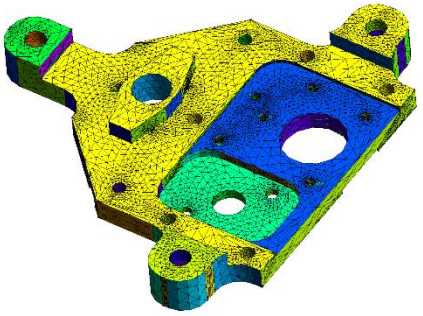
10th Geant4 Space User's Workshop

Huntsville, May 27 – 29, 2014



A multi-format multi-geometry interface for Geant4/GRAS

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The Space Radiation Engineering

Recently, radiation engineering have to face new and demanding scenarios

⇨ Missions to severe environments that require a review/upgrade of models and methods

- Jovian system (JUICE) – extreme energetic electrons

  Internal charging problems or SeE (see R.Reed talk)

- Near Sun (BepiColombo, Solar Orbiter) – High ion fluxes

⇨ High perfomance P/L increase the use of COTS and state-of-the-art technologies

⇨ More complex radiation analyses are demanded, not only average quantities

- Background signal, detector simulation, device response, secondary production, activation, etc

⇨ Coupling with other physics simulations tools, e.g,

- SPIS – Spacecraft Plasma Interaction Simulation tool
- TCAD – For device simulation

But.... “traditional” engineering methodologies hardly address them (they cannot)

⇨ They are still based in very simple 1D models or 3D sector analysis

- Mission specifications use SHIELDOSE-like calculations or Sector Shielding
- In the best case, S/C primes only provide averaged 6-faces equivalent shielding data

⇨ Is Geant4 an alternative to cover these new challenges? It could be but...

- Still 3D modelling for particle propagation is not a common at industry level.
- Conservative simple analysis are preferred by most System Engineers or PMs.
- Even if 3D analyses are performed....there are no clear guidelines
- Almost no discussion is included in design standards, nor policies or applicable margins are defined.
- There’s no common way to exchange radiation information between different teams: S/C ↔ PL

“The I/F’s problem”

- No standard geometrical I/Fs with other engineering design tools.

“The CAD problem”

The I/F's Problem

- Space projects are participated by large consotiums, including R&D institutes, prime companies, SMEs, agencies, etc.
  - Each partner is responsible of part of the problem ... part of the design
- However, there's no analogue interfacing solution as used in other engineering domains, e.g.:
  - Thermal analysis → S/C provides thermal I/Fs to P/L
  - Mechanical analysis → Loads at system I/F
- Unless we have full mission visibility (unusual), it is needed
  - A way to exchange radiation boundary conditions between different design levels
  - From top S/C down to P/L parts.
  - Define a standard methodology to do it.

The CAD Problem

- Interfacing with engineering tools (CAD/CAE, TCAD) is not solved
- Several approaches to the problem but…
  - Based on STEP to Tessellated conversion. High Mem and CPU consuming
  - No native CSGs used.
  - No material/properties included.
  - Requires the users to manually review, edit and adapt the geometry externally
- So far, only a couple of integrated tools (Fastrad, Esabase2) provide…
  - CAD/CAE importing and editing capabilities.
  - Export/import to Geant4 (via GDML).
  - But still not complete. Not part of the Geant4 collaboration, Not free. Not open

Then...should Geant4 implement a native solution?

A native CAD importer?

The CIRSOS Project

ESA has been supporting a series of activities towards an integrated solution:

- ELSHIELD → Coupling of Geant4 and plasma tolos. Improving EM models
  → Combining Geant4 GDML with SPIS 3D Meshed geometries
- REST-SIM → An integrated framework to perform G4-based radiation simulations.

CIRSOS Project

Collaborative → Allow multiple teams to work concurrently on the same radiation 3D model

Iterative → Allow the continuous review and upgrade of the models along project phases

Radiation **S**hielding → Including all engineering radiation analysis capabilities

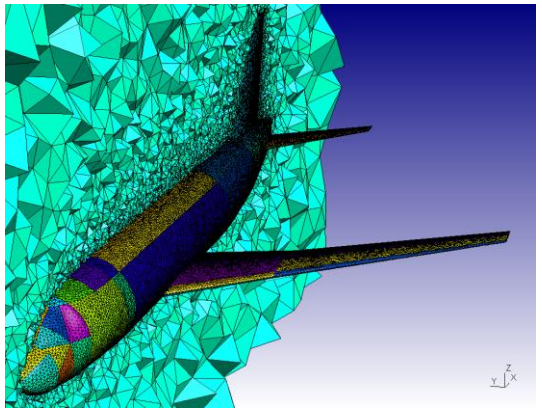
Optimization **S**ystem → Parametric analysis, optimization capabilities

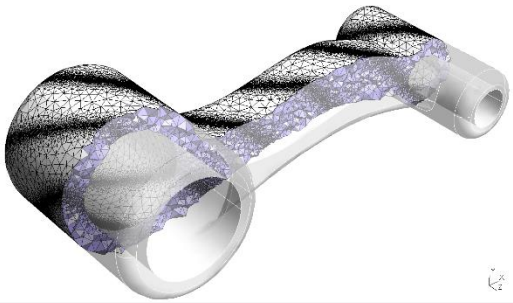
Cirsos will provide a first solution to

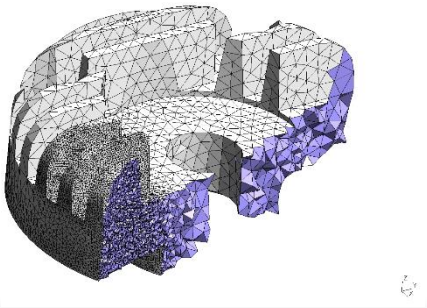
- The I/Fs problem → Phase Space files + 2-stage simulation
- The CAD problem → Multi-format/multi-geometry builder

Multi-Format I/F

- Allow different file-formats (and also provide an easy way to extend it to future file-formats)
- No re-coding a new set of parsers!! Use existing tools!!
- During ELSHIELD the Gmsh tool was identified as a good candidate as...
  - It is open-source, GPL v2. It is part of ESA's SPIS tool
  - C++ library (and also executable + GUI)
  - Included I/Fs to STEP, IGES, BREP
    (importing based on OpenCascade)
  - Many other formats supported (STL, VRML, BDF, VTK,...)
  - Use NetGen and TetGen for meshing (2D and 3D)
  - Easy and powerful viewer integrated







Multi-Format I/F

- File-formats tested and included in this Multi-Format interface:
  - GDML
  - Gmsh 3D tetrahedral mesh

  } Geant4 “native”
  } Based on Gmsh specification. Developed during ELSHIELD. Use G4Tets

  - CIF for TCAD layouts
    (using G4 CSGs, no mesh, no tesellation)

  } Developed internally at INTA

  - STEP (3D or 2D tessellation)
  - STL (tessellation)

  } Using Gmsh library. In development for CIRSOS

- Other formats under test:
  - IGES, Nastran BDF, VRML, …

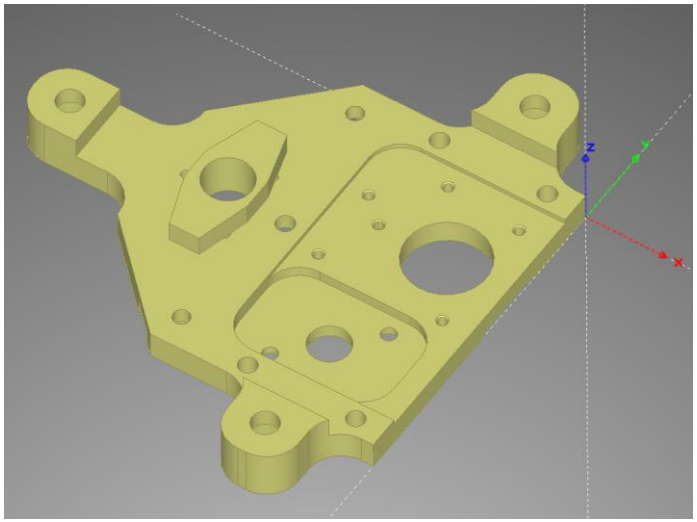
  } Will require the Gmsh library

- All these formats don’t include material information (except GDML). Specific UI commands have been added

Example: Importing a STEP geometry

Using an external application (FASTRAD):

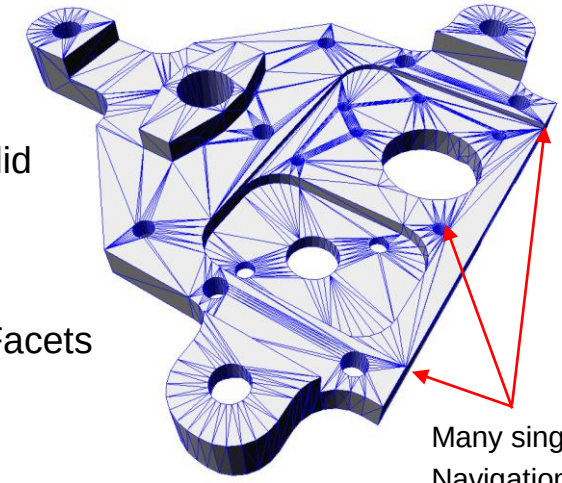
- Import original STEP file. Uses surface tessellation (algorithm?)
- Export to GDML. Uses G4TessellatedSolid



Original STEP

G4TessellatedSolid

4725 Triangular Facets



Many singular points?
Navigation problems?

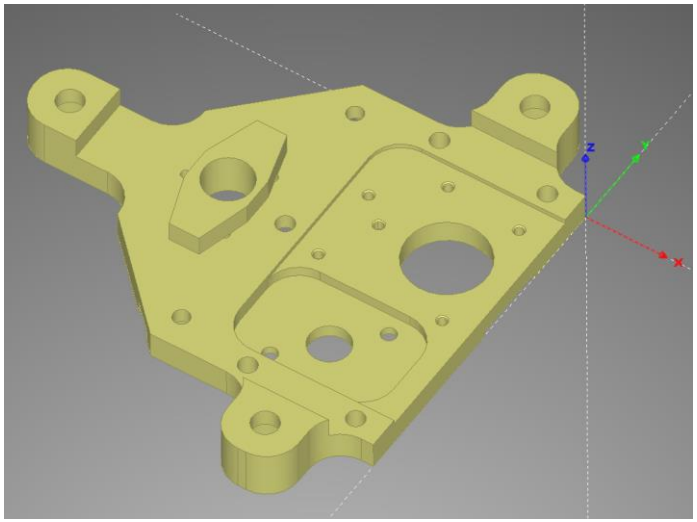
GDML Model

As loaded in Geant4/GRAS

Example: Importing a STEP geometry

Using Gmsh C++ API in Geant4/GRAS

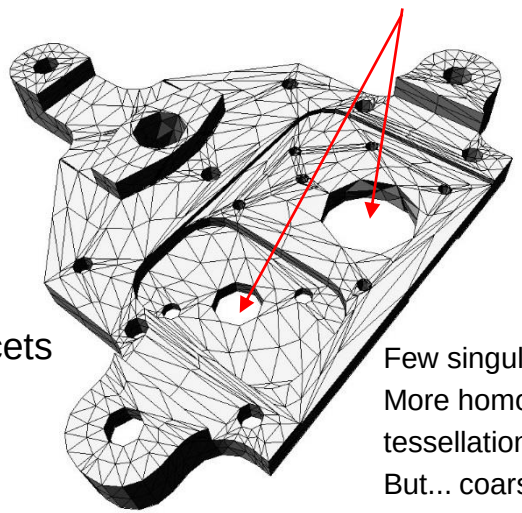
- Direct import of STEP file
- Volume surface is 2D Meshed. Using “MeshAdapt” algorithm
- Conversion to G4TessellatedSolid



Original STEP

G4TessellatedSolid

5124 Triangular Facets



Few singular points
More homogeneous tessellation
But... coarse defintion!!

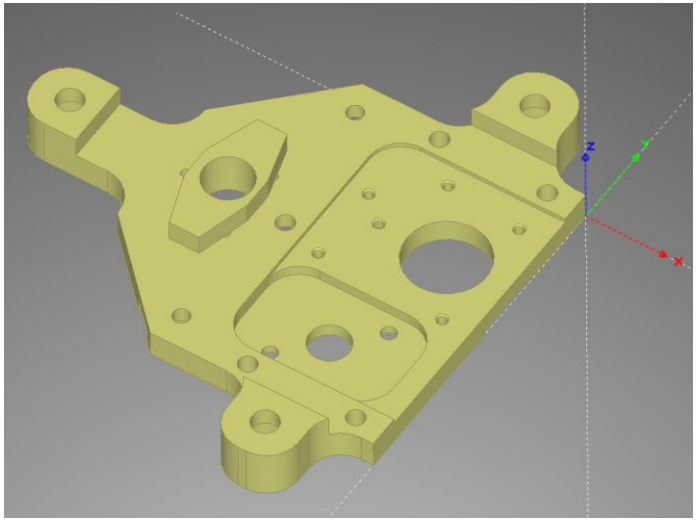
Meshed Model

As loaded in Geant4/GRAS

Example: Importing a STEP geometry

Using Gmsh C++ API in Geant4/GRAS

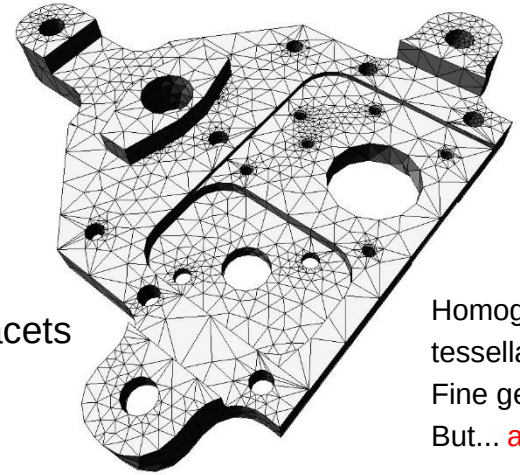
- Direct import of a STEP file
- Volume surface is 2D Meshed. “MeshAdapt” algorithm refined
- Converted to G4Tessellated Solid



Original STEP

G4TessellatedSolid

10852 Triangular Facets



Homogeneous tessellation
Fine geometry
But... at high cost!!

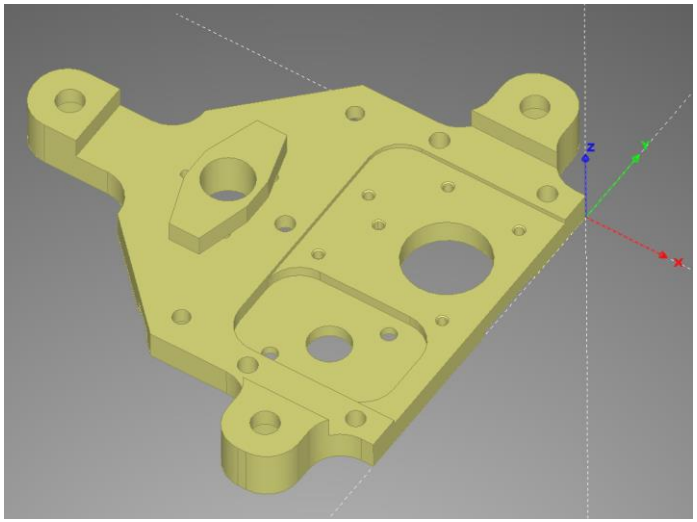
Meshed Model

As loaded in Geant4/GRAS

Example: Importing a STEP geometry

Using Gmsh C++ API in Geant4/GRAS

- Direct import of a STEP
- Volume surface is 2D and 3D meshed (Delaunay algorithm)
- Converted to G4Tessellated Solid and/or G4Tet's

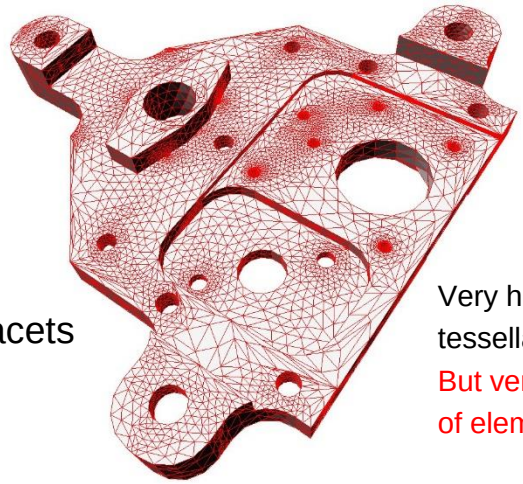


Original STEP

G4TessellatedSolid

20824 Triangular Facets

102608 Tetrahedra

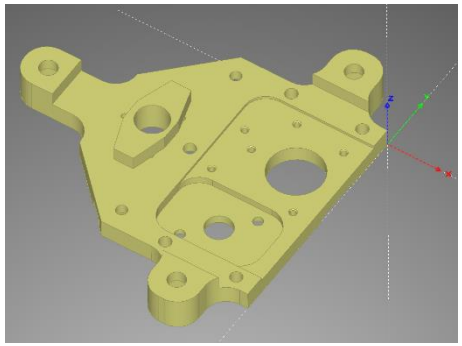


Very homogeneous tessellation
But very high num of elements

Meshed Model

As loaded in Geant4

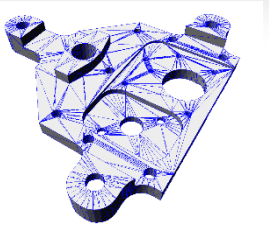
Example: Importing a STEP geometry



Original STEP

Fastrad w/ GDML

G4TessellatedSolid
4725 Triangular Facets
Fine Tessellation

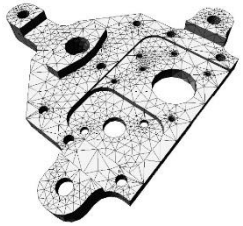


Gmsh
MeshAdapt

G4TessellatedSolid
5124 Triangular Facets
Coarse tessellation

Gmsh
MeshAdapt
Refined

G4TessellatedSolid
10852 Triangular Facets
Fine Tessellation



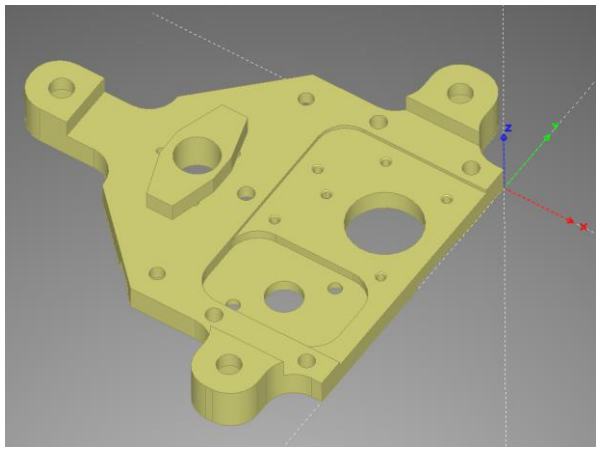
Gmsh
Dealunay
Refined

20824 Triangular Facets
102608 Tetrahedra
Very fine tessellation

Example: Importing a STEP geometry

Is it possible in Gmsh to import a STEP file with:

- fine meshing? Fitting curves with a good approximation?
- a low number of facets?
- 2D triangular tessellation?
- and 3D tetrahedral mesh?



Original STEP

YES

Adapting Gmsh parameters

5256 Triangular Facets
Or
11054 G4Tets

Homogeneous tessellation
Fine geometry
Similar cost as Fastrad

Meshed Model

As loaded in Geant4

Example: Importing a STL geometry

Using GMSH C++ API in Geant4/GRAS

- Direct import of a STL
- Volume is already 2D mesh. Uses the STL facets
- Converted to a G4TessselatedSolid

Original STL

No meshing, just loading
And conv. to G4Tessellated

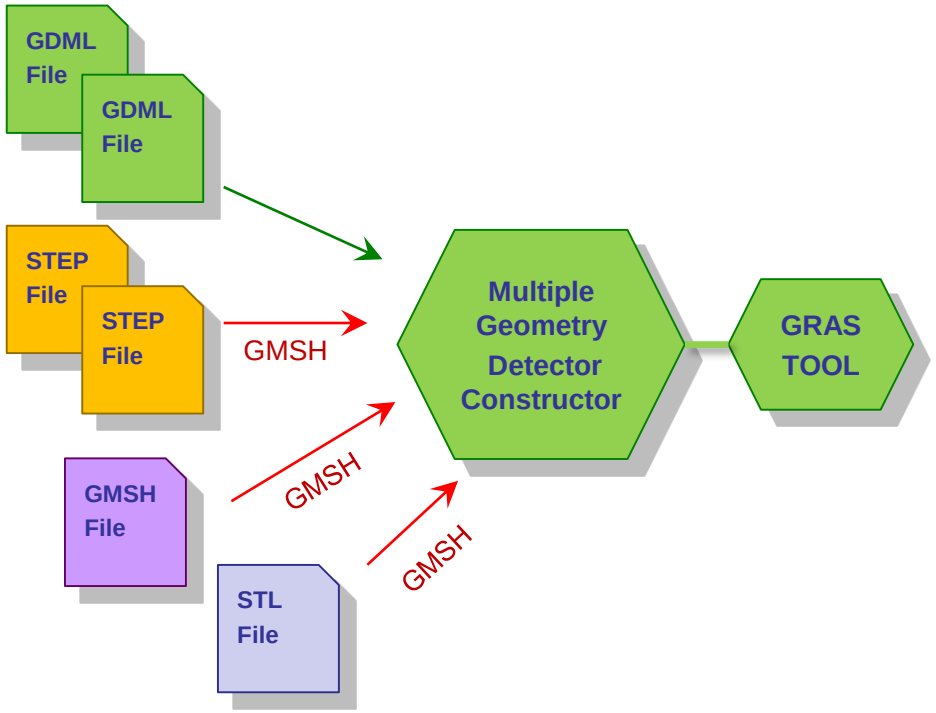
4090 Triangles

Meshed Solid

As loaded in Geant4

Multi-Geometry I/F

- Load several geometry files at same time
- Combine them coherently
- Fullfil the “collaborative” requirement
  - Combining parts or assemblies developed by independent teams
  - Solving the problem of re-importing of parts, editing, combining and re-exporting to G4 each time a part is changed



Multi-Geometry I/F

- Each new geometry is loaded, parsed and converted to G4.
- Its world volume is removed. Top level volumes are re-positioned inside a new mother.
- Containing world dimensions are re-calculated

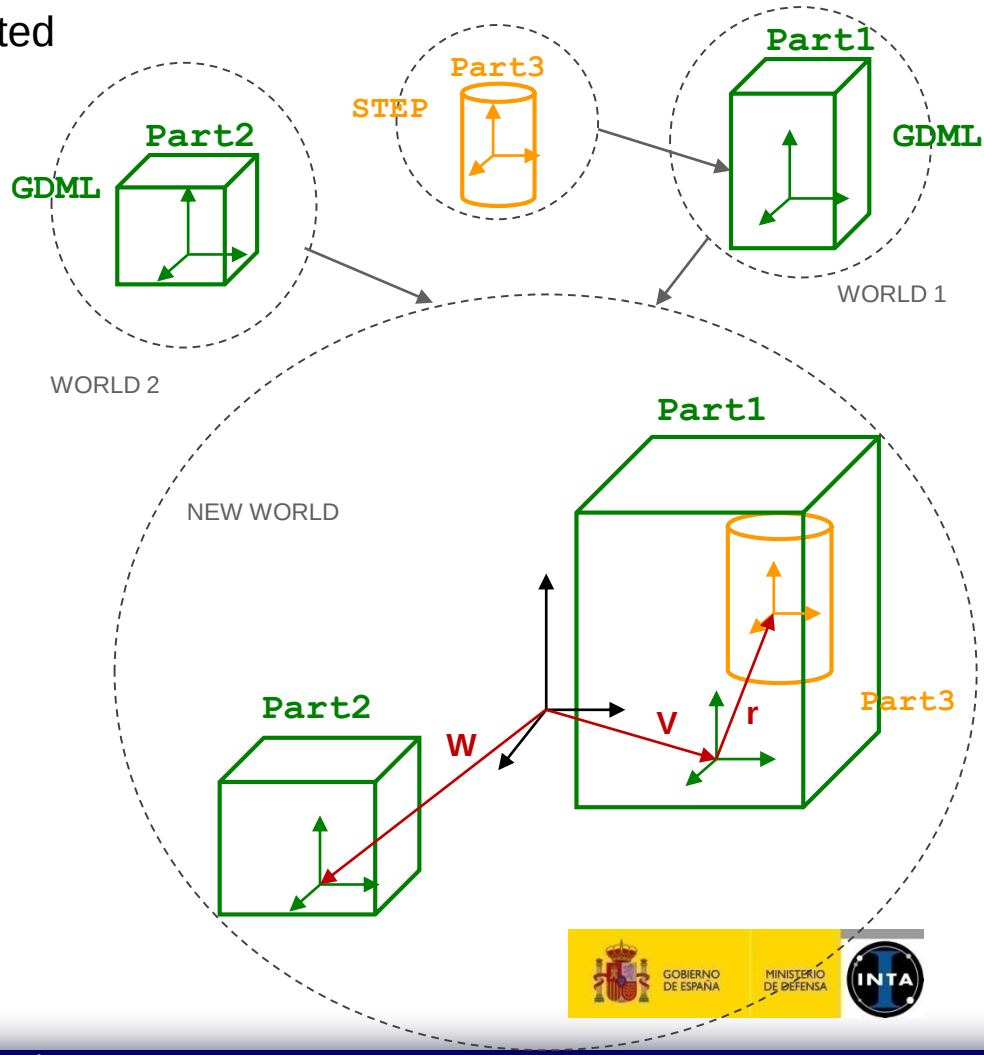
```
/gras/geometry/type multi

/gras/multi/addNewPart Part1
/gras/multi/Part1/type gdml
/gras/multi/Part1/file part1.gdml
/gras/multi/Part1/setMotherVol 0
/gras/multi/Part1/setPosition Vx Vy Vz mm

/gras/multi/addNewPart Part2
/gras/multi/Part2/type gdml
/gras/multi/Part2/file part2.gdml
/gras/multi/Part2/setMotherVol 0
/gras/multi/Part2/setPosition Wx Wy Wz mm

/gras/multi/addNewPart Part3
/gras/multi/Part3/type step
/gras/multi/Part3/file part3.stp
/gras/multi/Part3/… /*STEP commands*/
/gras/multi/Part3/setMotherVol part1
/gras/multi/Part3/setPosition rx ry rz mm

[…OTHER PARTS…]
```



Summary

- A new alternative for the CAD I/F problem is under development
  - Based on Gmsh library using 2D and 3D meshing
  - Integrated in Geant4/GRAS as new set of UI commands
  - Capable of importing a wide number of CAD formats
  - Converting solids to both G4Tesselated and/or a mesh of G4Tets
- Additionally, a multi-geometry I/F is also provided
  - Capable of loading and combining geometrical models with same/different format
- Expected release as part of GRAS → Summer 2014
  - It can be also used in any G4 application as Detector Construction
  - Requirement → install Gmsh library and devel packages