LaGriT Mesh Generation of the LA Basin GOCAD Microblock Model

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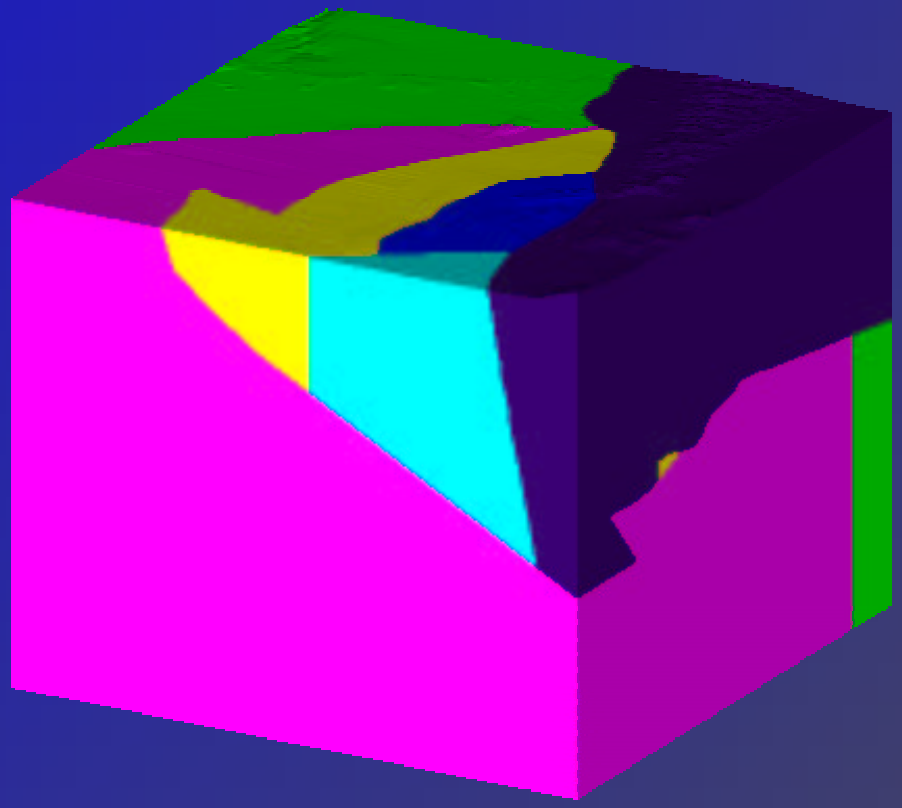


Los Alamos

Building a 3D Mesh From GOCAD T−surf Input

- Read GOCAD format
- Repair GOCAD geometry and topology
- Optimize triangles from GOCAD T−surf
- Define geometry from GOCAD T−surf data
- Test geometry definition on FD grid
- Octree adaptive mesh refinement
    - AMR mesh of geometry
    - Create point distribution for tetrahedral mesh generation
- Build 3D tetrahedral mesh
- Optimize (refine, merge, smooth) 3D mesh

GOCAD − LaGriT

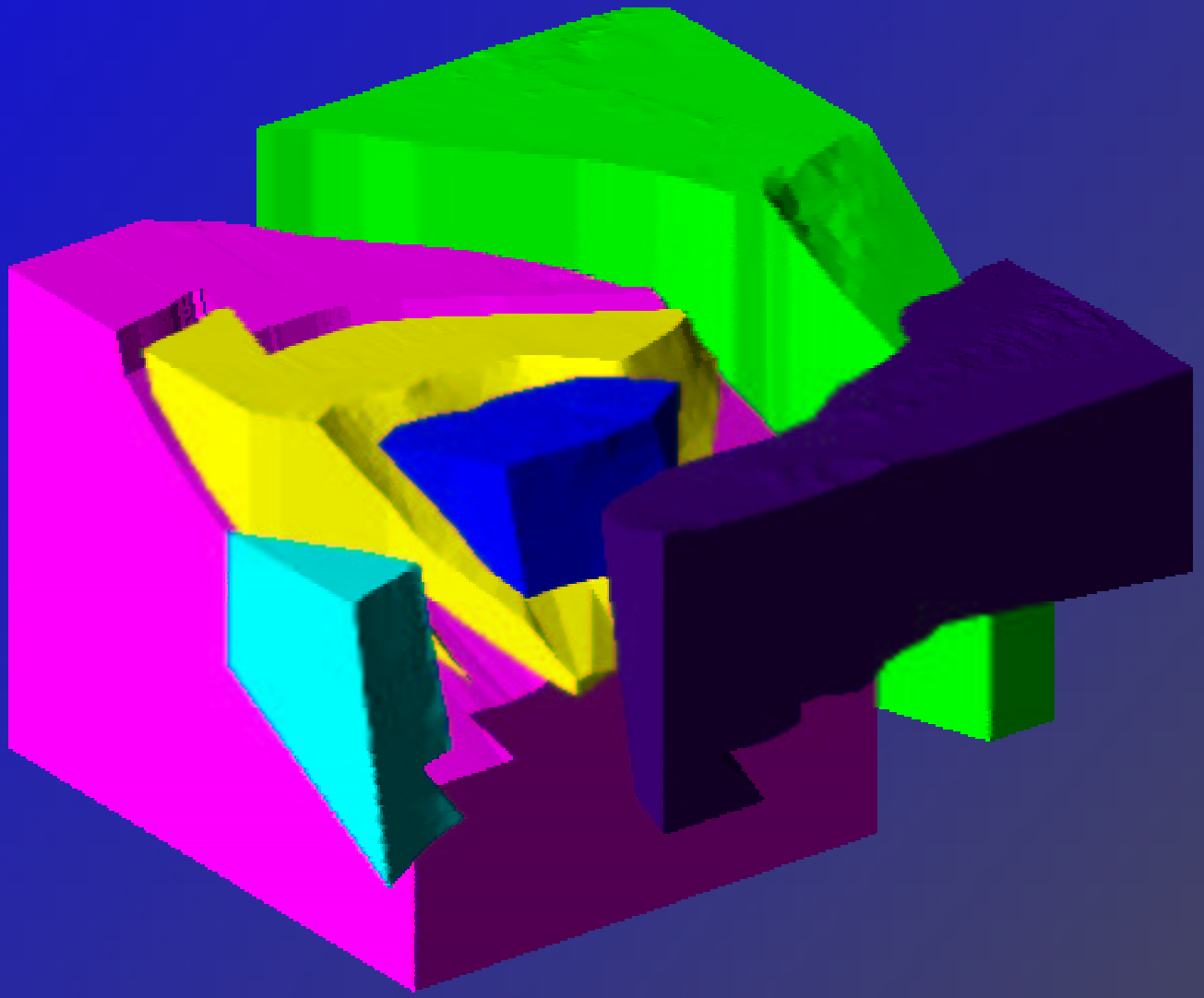
Write GOCAD t−surf reader module

- **Keyword driven parser**
- **Written as ’user’ module in LaGriT**
- **Can be incorporated into ’standard’ LaGriT**

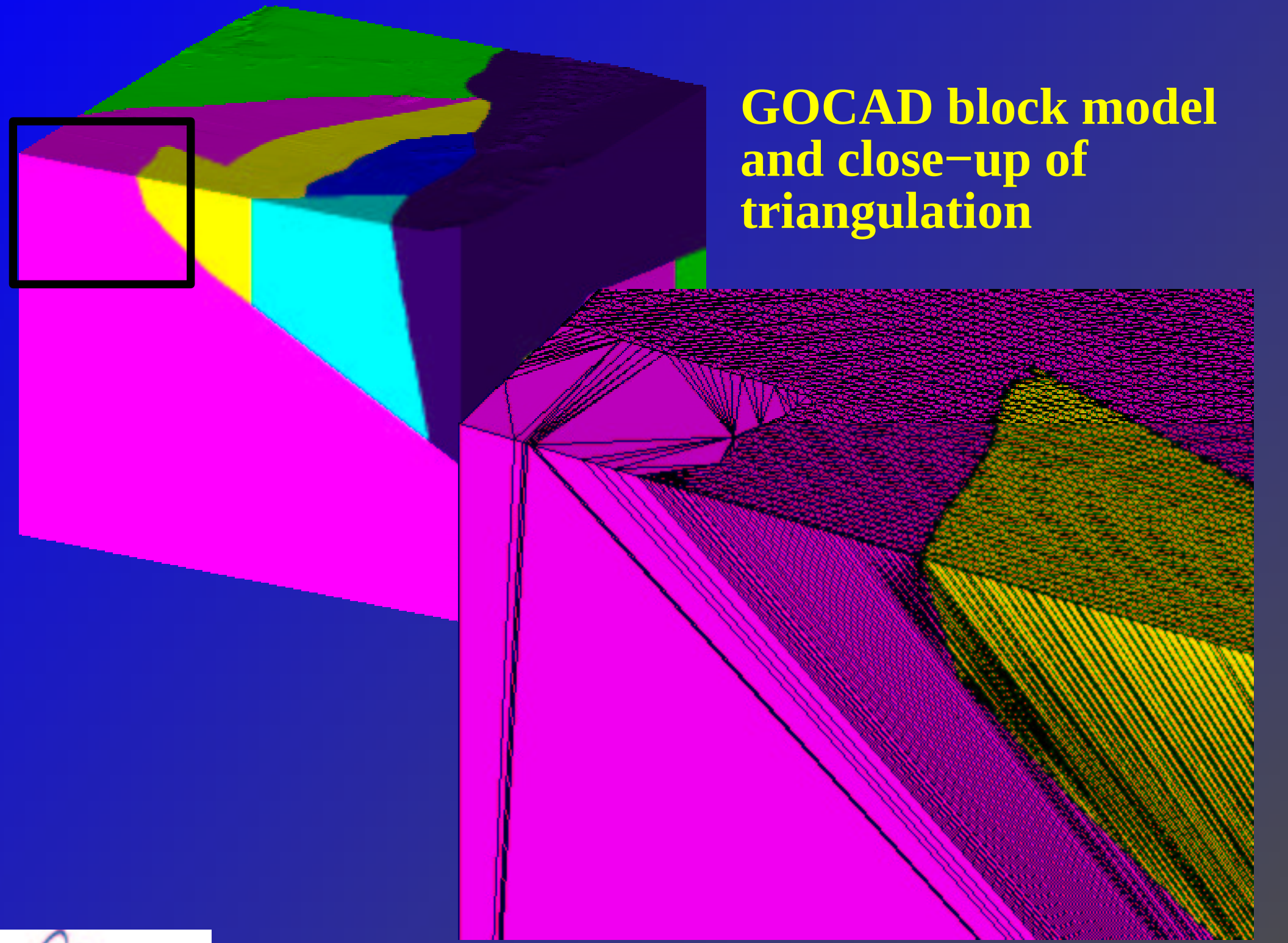
Problems Encountered

- **GOCAD does not use consistent normals so definition of what is above/below and inside/outside surface is inconsistent.**
- **Concatination of surfaces in a block does not form an air tight volume and shared edges are not geometrically and topologically consistent.**

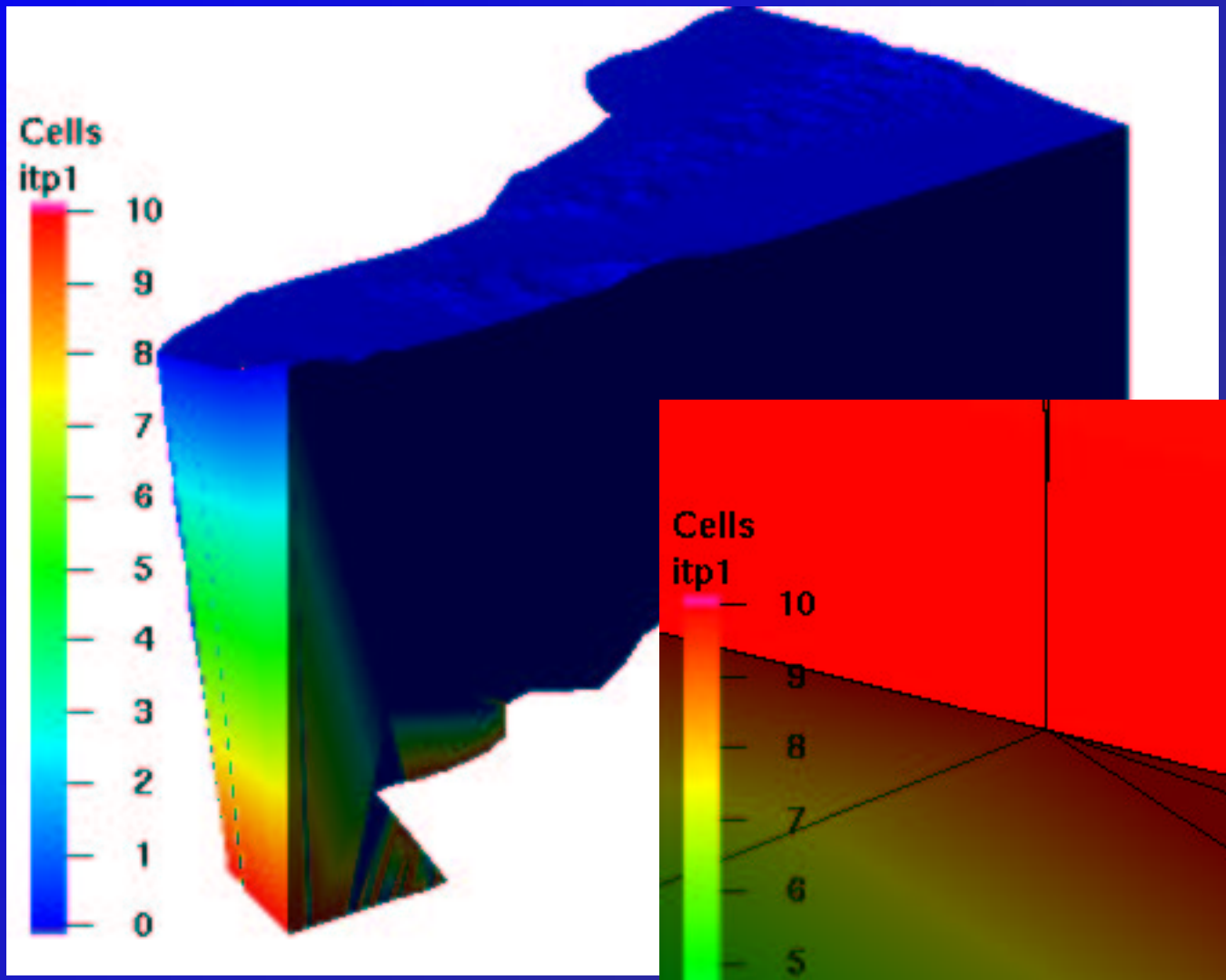
Exploded View of Five Blocks

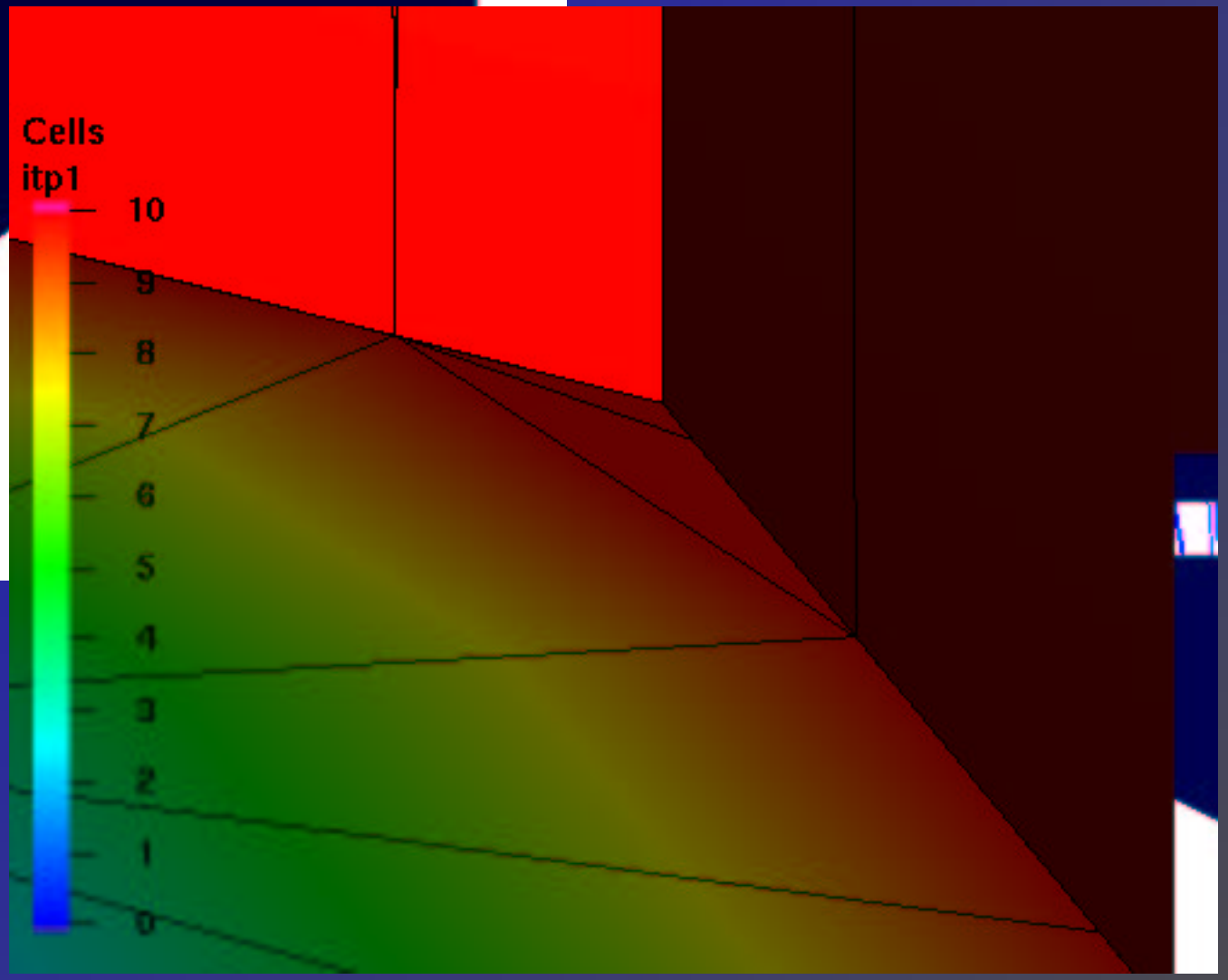


GOCAD block model and close-up of triangulation



Topological Problems Result in non−airtight Volumes

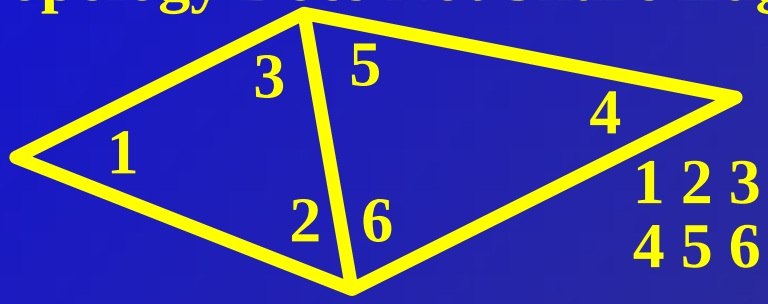




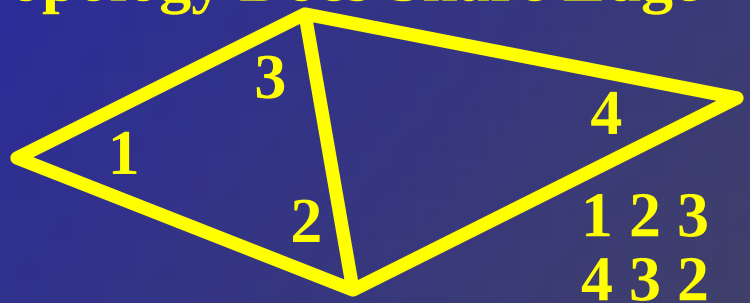
Attempt Geometric and Topological Repair

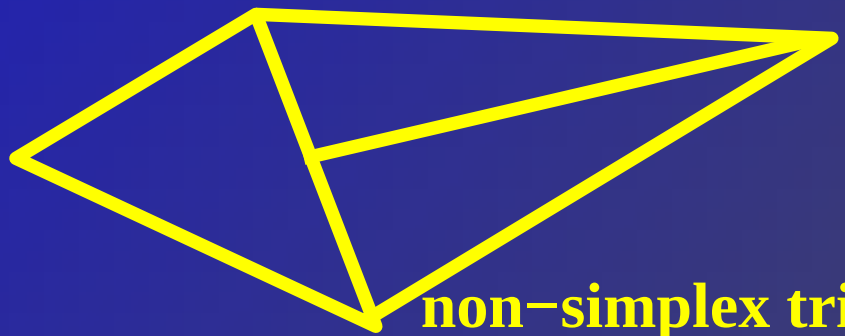
- Trial and Error process
- `filter` point distributions in an attempt to remove nodes that are close but seperated by a small distance.
- `filter` with a merge criteria of 1.0m. This fixed blocks 1, 2, 3, 4.
- Problems with block5 and block6 are due to mis−matched triangles with finite edge length.
- Move forward using only block1 − block4

Topology Does Not Share Edge



Topology Does Share Edge

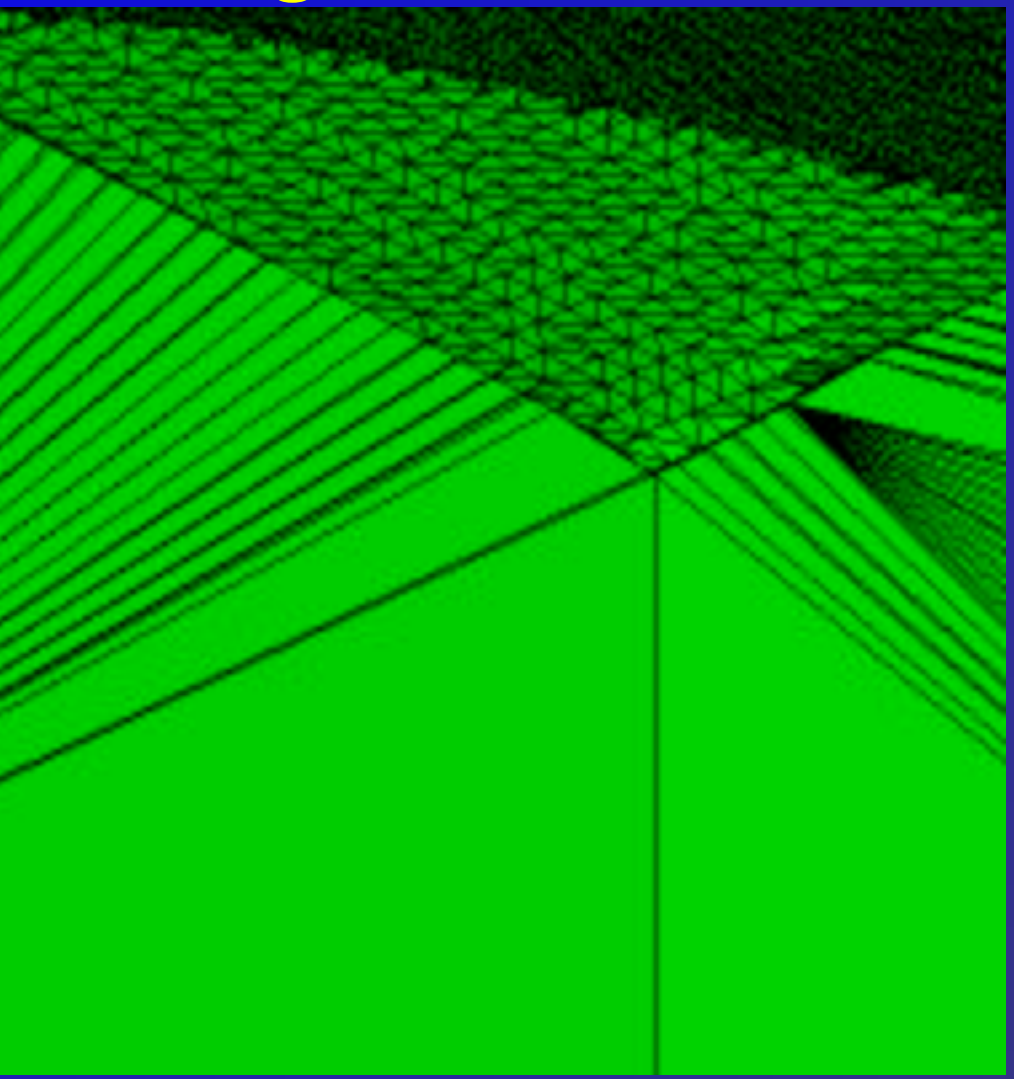




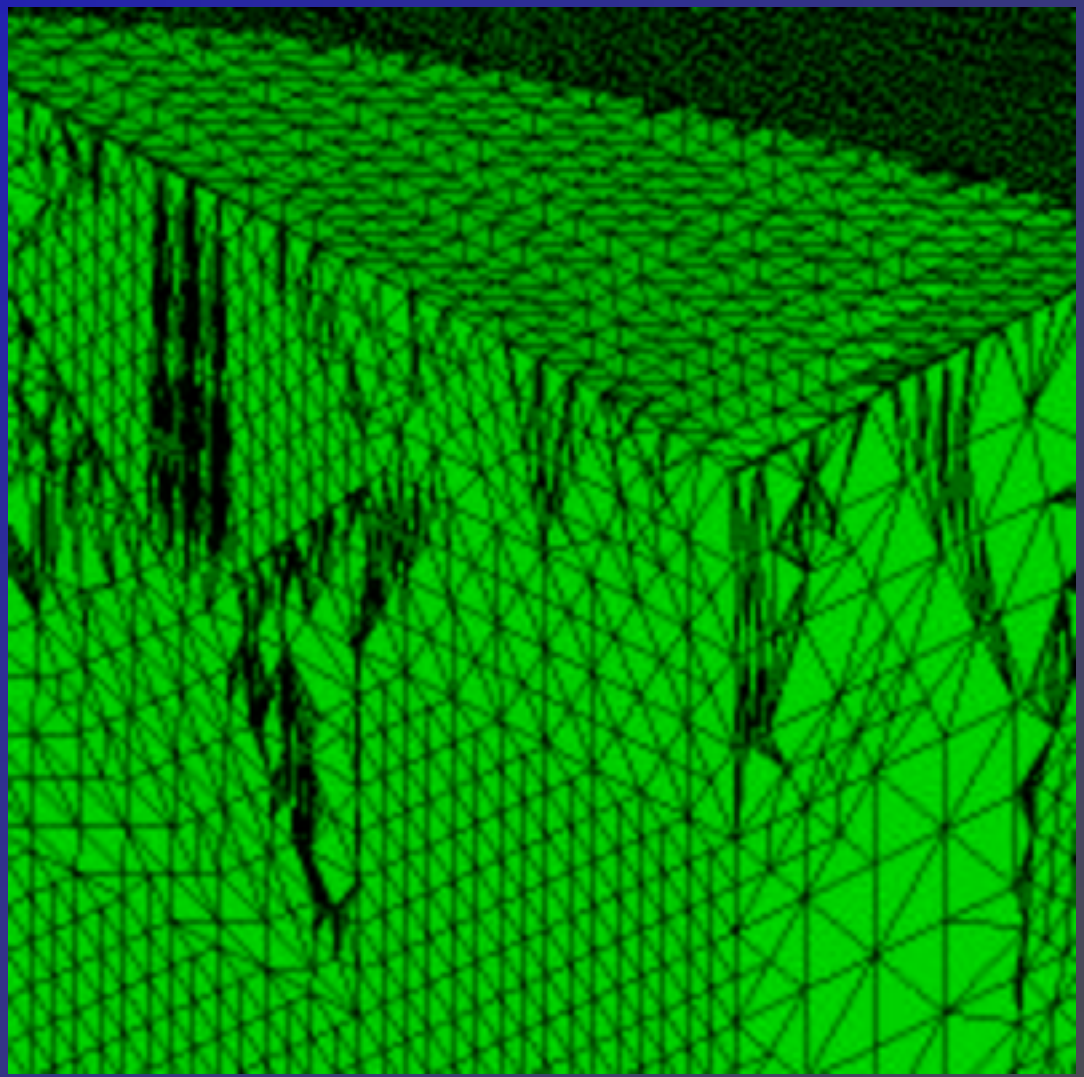
non−simplex triangulation

Improve Surface Triangulation
– Use RIVARA refine algorithm

Original



After Refine

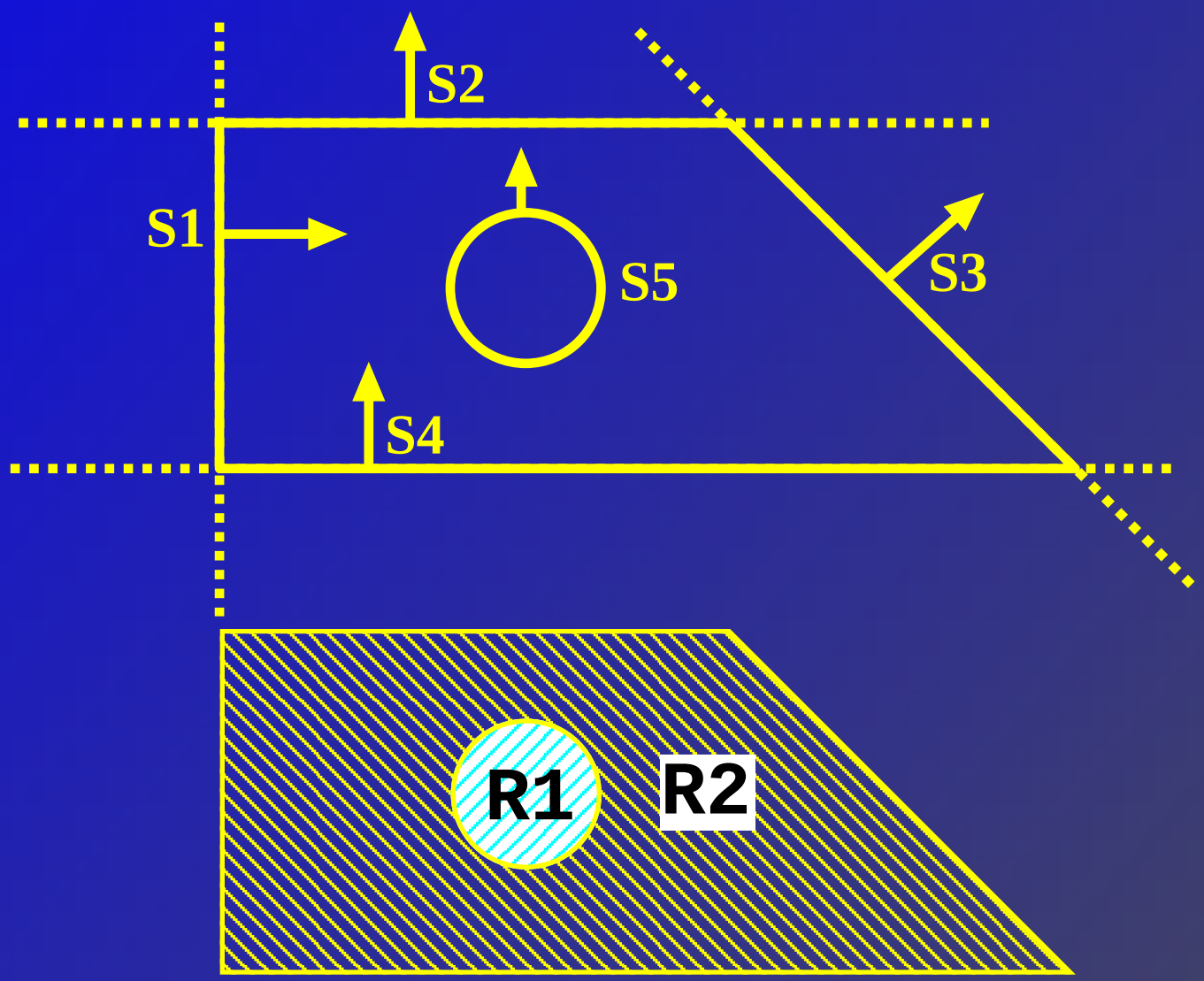


Geometry/Topology Definition

Constructive Solid Geometry

- **Volumes bounded by surfaces**
  - **>Analytic Surfaces (cone, sphere, plane, etc)**
  - **>Splines, NURBS**
  - **>Tessellations (triangle surface)**
- **Cellular/Grid Volumes**
- **CAD Definition**

Boolean Operators For Region Definition




```
R1 = Volume (lt S5)
R2 = Volume(gt S1 and lt S2 and lt S3
        and gt S4 and gt S5)
```

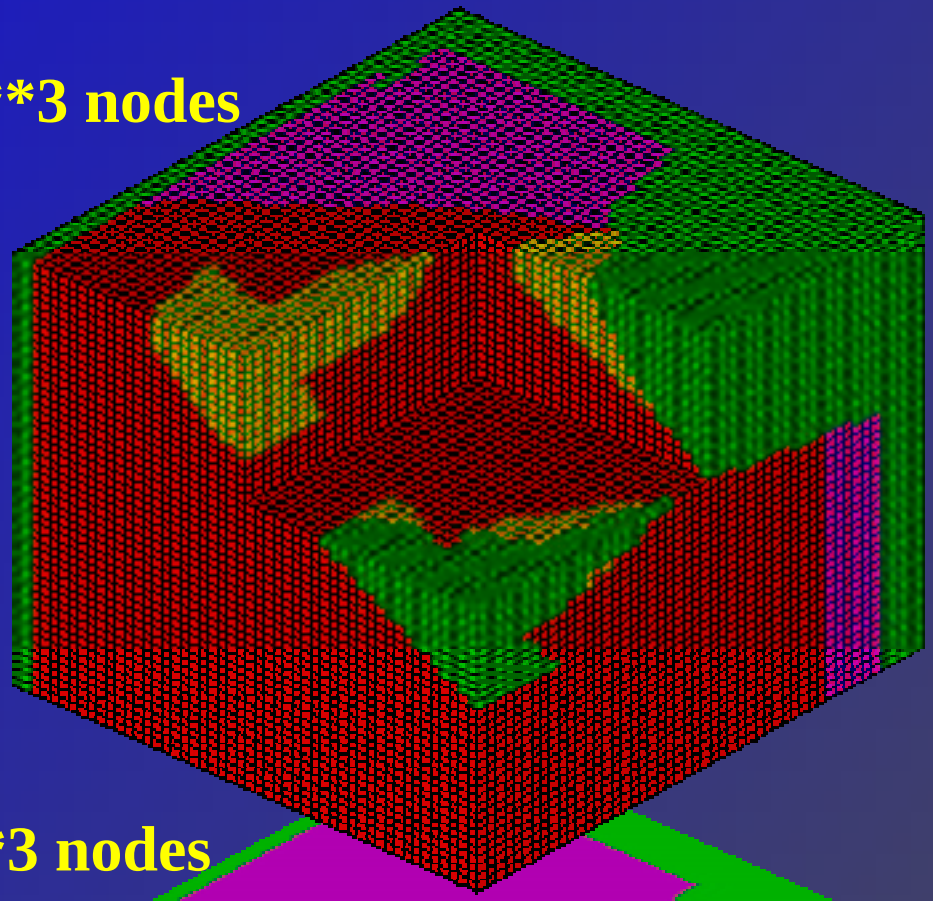
Define Micro−block model Geometry Using GOCAD T−surf files

NOTE: Block3 was inside out!

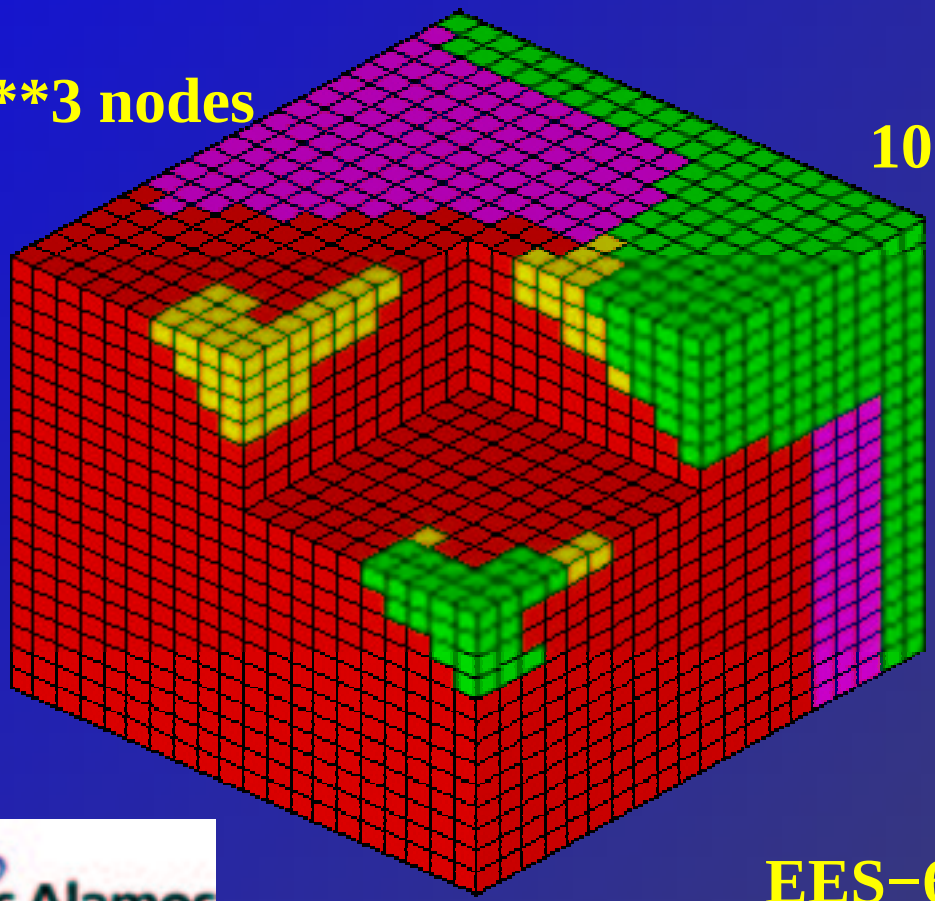
```
read / gmv / b1_filter_m00.gmv / cmo1
read / gmv / b2_filter_m00.gmv / cmo2
read / gmv / b3_filter_m00_flip2.gmv / cmo3
read / gmv / b4_filter_m00.gmv / cmo4
*
surface/ sbox  /reflect/box/XMIN YMIN ZMIN/XMAX YMAX ZMAX
surface/ surf1 /intrface/sheet/ cmo1
surface/ surf2 /intrface/sheet/ cmo2
surface/ surf3 /intrface/sheet/ cmo3
surface/ surf4 /intrface/sheet/ cmo4

mregion / mr1 / lt surf1
mregion / mr2 / lt surf2
mregion / mr3 / lt surf3
mregion / mr4 / lt surf4
mregion / mr0 / le sbox and gt surf1 and gt surf2 and &
                            gt surf3 and gt surf4
```

Uniform finite difference grid to test geometry definition.

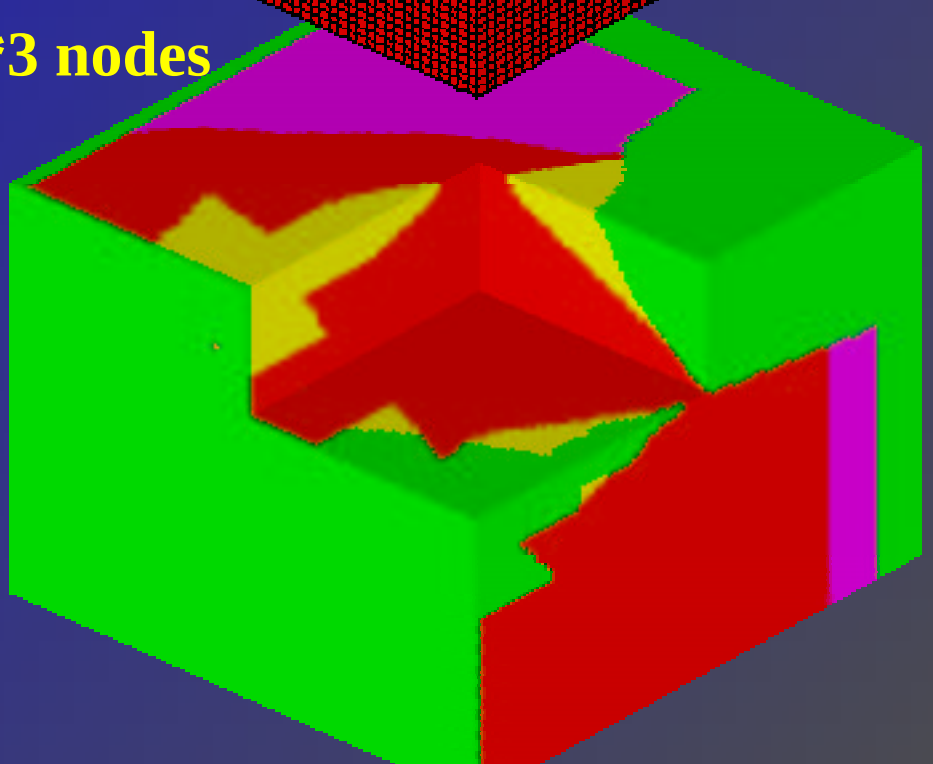
51**3 nodes



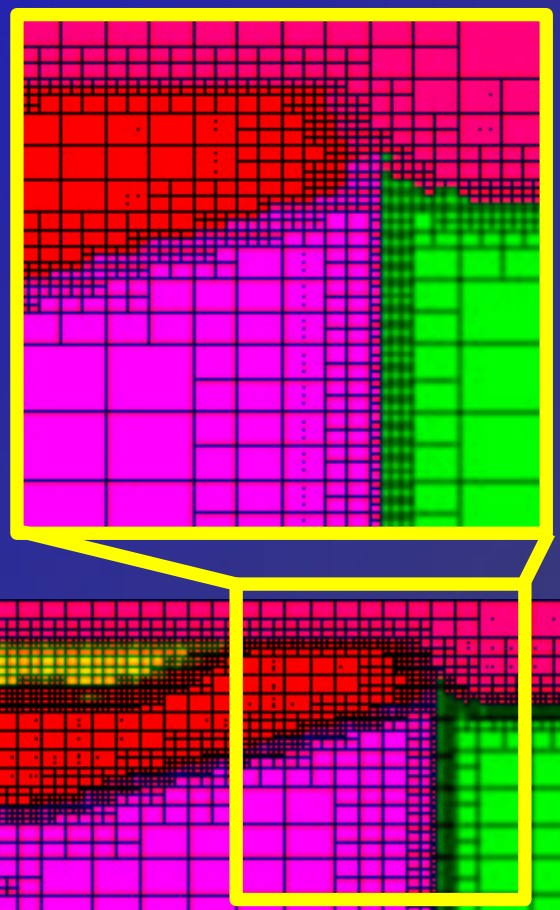
11**3 nodes

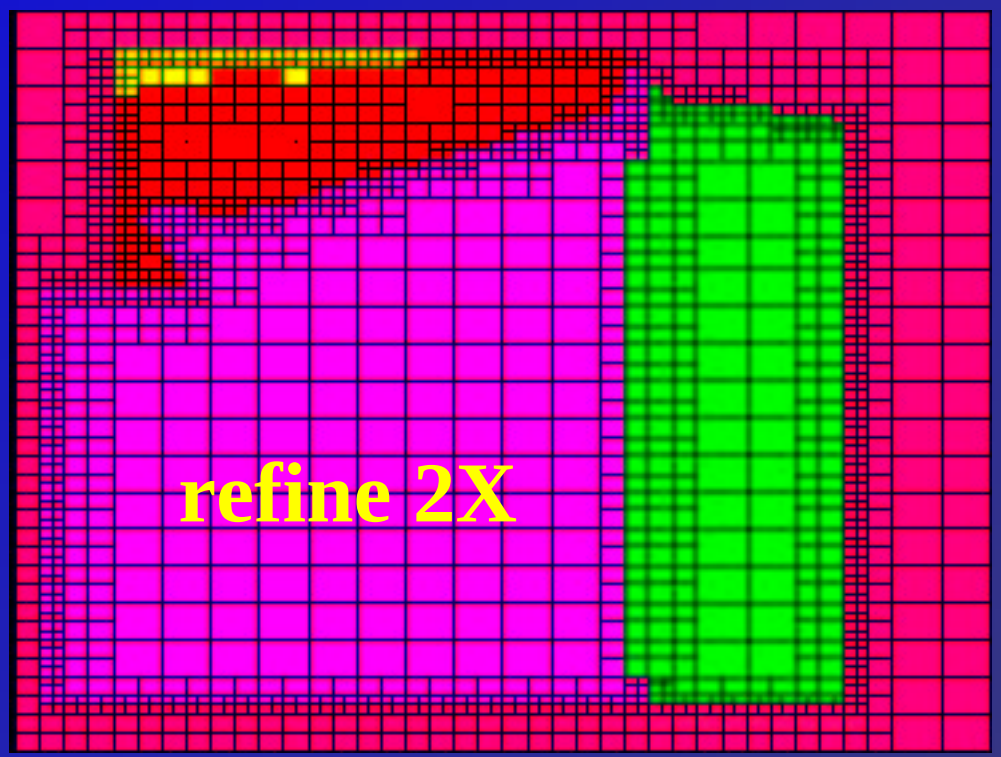


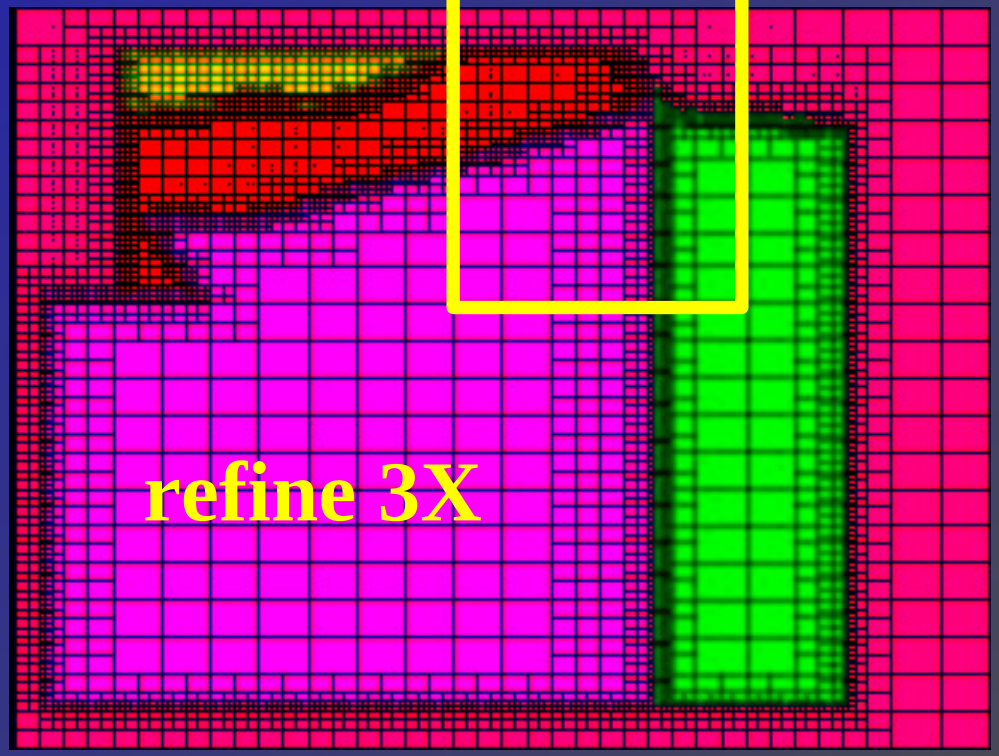
101**3 nodes



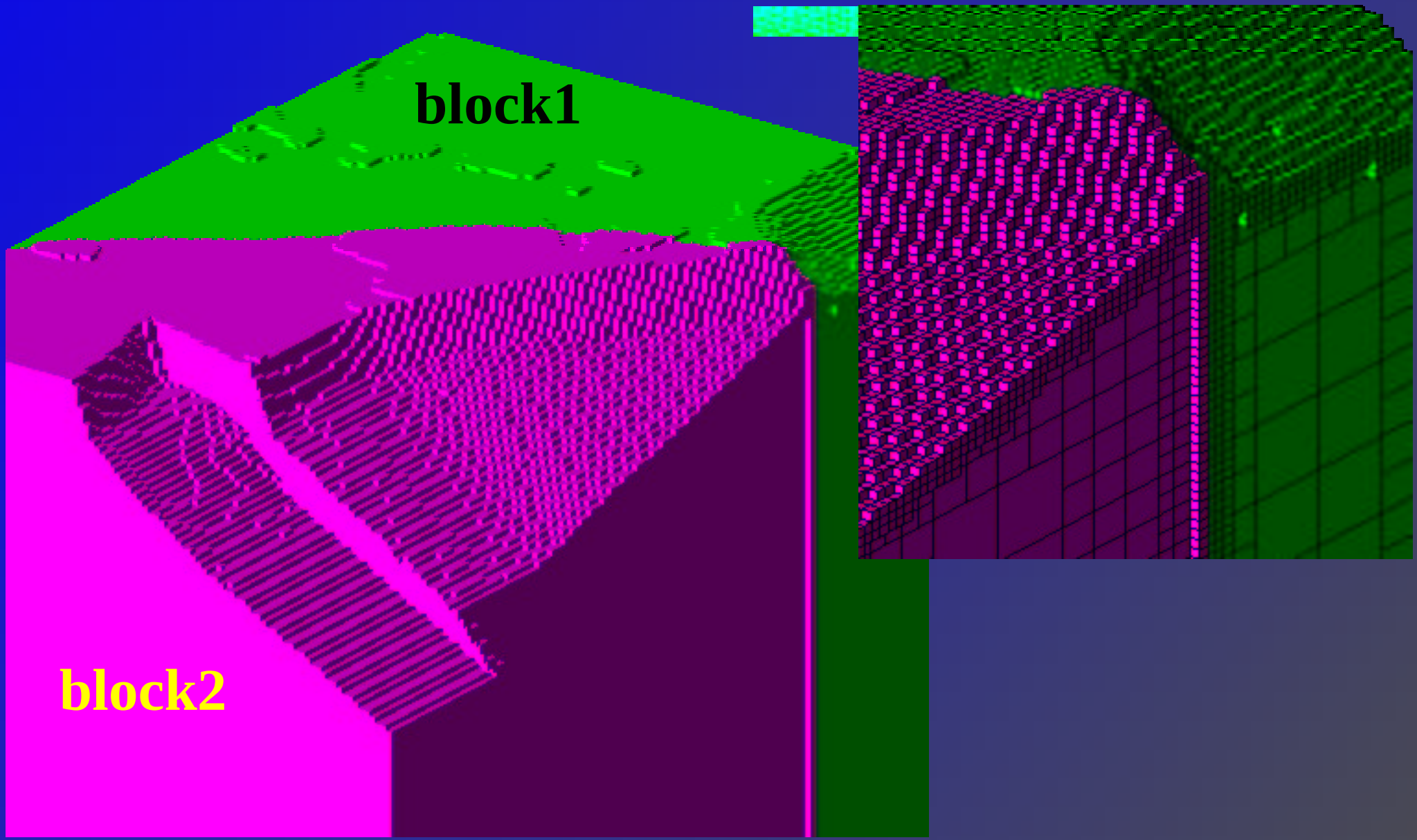
Develop a point distribution for use in tetrahedral mesh generation. Use octree adaptive mesh refinement to create high density nodes along material boundaries.





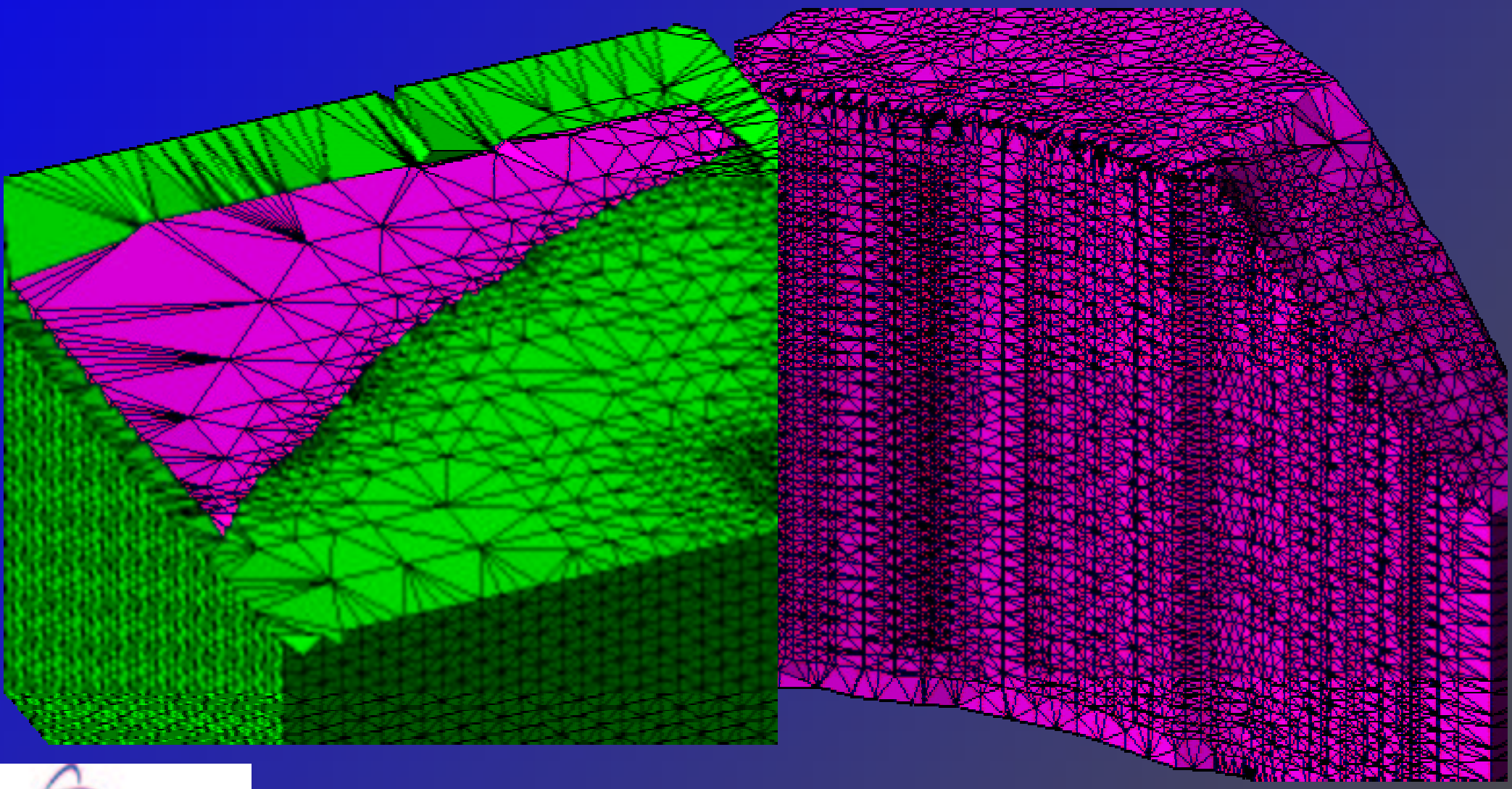


block1 and block2 illustrate octree mesh following GOCAD T−surf geometry



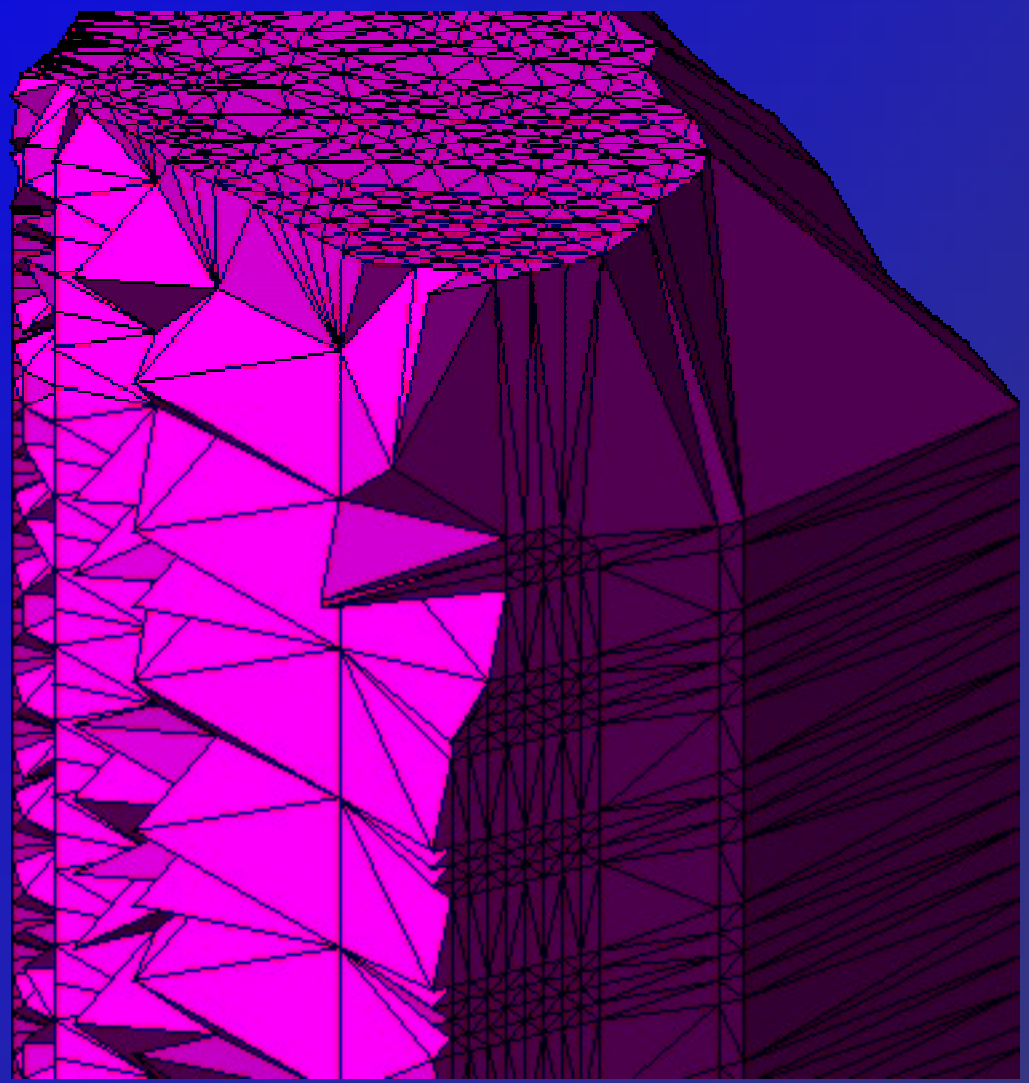
Tetrahedral Volume Mesh

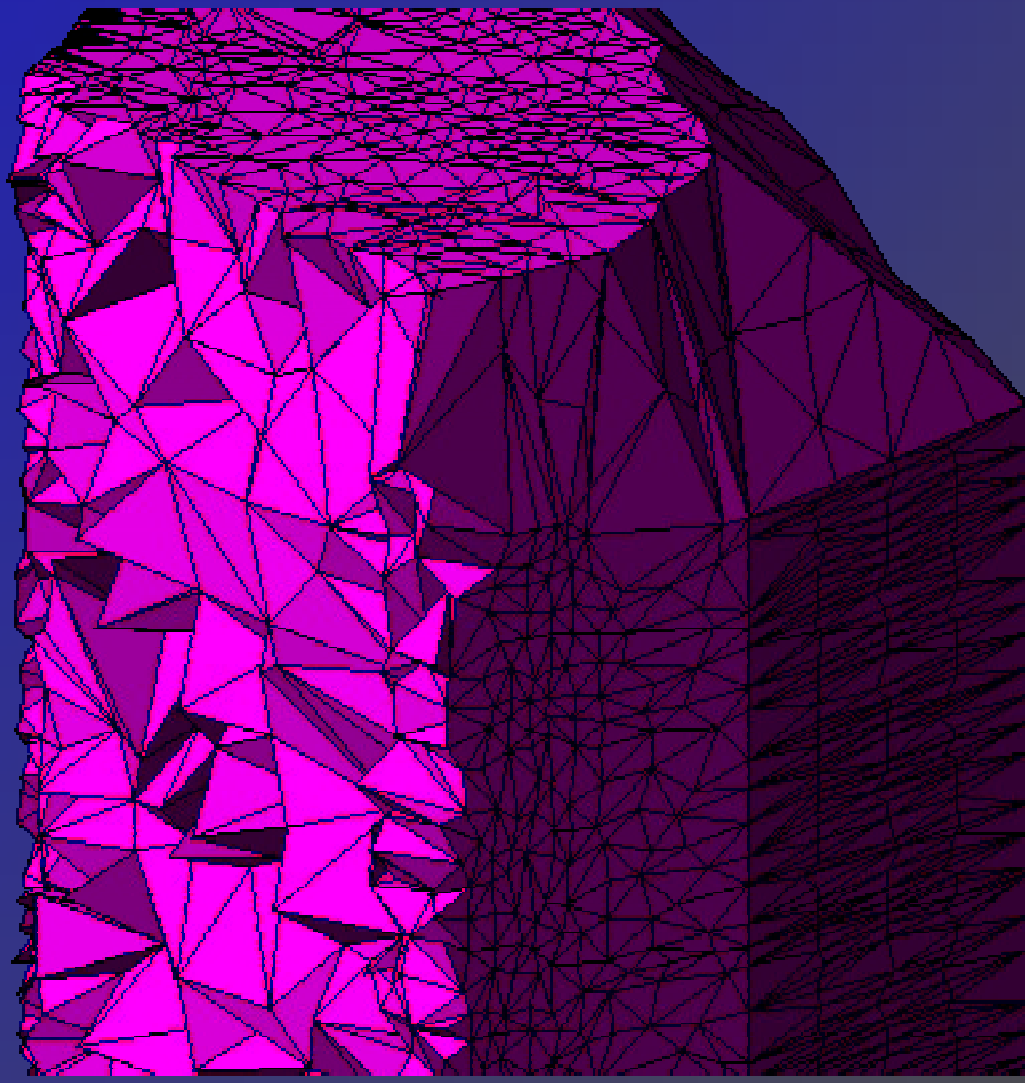
- concatenate T-surf point distribution w/ octree point distribution
- Apply 3D Delaunay tetrahedralization algorithm
- Break edges that cross material boundary by point addition at location where edge intersects boundary



Optimize Mesh Using `massage`

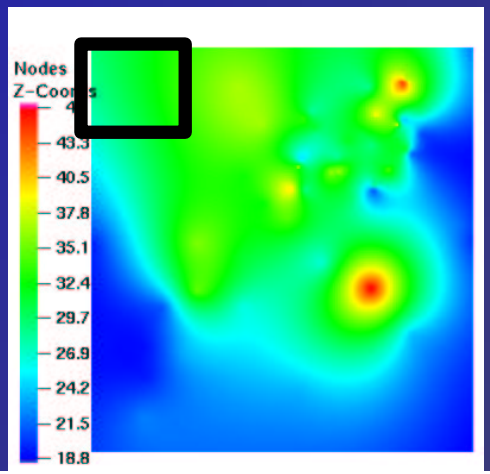
- Refine edges with length greater than 3000m
- Merge edges with length less than 50m
- Allow damage to material interfaces of 1m
- Smooth interior nodes

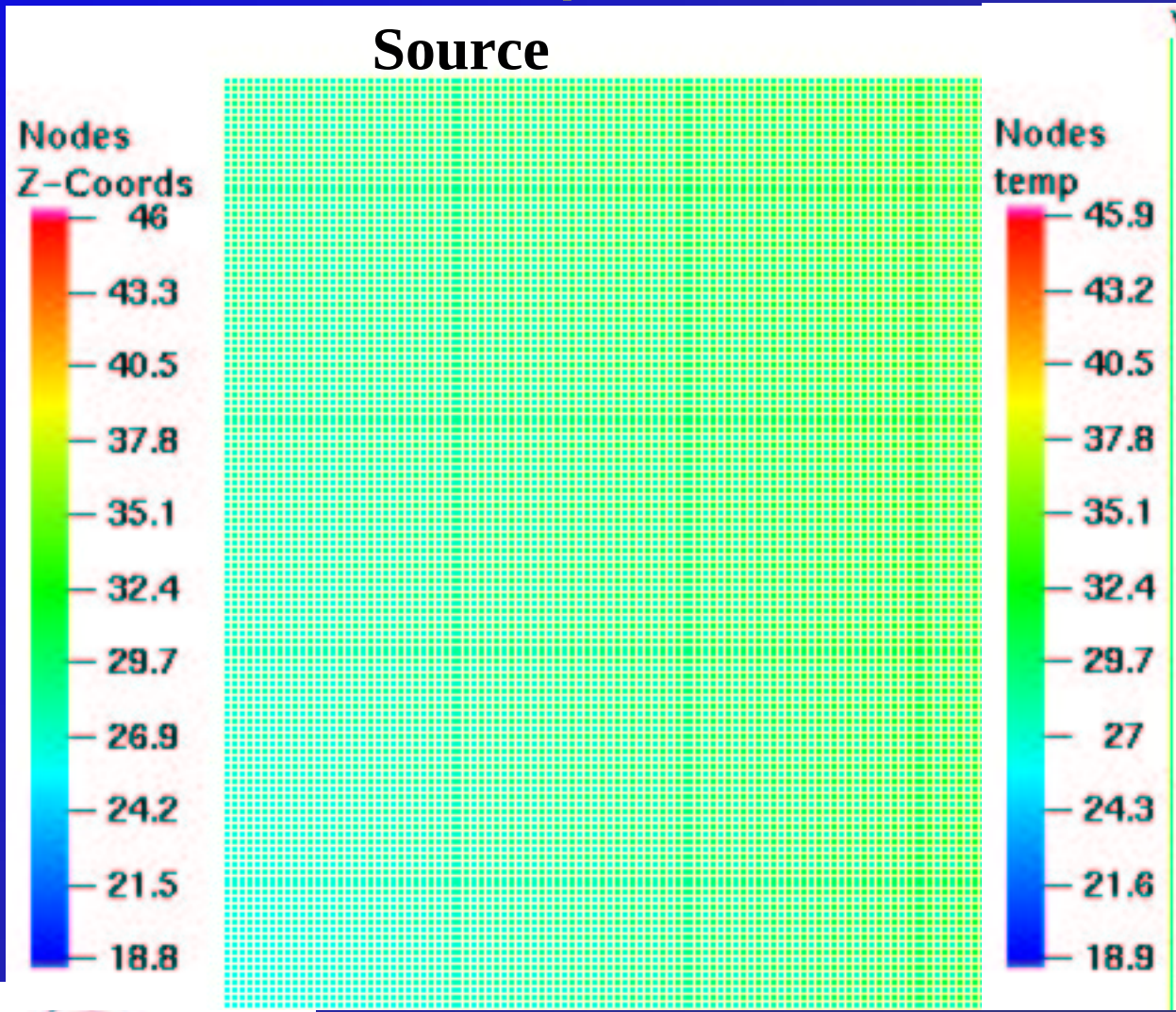


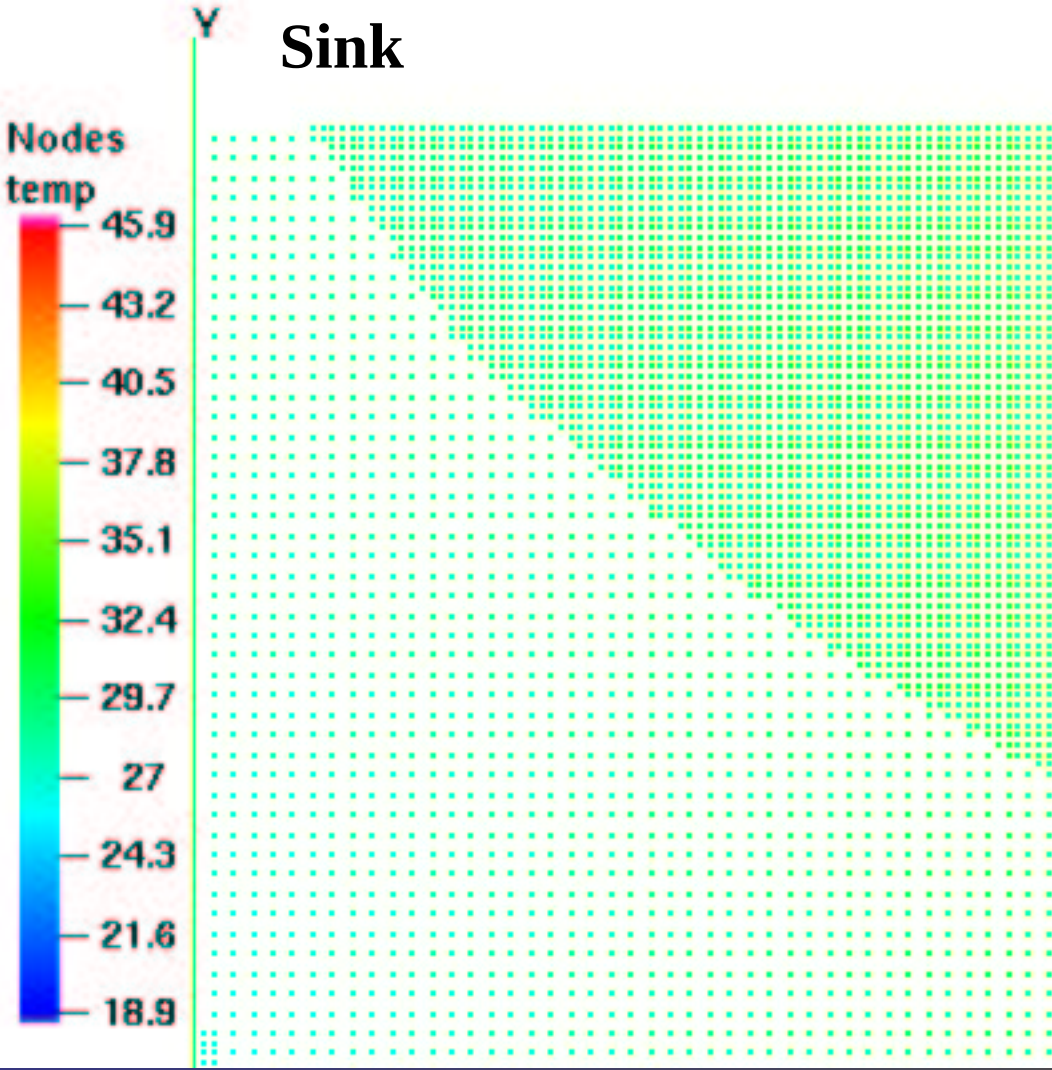


Grid to Grid Interpolation – Input is a regular 100m grid 50kmX53km (266031 nodes). Temperature values are interpolated onto irregular node distribution on the top surface of a hydrology flow model.

```
LaGriT Command : interpolate / continuous / cmo_sink temp / 1,0,0 / cmo_source temp / 0.0
```



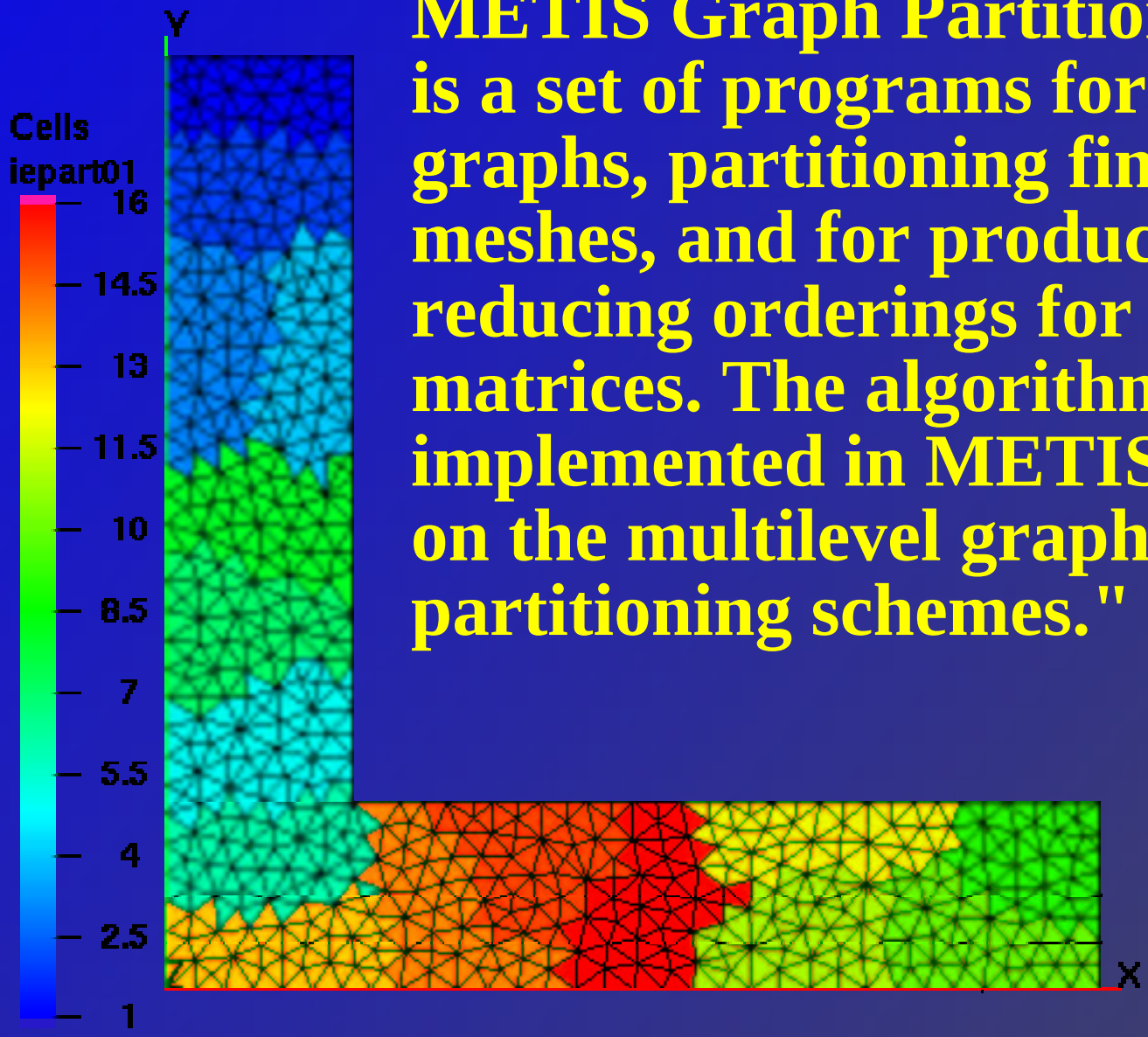




Point Sets / Element Sets

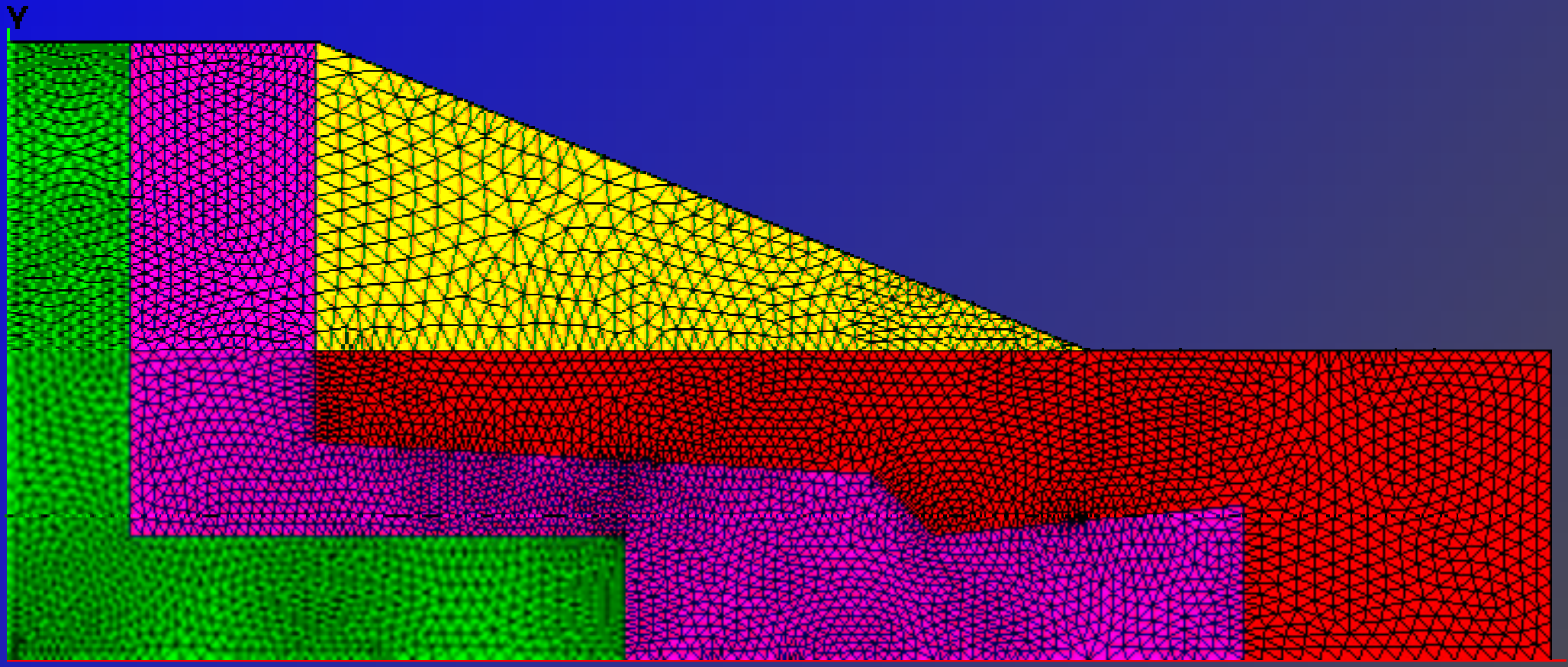
Sets of nodes and elements can be created using criteria such as:

- **attribute value**
- **attribute range**
- **location (xyz, rtz, rtp)**
- **region/mregion**
- **logical operations (intersection, union, not)**



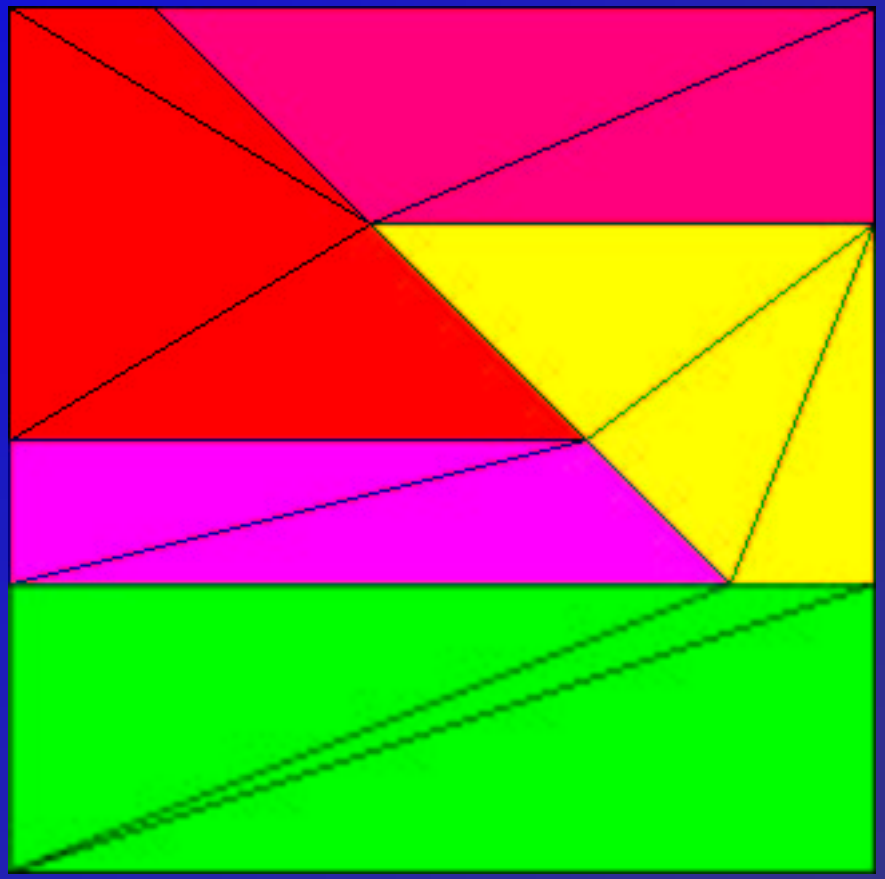
METIS Graph Partition – "METIS is a set of programs for partitioning graphs, partitioning finite element meshes, and for producing fill reducing orderings for sparse matrices. The algorithms implemented in METIS are based on the multilevel graph partitioning schemes."

`triangulate` polygons – a set of polygons with coincident shared sides are triangulated, refined, smoothed and reconnected into a Delaunay mesh.

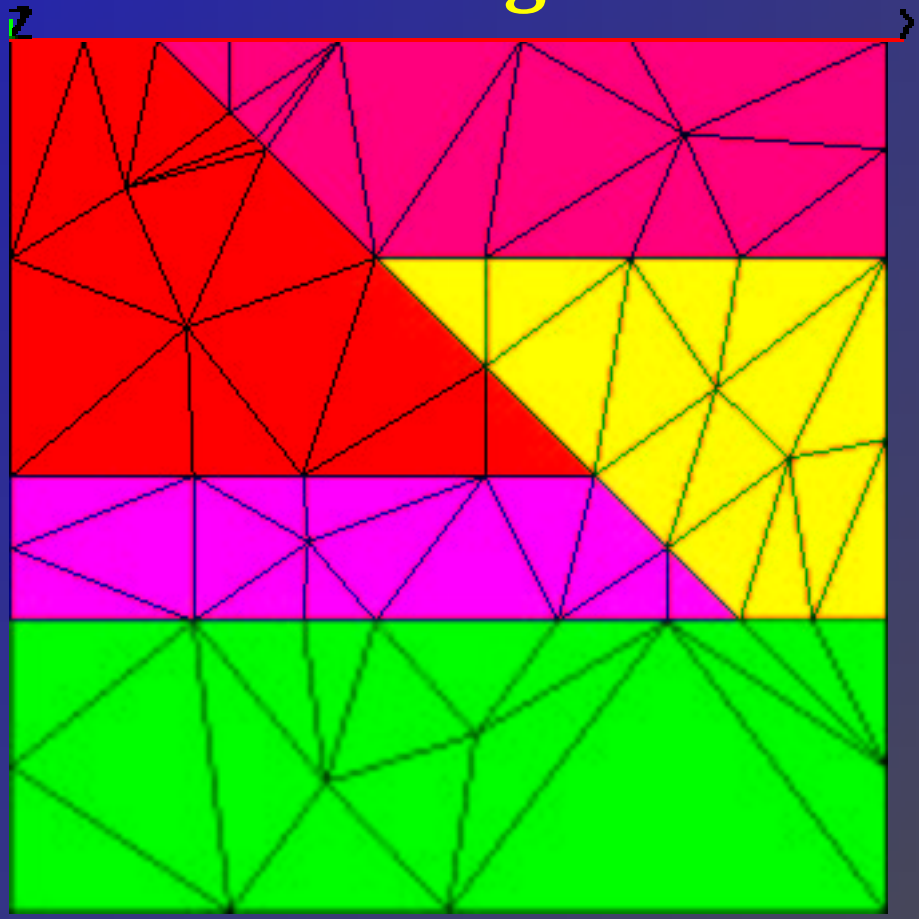


Benchmark 5 – Mesh Generation

Triangulate Polygons

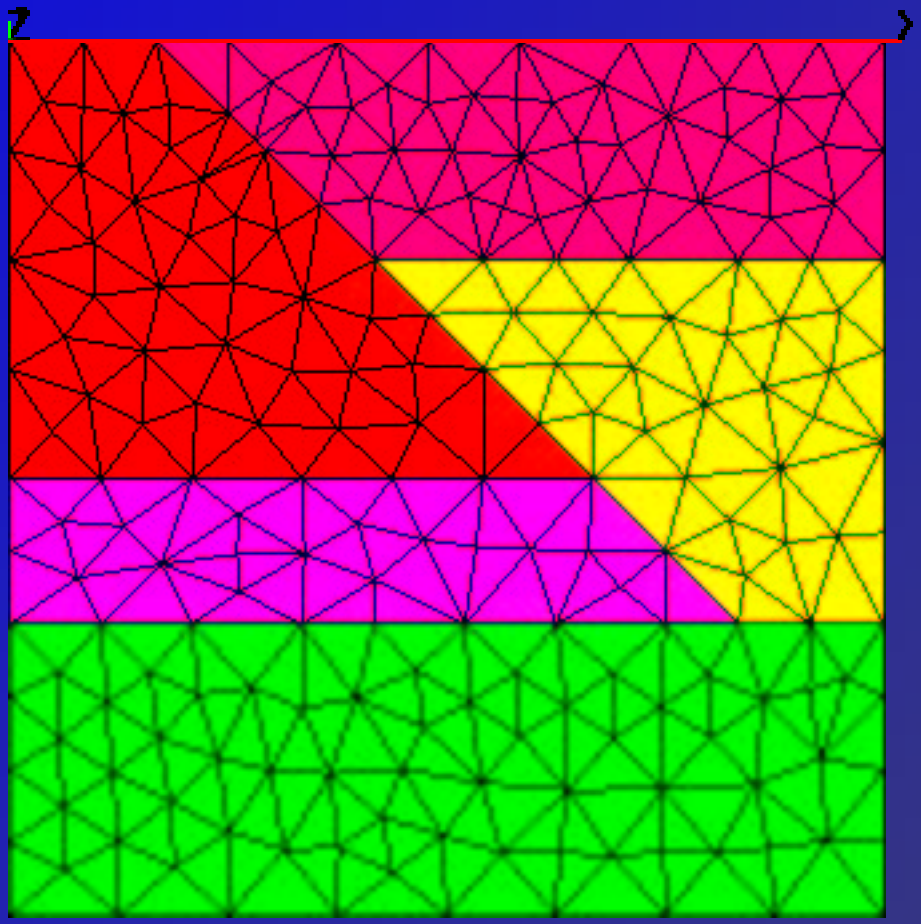


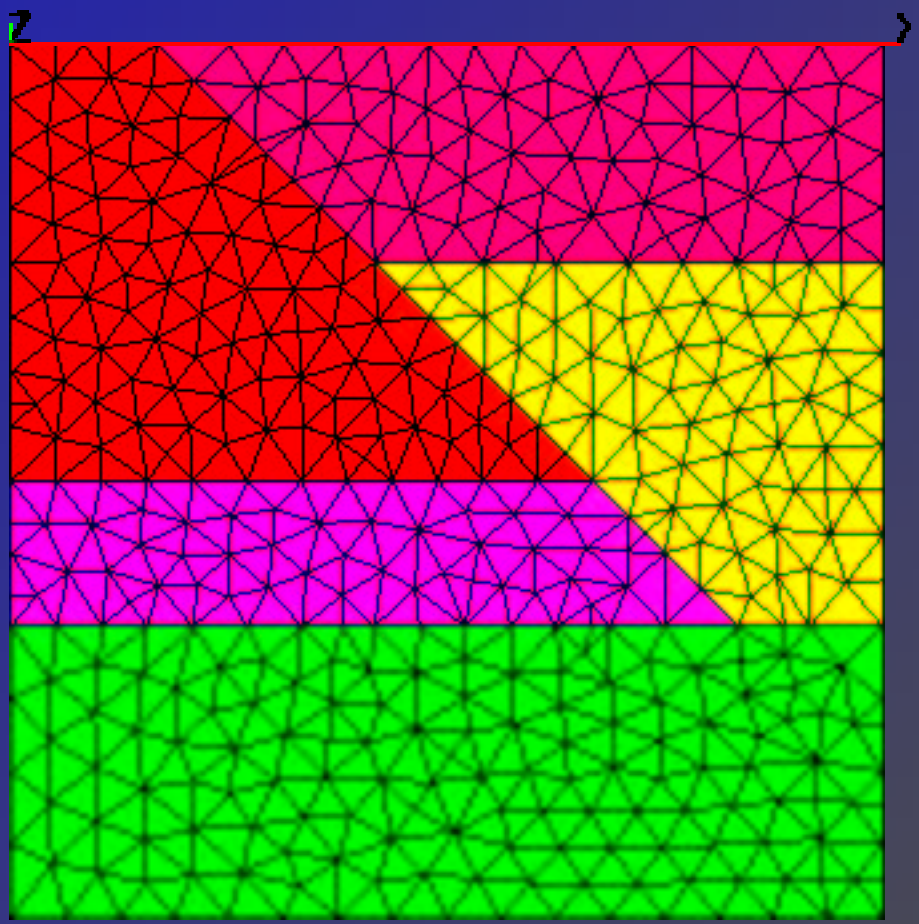
Refine Triangles



Benchmark 5 – Mesh Generation

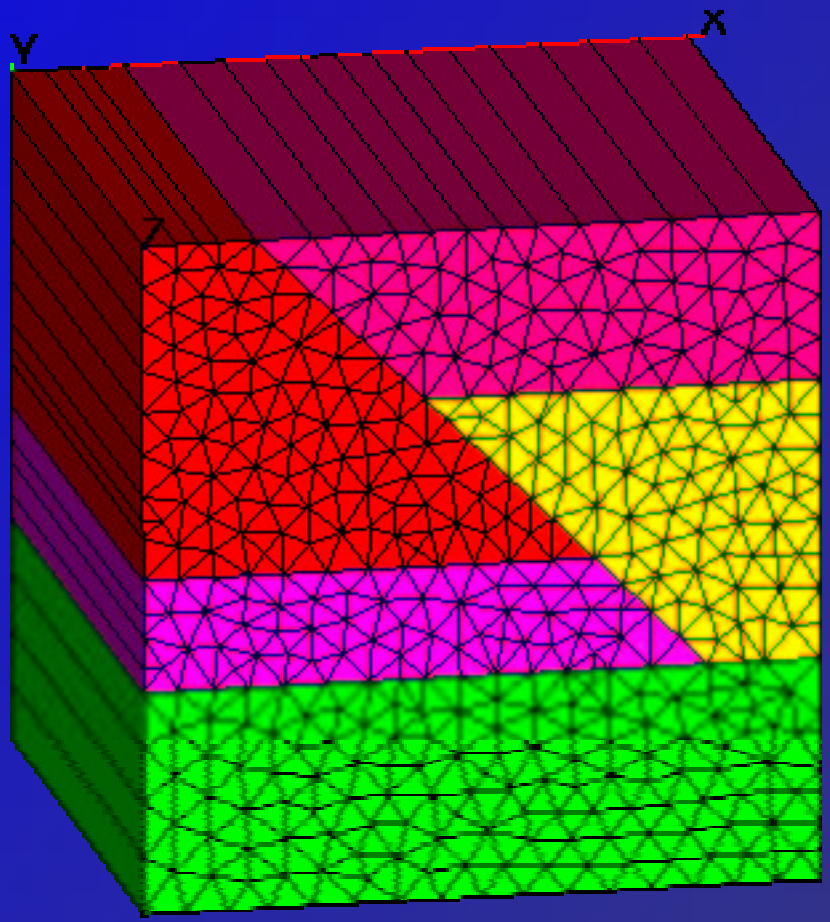
```
refine/rivara///edge/1 0 0/300.///inclusive
resetpts / itp
smooth / position / esug / 1 0 0
recon 0
smooth / position / esug / 1 0 0
recon 0
smooth / position / esug / 1 0 0
recon 0
smooth / position / esug / 1 0 0
recon 0
dump / gmv / output_smooth2.gmv / cmo_all
```





Benchmark 5 – Mesh Generation

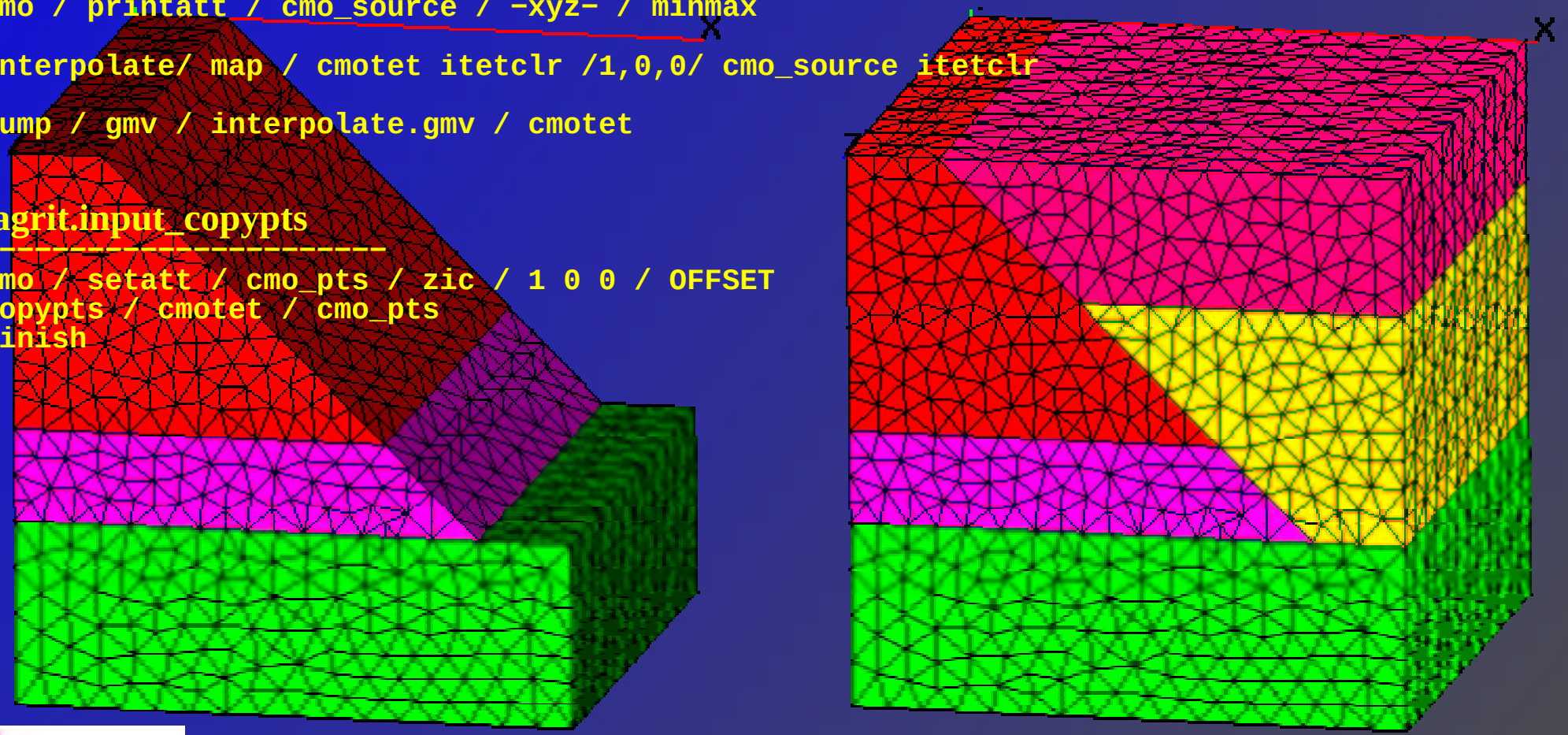
```
read / gmv / output_smooth3.gmv / cmo_tri
resetpts / parents
rmpoint / compress
cmo / setatt / cmo_tri / zic / 1 0 0 / 2400.0
extrude/cmo_prism/cmo_tri/const/ 2400.0/volume
cmo / printatt / cmo_prism / -xyz- / minmax
quality
dump / gmv / output_smooth3_extrude.gmv / cmo_prism
```



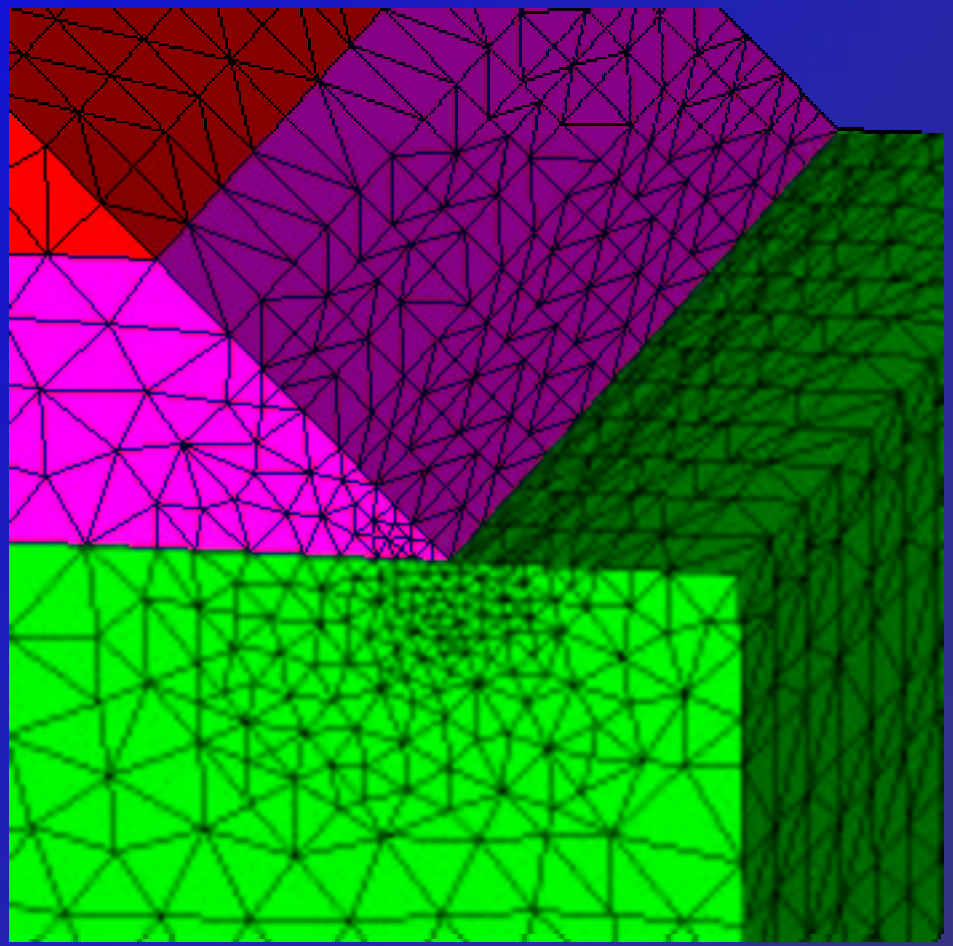
```
read / gmv / output_smooth3.gmv / cmo_pts
resetpts / parents
rmpoint / compress
cmo / create / cmotet / / / tet
loop/ do / OFFSET / 0 / 2400 / 200 / loop_end / infile lagrit.input_copypts
dump / gmv / points.gmv / cmotet
filter 1 0 0
rmpoint / compress
connect / noadd
dump / gmv / tets.gmv / cmotet
read / gmv / output_smooth3_extrude.gmv / cmo_source

cmo / printatt / cmotet / -xyz- / minmax
cmo / printatt / cmo_source / -xyz- / minmax

interpolate/ map / cmotet itetclr /1,0,0/ cmo_source itetclr

dump / gmv / interpolate.gmv / cmotet
```

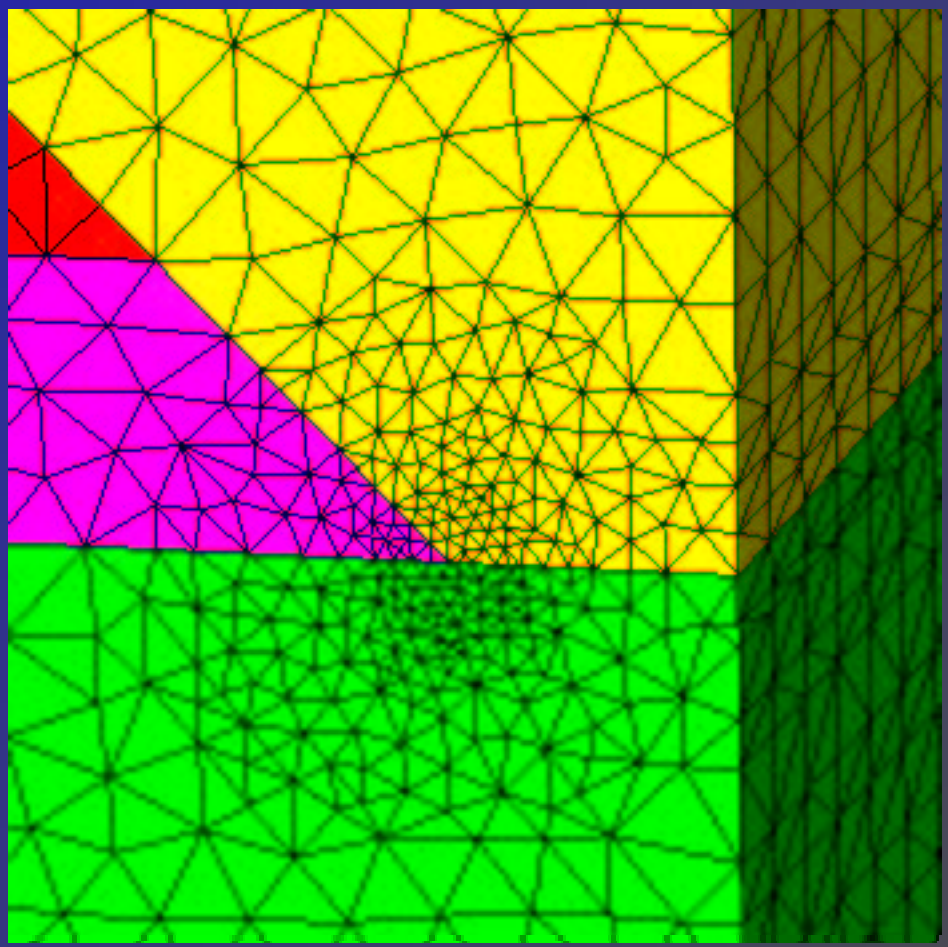
lagrit.input_copypts

```
cmo / setatt / cmo_pts / zic / 1 0 0 / OFFSET
copypts / cmotet / cmo_pts
finish
```



```
read / gmv / output_smooth3.gmv / cmo_all
*
* Refine around the tip of the fault x = 2000. , y = -1600.
*
pset/prefine/geom/rtp/1 0 0/0.,0.,0./300.,360.,360./2000.,-1600.,0.
refine/rivara///edge/pset get prefine/100.///inclusive
resetpts / itp
recon 0
pset/prefine/geom/rtp/1 0 0/0.,0.,0./350.,360.,360./2000.,-1600.,0.
smooth / position / esug / pset get prefine
recon 0
pset/prefine/geom/rtp/1 0 0/0.,0.,0./350.,360.,360./2000.,-1600.,0.
smooth / position / esug / pset get prefine
dump / gmv / output_rivara100.gmv / cmo_all
```





...and to take it a step further ...