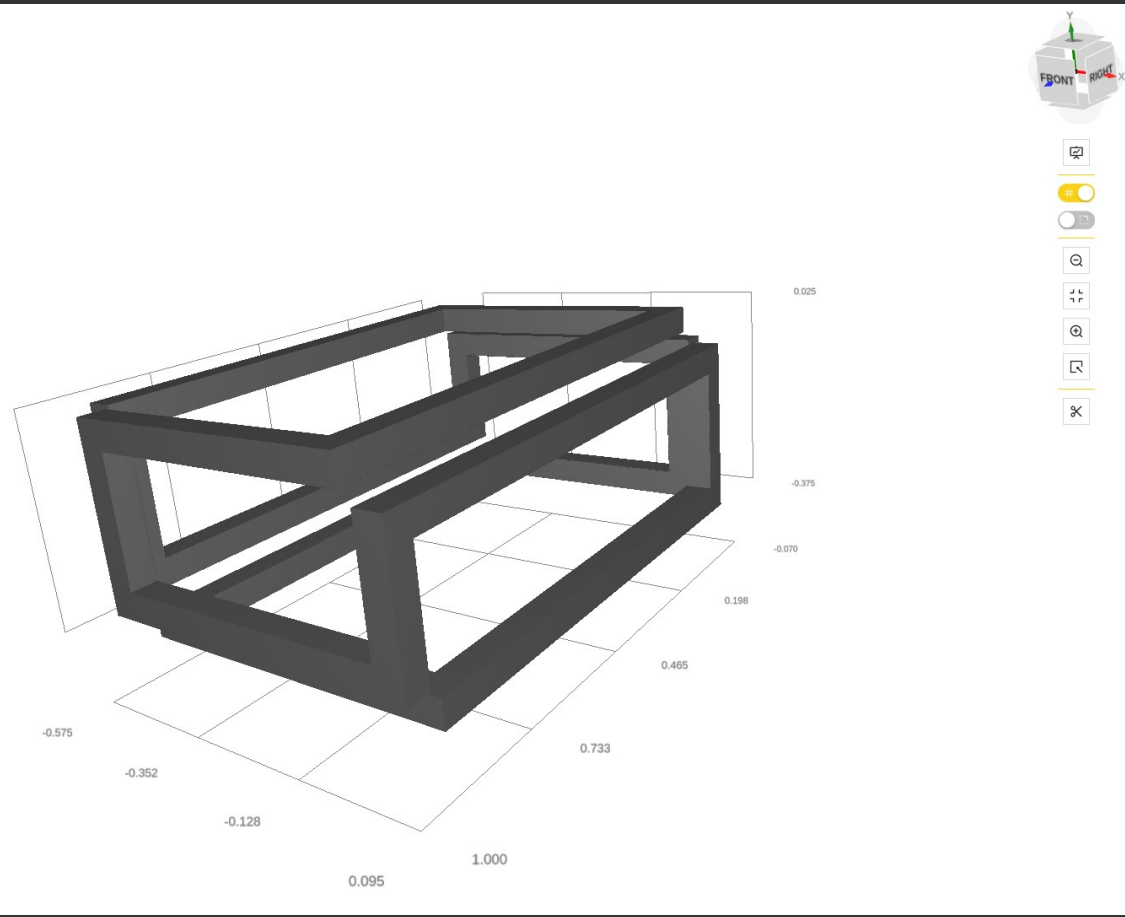
Number of mesh adaptation loops

2

Finite element space

[Ux, Uy, Uz]

P2



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## Boundary conditions

Boundary condition ✕

Boundary condition name

Boundary condition type

Ux

Uy

Uz

Filters

Face 1

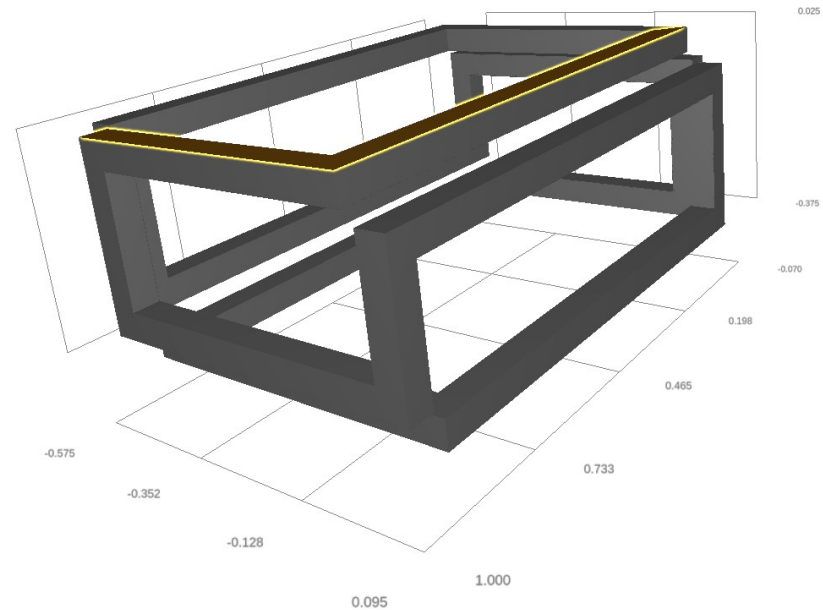
Face 2

Face 3

Face 4

Face 5

Face 6



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## Run + Results

**ANATLOC**

Return to dashboard

Infinite table

**GEOMETRIES (1)**

New Geometry

Infinite table

**SIMULATIONS (1)**

New Simulation

Linear elasticity

- About
- Geometry
- Materials
- Parameters
- Boundary conditions
- Run**

**Run**

Computational resource  
Plugin: Local  
Name: Local

Modify the resource

Run

Run

Mesh (1/2)

Simulation (2/2)

**Results**

- Mesh
- Displacement (magnitude)
- Displacement (component 1)
- Displacement (component 2)
- Displacement (component 3)
- vonMises
- gamma11
- gamma12
- gamma13
- gamma22
- gamma23
- gamma33

0 1.883

0.025  
-0.375  
-0.070  
0.197  
0.465  
0.732  
1.000  
0.095  
-0.575  
-0.352  
-0.128

FRONT RIGHT X

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## Post-processing

**ANATLOC**

**Run**

Return to dashboard

Infinite table

**GEOMETRIES (1)**

New Geometry

Infinite table

**SIMULATIONS (1)**

New Simulation

Linear elasticity

- About
- Geometry
- Materials
- Parameters
- Boundary conditions
- Run

Computational resource

Plugin: Local

Name: Local

Modify the resource

Run

Run

Mesh (1/2)

Simulation (2/2)

Results

- Mesh
- Displacement (magnitude)
- Displacement (component 1)
- Displacement (component 2)
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- vonMises
- gamma11
- gamma12
- gamma13
- gamma22
- gamma23
- gamma33

0 1.883

Post-processing

Filter: Warp by vector

Vectors

Displacement

Scale factor

-0.1

Run

Post-processing warpByVector

- Displacement (magnitude)
- Displacement (component 1)
- Displacement (component 2)
- Displacement (component 3)
- vonMises
- gamma11
- gamma12
- gamma13
- gamma22
- gamma23
- gamma33

-0.592 -0.357 -0.123 0.112 1.018 0.741 0.464 0.187 -0.090 -0.492 -0.268 -0.043



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**Basic behavior**

**A word of templates**

Meshing tool: Gmsh

→ Gmsh script template

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## Basic behavior

## A word of templates

Meshing tool: Gmsh

→ Gmsh script template

Simulation tool: FreeFEM

→ FreeFEM script template

```
41
42 <!--# Problem -->
43 <!--
44 const dirichlet = boundaryConditions.dirichlet.values || []
45 const neumann = boundaryConditions.neumann.values || []
46 const rhs = parameters.rightHandSide.children[0]
47 const rhsValue = rhs.value ?? rhs.default
48 -->
49 // Problem
50 appendLog("Define the problem..");
51
52 varf vLaplacian (u, uh)
53   = intN(Mesh)(
54     | grad(u)' * grad(uh)
55   )
56 <!-- for (const d of dirichlet) { -->
57   + on(<!--= d.selected.map(s => s.label).filter(s => s).join() -->, u=0)
58 <!-- } -->
59 ;
60
61 varf vLaplacianRHS (u, uh)
62   = intN(Mesh)(
63     | (<!-- rhsValue -->) * uh
64   )
65 <!-- for (const n of neumann) { -->
66   - intN1(Mesh, <!--= n.selected.map(s => s.label).filter(s => s).join() -->) {
67     (<!-- n.values[0].value ?? n.values[0].default -->) * uh
68   }
69 <!-- } -->
70 <!-- for (const d of dirichlet) { -->
71   + on(<!--= d.selected.map(s => s.label).filter(s => s).join() -->, u=<!-- d.values[0].value ?? d.values[0].default -->)
72 <!-- } -->
73 ;
74
75 <!--# Solver -->
76 <!-- const solver = parameters.solver.children[0].value ?? parameters.solver.children[0].default -->
77 <!-- include('/blobs/solver.edp.ejs', {
78   | solver
79   }) -->
80
81 <!--# Solve -->
82 // Solve
83 appendLog("Solve the problem...");
84
85 matrix Laplacian = vLaplacian(<!-- finiteElementSpace.name -->, <!-- finiteElementSpace.name -->, solver=solver);
86 real[int] LaplacianRHS = vLaplacianRHS(0, <!-- finiteElementSpace.name -->);
87 u[] = Laplacian^-1 * LaplacianRHS;
88
```

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## Basic behavior

### A word of templates

Meshing tool: Gmsh

→ Gmsh script template

Simulation tool: FreeFEM

→ FreeFEM script template

Post-processing tool: Paraview (pvpython)

→ Python script

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**Main target** Engineers  
Easy access to simulations

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## Next steps

→ Public access (only Airthium and Denso for now)

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- Open-source (??? GPL3 + specific terms)

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**Main target** Engineers

Easy access to simulations

## Next steps

- Public access (only Airthium and Denso for now)
- Open-source (??? GPL3 + specific terms)
- Code template editor  
Your FreeFEM code integrated in Tanatloc, shareable with other researchers, students, ... through *Organization*

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**Thank you  
for your attention**

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