Pamgen
A Parallel Finite-Element Mesh Generation Library

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Presenting for

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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Parallel Mesh Generation Library Driver & Challenges

- Analysis codes and capability machines are leaving pre-processing tools and shared memory machines behind
- Serial mesh generation strategies were unable to supply analysts' demands for:
  - Billions of Elements
  - Quick Turn-around

R.S. 12960 Nodes

- Scale well: multiple thousands of processors and billion + elements
  - Exploit determinism
  - Eschew communication
- Ease of Use: run different decompositions without modifying input deck
  - Automatic load balancing
  - Consistent topology/geometry

Purple, 1532 nodes

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Enabling/Limiting Assumptions

- All Processor Have Identical Information
  - No need to communicate
- All Processors are Identical (except for Ids)
  - Calculations produce identical results
  - No need to communicate
- Communication is Unavailable
  - Resist the temptation
  - Scale really well
- All Meshes Will Consist of One or More Structured Blocks
  - Connectivities easily calculated
  - Geometries derive from topologies

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Execution Stages

- Information Distribution – Each processor gets a complete description of the mesh.
- Decomposition, run equivalently on each processor such that each processor:
    - Receives a list of its local elements
    - Can calculate the processor of any element
- “Serial” Information Generation – Nodes, Elements, Connectivity local to a processor
- “Parallel” Information Generation – Inter-processor communication information.
- Geometric Transformations – User provided subroutines to calculate new nodal coordinates

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Library Interface

- Create a “mesh” within the library

```
int Create_Pamgen_Mesh(char *
mesh_description, int dimension, int
rank, int num_procs);
```

- Query the library to build up representation in client code – the same as may be done with a file interface API

```
Im_ex_get_info(…)

Im_ex_get_connectivit(…)
```

- After queries are completed the library memory can be cleared with a delete function.

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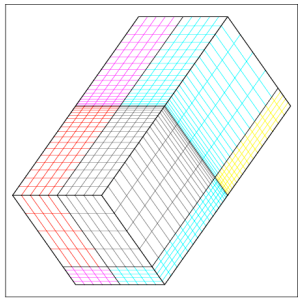
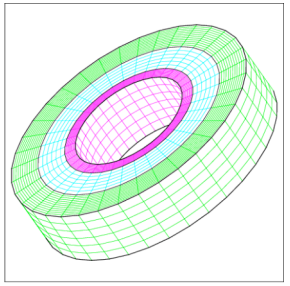
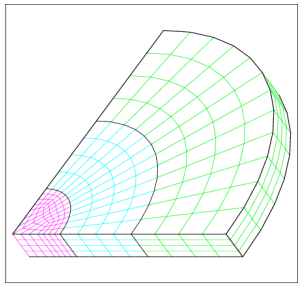
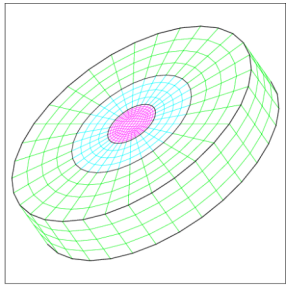
Capabilities

- Topologies
  - Cubes
  - Solid Cylinders – Full and partial
  - Hollow Cylinders – Full and partial
- Geometries
  - Those suggested above plus projection to sphere
  - Arbitrary user-specified geometry transformation
- Boundary conditions – Call out nodes and element faces on topological faces,edges,corners
- Decompositions
  - Optimal bisection
  - User controlled
  - Sequential
  - Random









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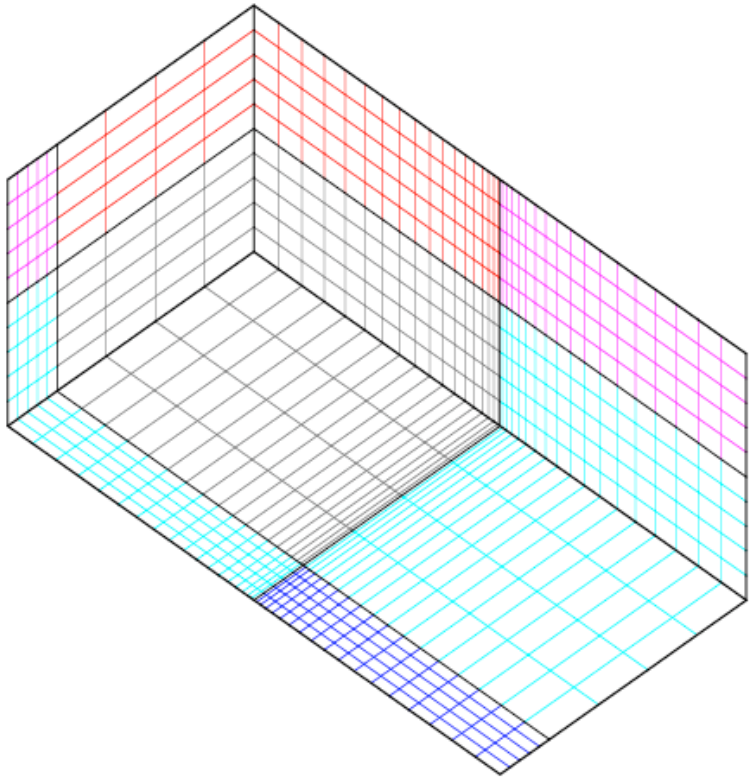
Example
A Brick mesh

```
mesh
  brick
  numz 2
    zblock 1 2. interval 5
    zblock 2 8. interval 4
  numx 2
    xblock 1 5.0 interval 5
    xblock 2 5.0 interval 5
  numy 2
    yblock 1 10. first size
 1. last size .1
    yblock 2 10. first size
 .1 last size 1.
  end
end
```



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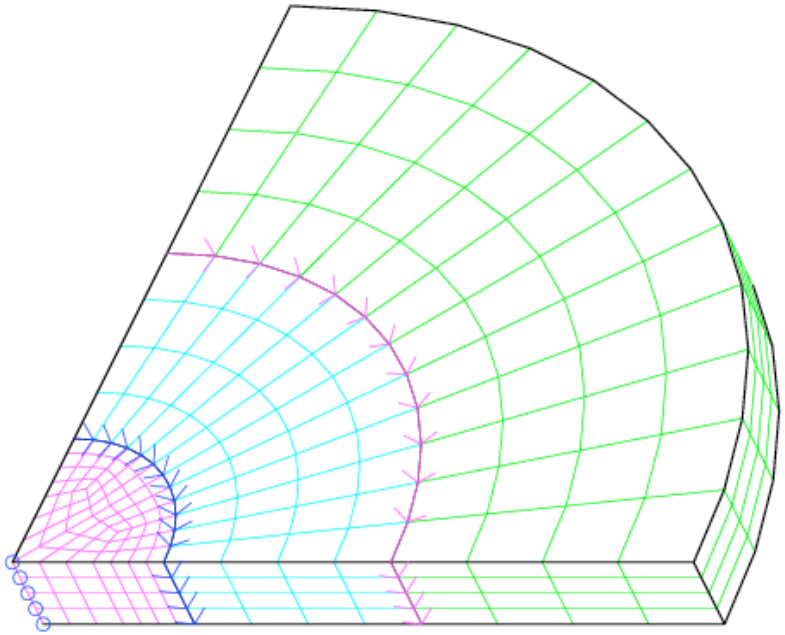
Example
A Partial Cylinder with Node Sets and Side Sets

```
mesh
  radial trisection
    trisection blocks, 2
    zmin -0.00075
    numz 1
      zblock 1 1. interval 4
    numr 3
      rblock 1 2.0 interval 4
      rblock 2 3.0 interval 4
      rblock 3 4.0 interval 4
    numa 1
      ablock 1 90. interval 12
    end
  set assign
    nodeset, ilo, 100
    block sideset, ilo, 35, 2
    block sideset, ihi, 45, 2
  end
end
```



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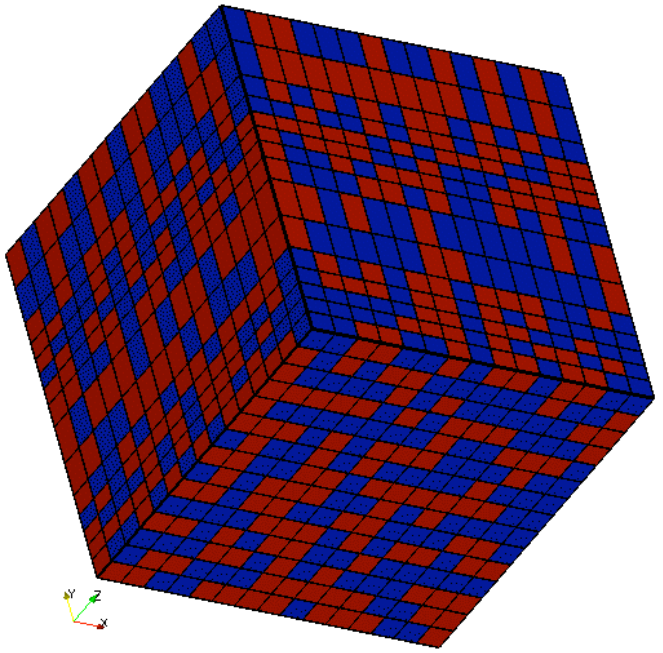
Example
A Brick With Random Decomposition for 2 Processors

```
mesh
  brick
  numz 1
    zblock 1 2.0 interval 15
  numx 1
    xblock 1 2.0 interval 15
  numy 1
    yblock 1 2.0 interval 15
  end
  decomposition stratgy
    random
  end
end
```



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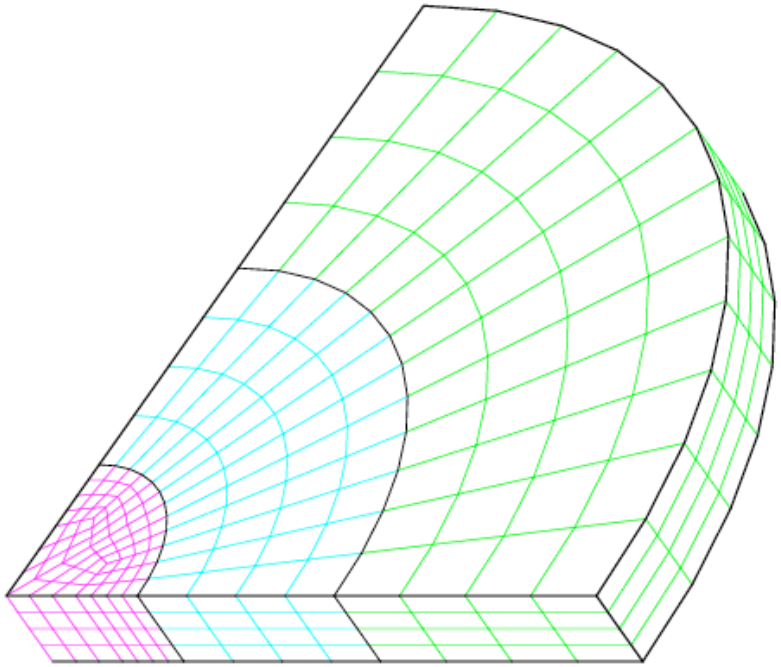
Example
A Portion of a Solid Cylinder

```
mesh
  radial trisection
  trisection blocks, 2
  zmin -0.00075
  numz 1
    zblock 1 1. interval 4
  numr 3
    rblock 1 2.0 interval 4
    rblock 2 3.0 interval 4
    rblock 3 4.0 interval 4
  numa 1
    ablock 1 90. interval 12
  end
end
```



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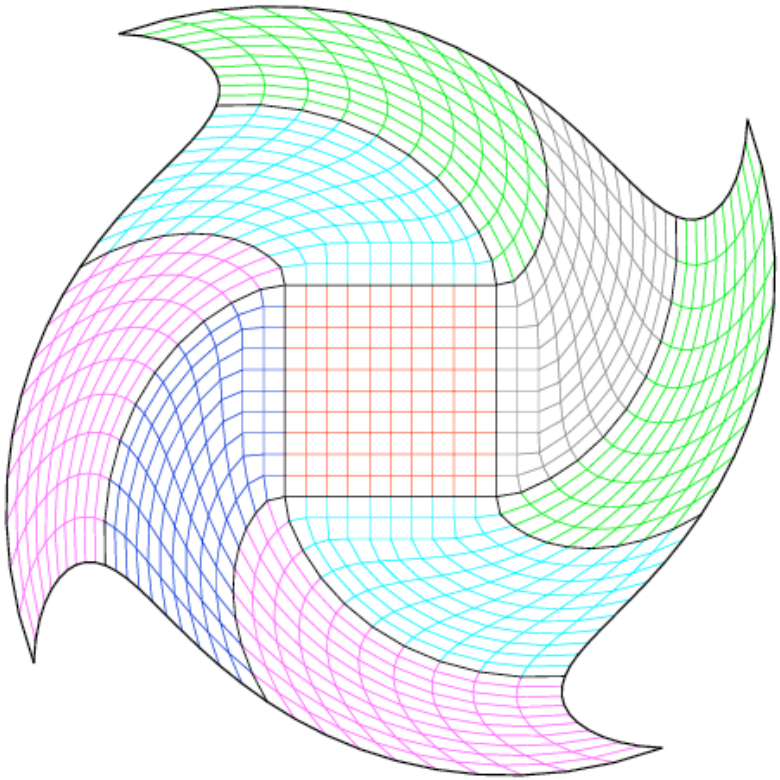
Example
A 2D Block of Mesh with Geometry Transformation

```
mesh
  rectilinear
    nx = 10
    ny = 10
    bx = 3
    by = 3
    gmin = -1.0 -1.0
   gmax = 1.0 1.0
  end
  user defined geometry transformation
  "
    double r = sqrt(inxcoord*inxcoord
  +inycoord*inycoord);
    double theta = atan2(inycoord,inxcoord);
    if(r > 0.5)
    {
    theta = theta + (3.14159 / 4.0)*((r-
  0.5)/0.5);
    outxcoord = r*cos(theta);
    outycoord = r*sin(theta);
   }
  "
  end
end
```



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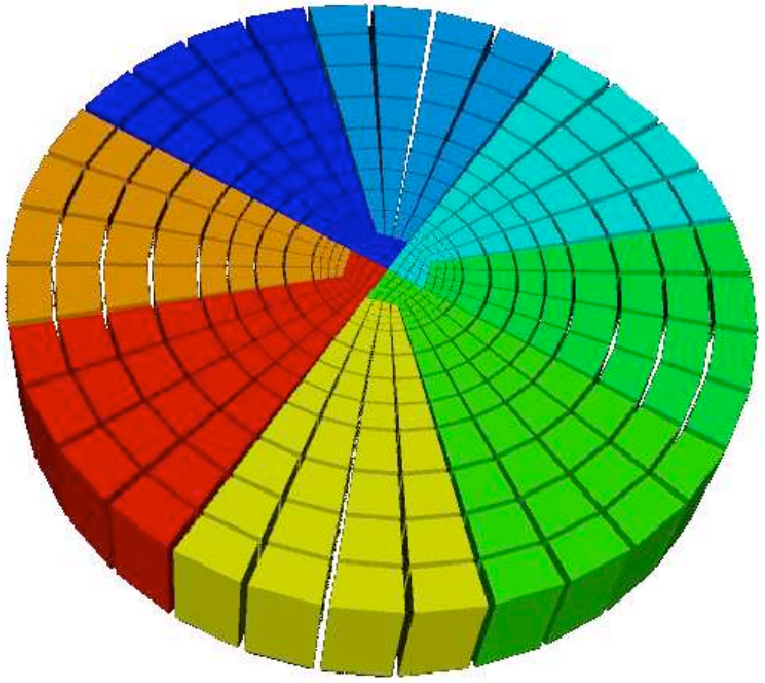
Example
A 3D Solid Cylinder Decomposed for Eight Processors

```
mesh
  radial trisection
    trisection blocks, 4
    numz 1
      zblock 1 4.0 interval 1
    numr 3
      rblock 1 2. interval 4
      rblock 2 3. interval 4
      rblock 3 5. interval 4
    numa 1
      ablock 1 360. interval 32
  end
  decomposition strategy
    numprocs j, 8
  end
end
```



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Availability and Distribution

- Available under GNU Lesser General Public License (LGPL).
- Distributed as a component of Trilinos
- Documented in report: SAND 2008-1933

http://trilinos.sandia.gov/packages/pamgen

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