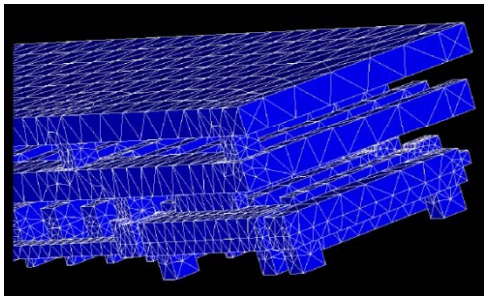
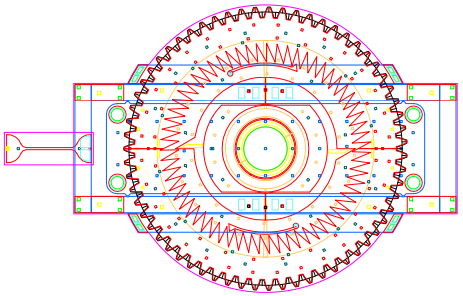
Sandia MEMS Design Tools

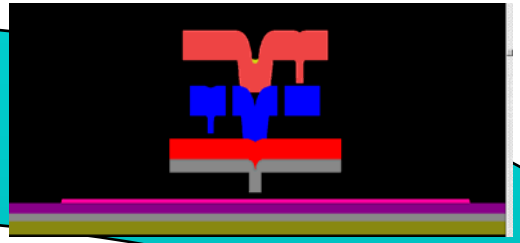
SAND Number: 2010-8117 W



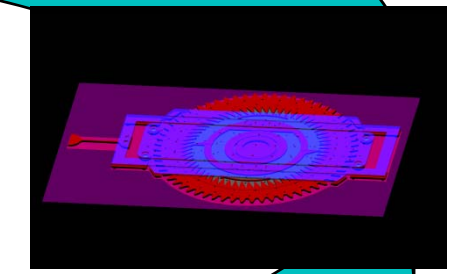
Design & Analysis



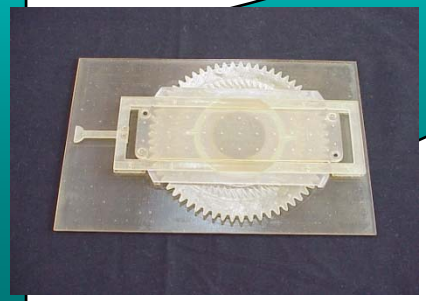
Layout

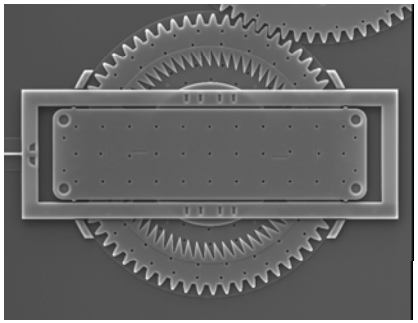


Visualization



Verification



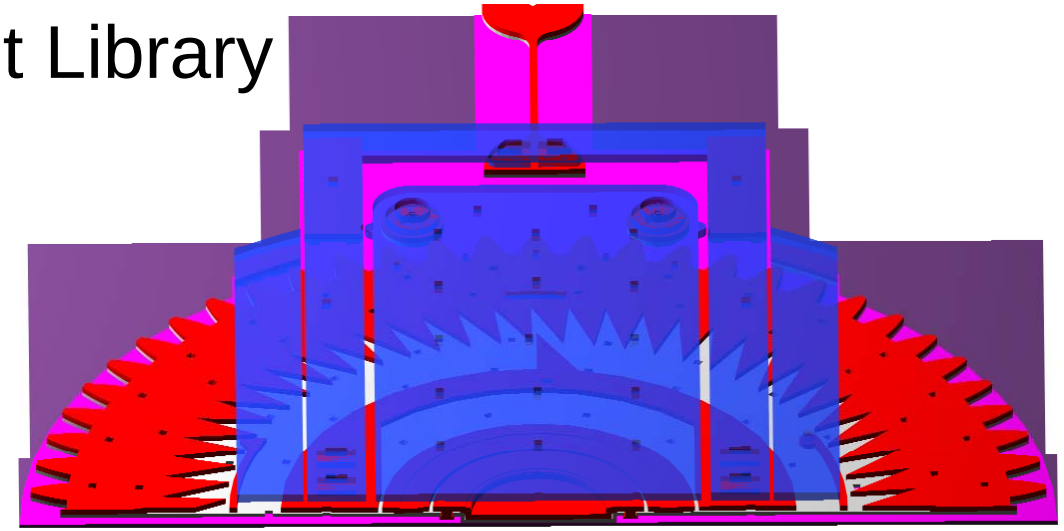


First pass success!

Sandia National Laboratories

Sandia MEMS Design Tools Overview

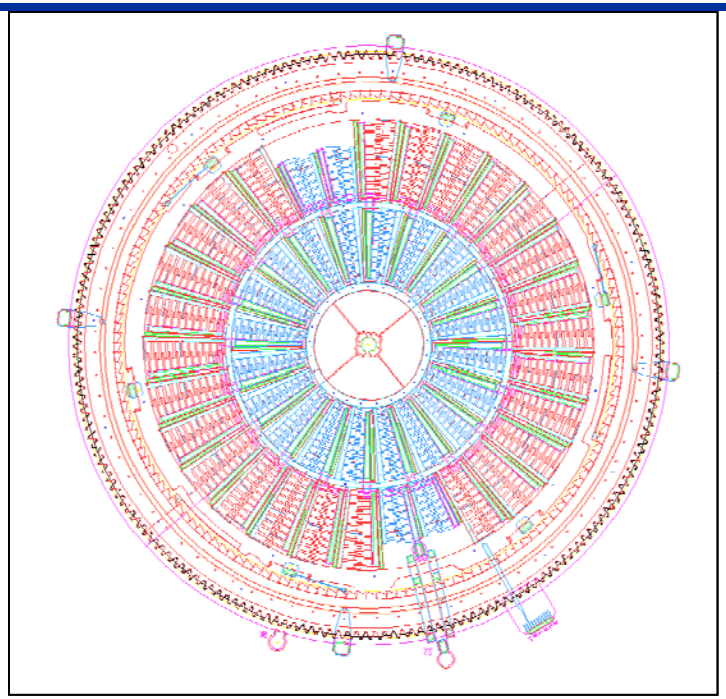
- Why do we need Design Tools?
- The MEMS Design Process Flow
- Analysis Capabilities
- 2D Process Visualizer
- MEMS 3D Modeler
- MEMS Design Rule Checker
- Standard Component Library

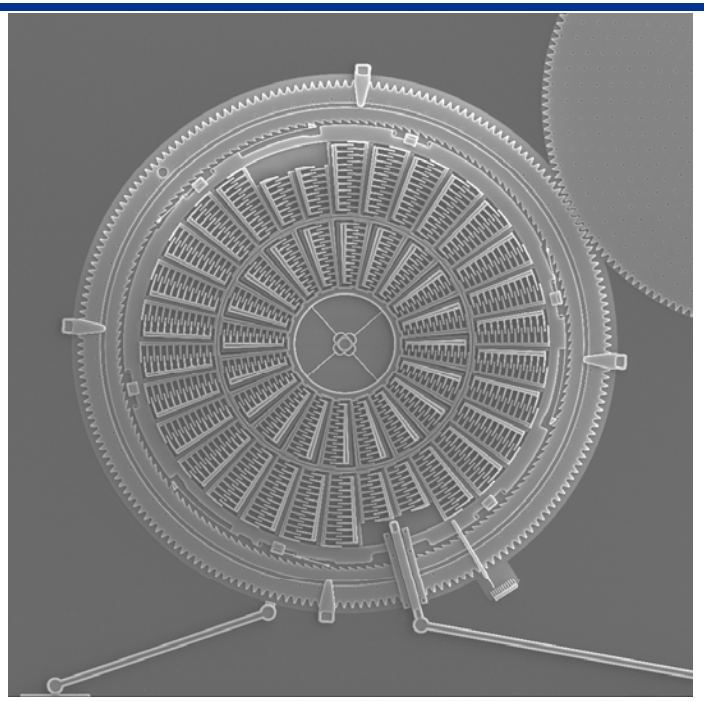


Sandia National Laboratories

MEMS Design

Why do we need specialized MEMS Design Tools?





2-D mask layers

+

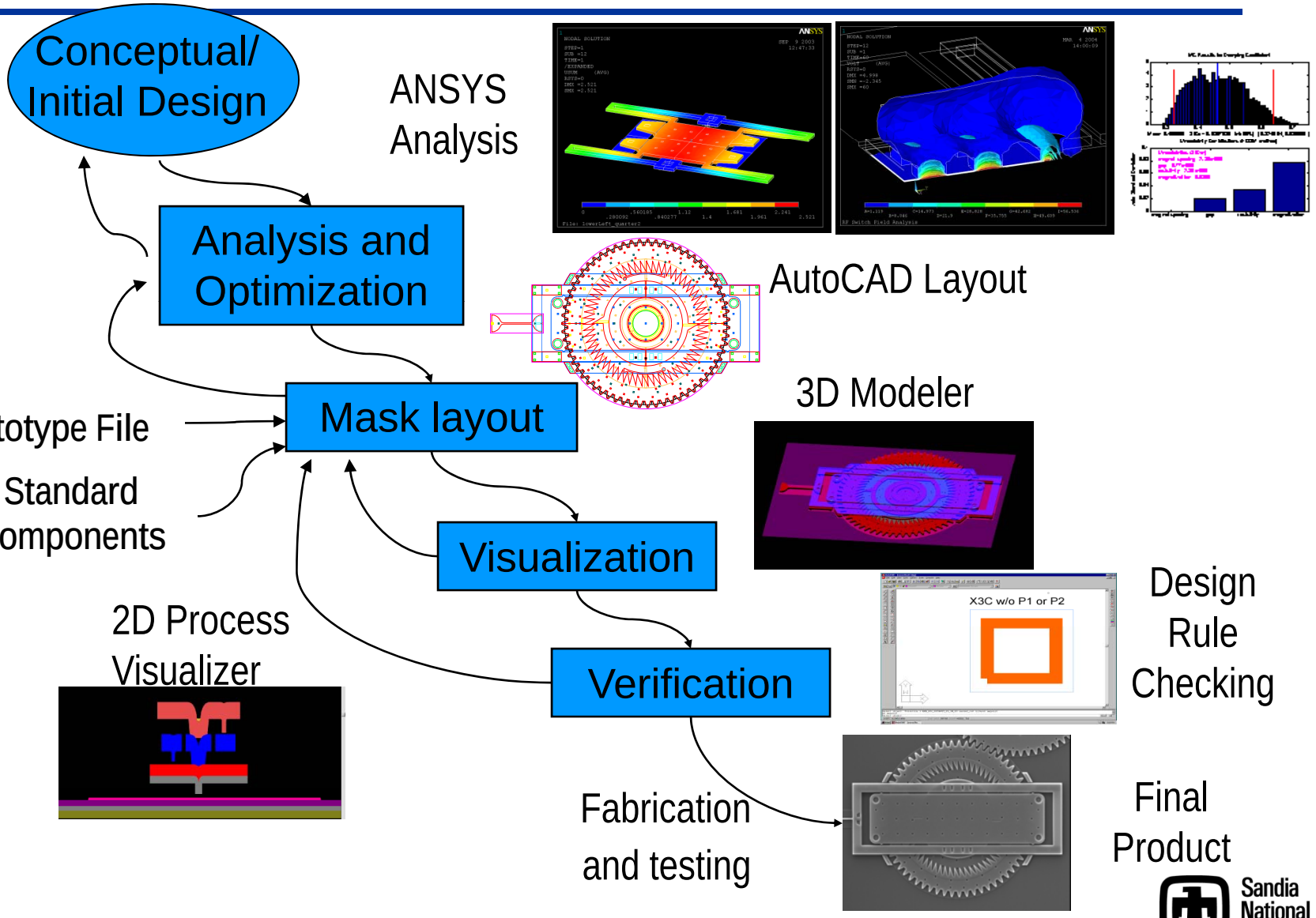
Fabrication process

difficult-to-visualize

systems with complex shapes

Sandia National Laboratories

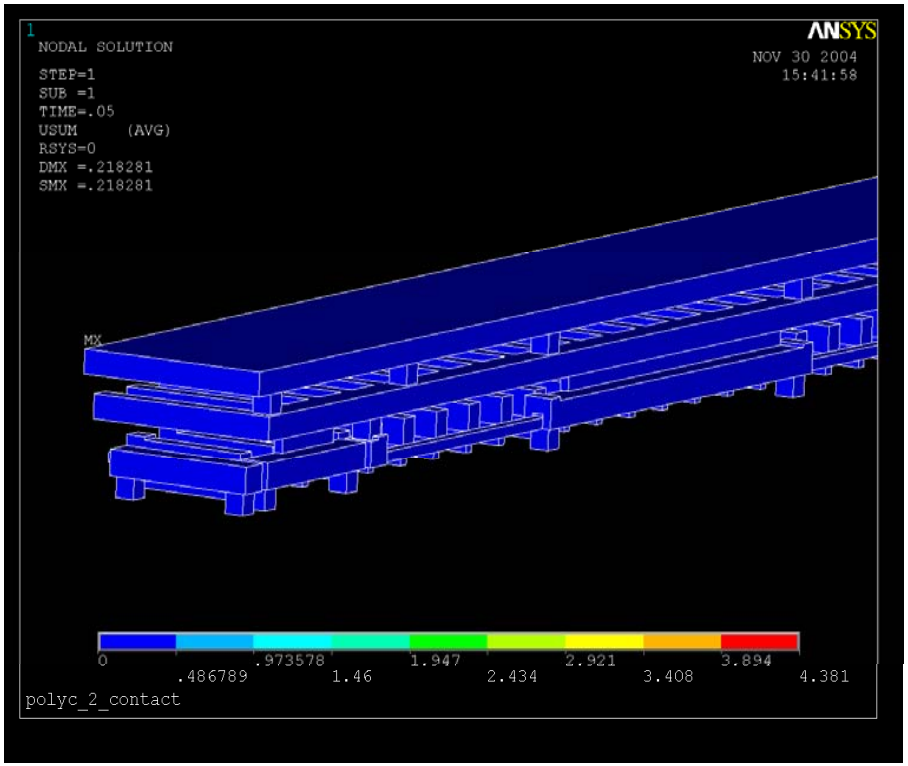
MEMS Design Process Flow



Sandia National Laboratories

MEMS Analysis
Current Capabilities

- System Level simulation (Spice)
- Optimization (Matlab)
- Design synthesis (Sugar)
- Electrostatics (Ansys)
- Rigid Body Dynamics (Ansys)
- Thermal (Ansys)
- Structural (Ansys)
- Coupled Structural Electrostatics (Ansys)
- Coupled Structural Thermal Electrical (Ansys)
- Squeeze film damping (Ansys)
- Fluid Dynamics (CFDRC, Ansys CFX)
- Magnetostatics (CFDRC)



Sandia National Laboratories

MEMS Design Tools Summary For AutoCAD

Design Rule Checker

Text Generator

Gear Generator

Trace Generator

Design Difference Tool

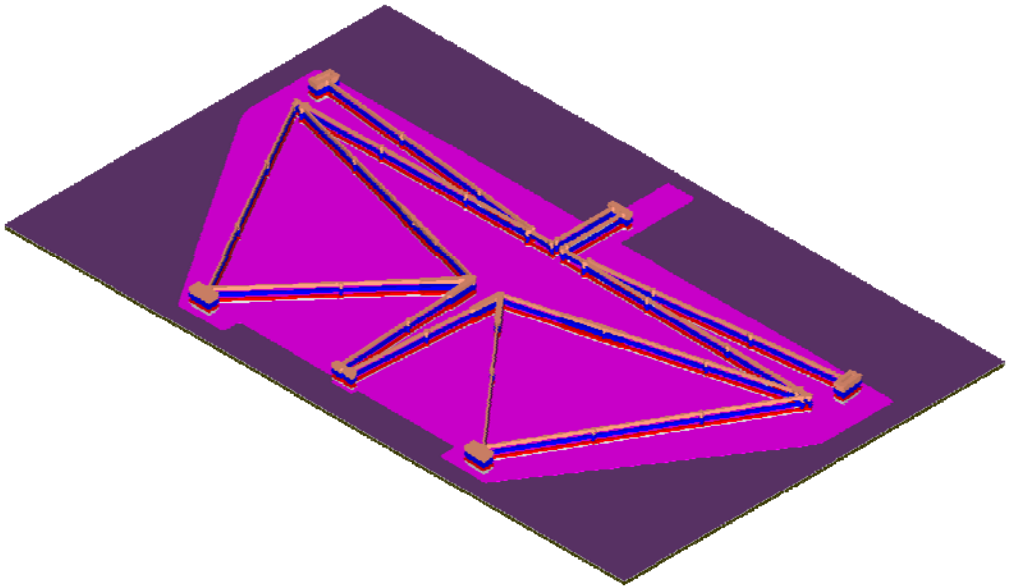
Safe Explode Utility

Online Documentation

2D Process Visualizer

3D Visualizer

3D Modeler



Layer Controls:

Isolate layer

Set layer

Freeze layer

Thaw layer

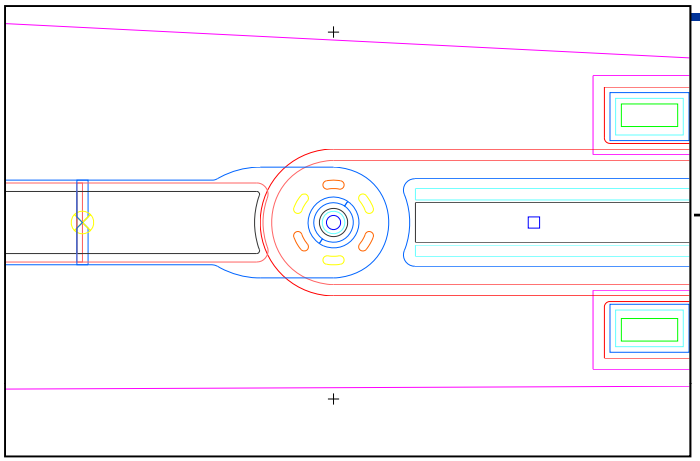
Create abutted “C” from two circles

Create abutted “C” from two circles

Join Polygons

Sandia National Laboratories

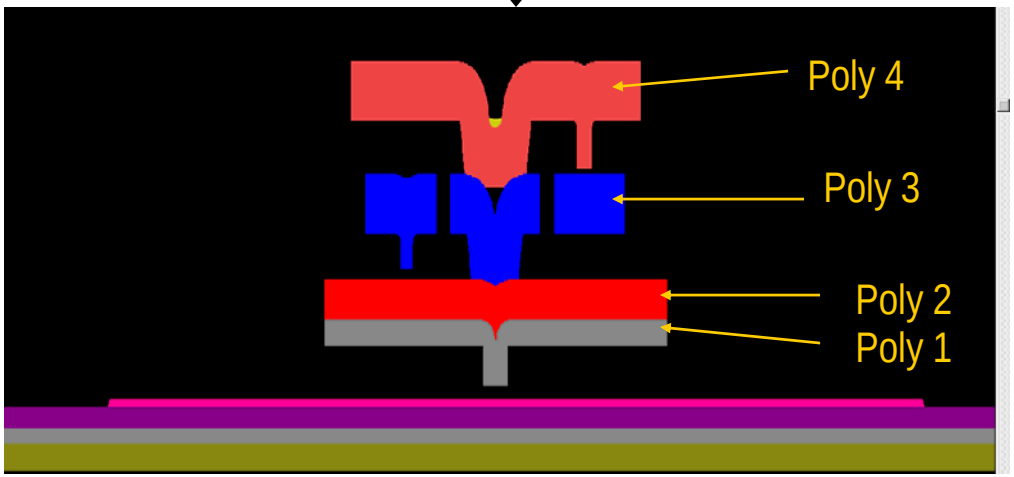
2D Process Visualizer



AutoCAD
2D Mask
geometry

SUMMiT V Process
definition file

2D Process
Visualizer

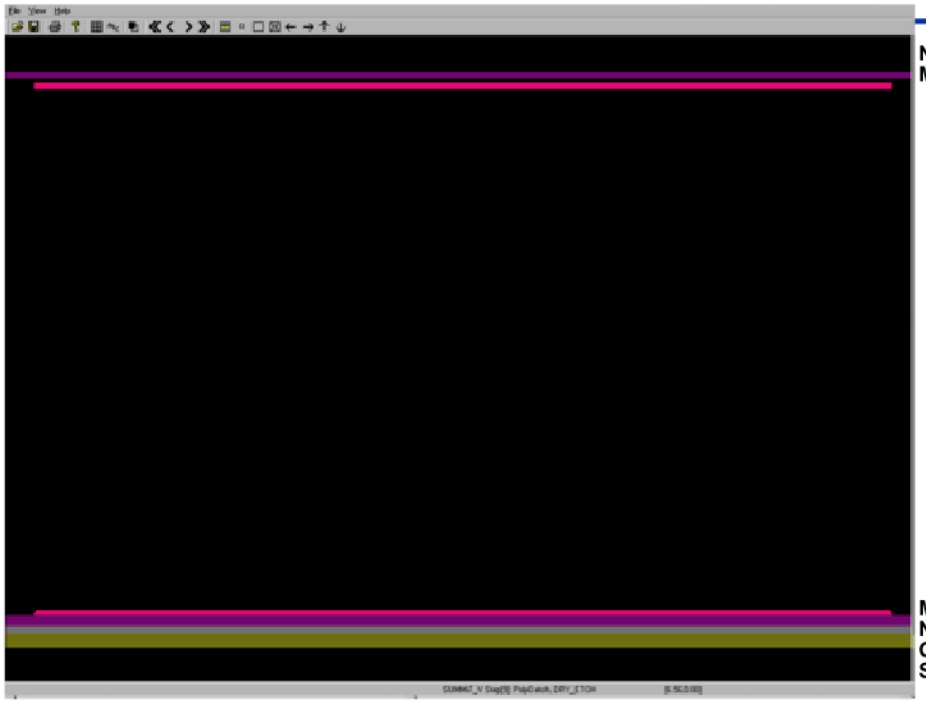


Automatically creates cross-section of AutoCAD MEMS device layout based upon process steps and mask geometry.

Sandia National Laboratories

2D Process Visualizer
Example - Flex Link Pivot

2D Process Visualizer
Example - Flex Link Pivot

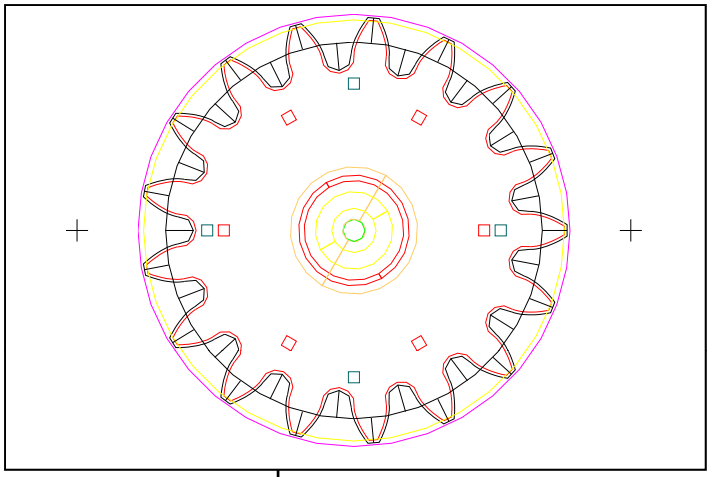


Intro to Tools
Page
© 2007 Sandia National Laboratories

Sandia National Laboratories

Sandia National Laboratories

MEMS 3D Model Generation



AutoCAD
2D Mask
Geometry

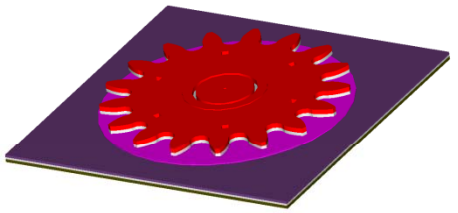
ACIS
SAT
File

SUMMiT V Process
Definition File

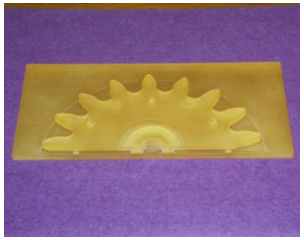
3D Geometry
Modeler

Automatically creates 3D Model of AutoCAD MEMS device layout based upon process steps and mask geometry.

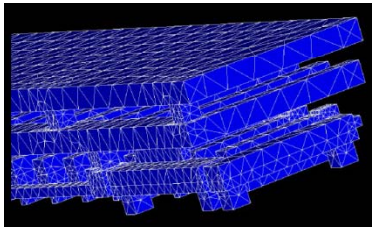
3D Visualization
(in AutoCAD)



Stereo
Lithography
Prototype



ANSYS
Analysis



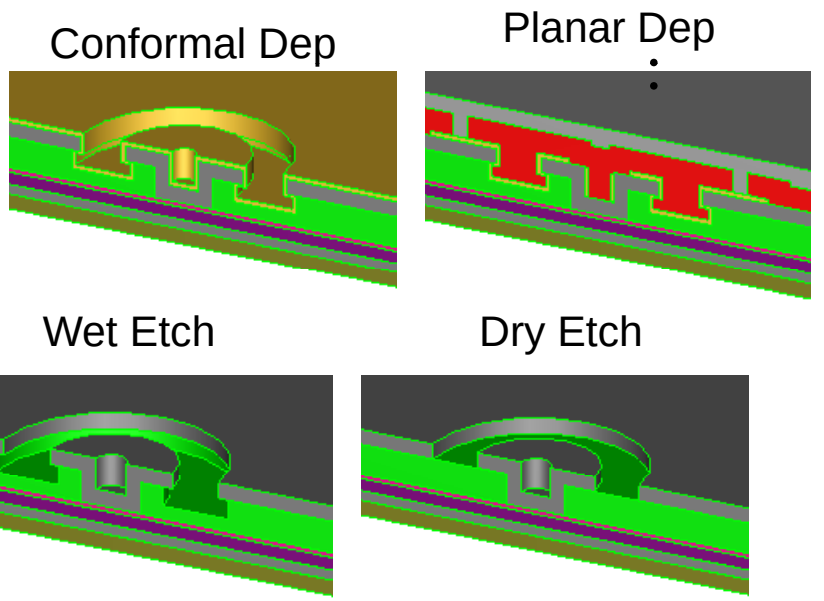
CFDRC
Analysis

Sandia National Laboratories

MEMS 3D Modeler

Basics

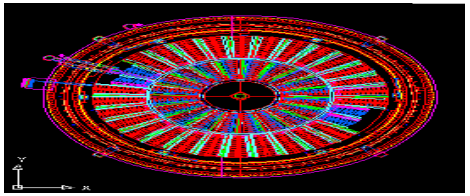
- Process based geometric modeler
- Generates 3D solid by simulating each process step using a mask set
- Current process steps:
  - conformal deposition
  - planar deposition
  - wet etch
  - dry etch
  - release etch
- Model contains proces artifacts (trapped oxide)

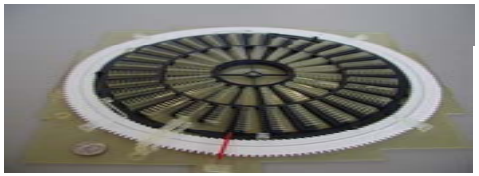


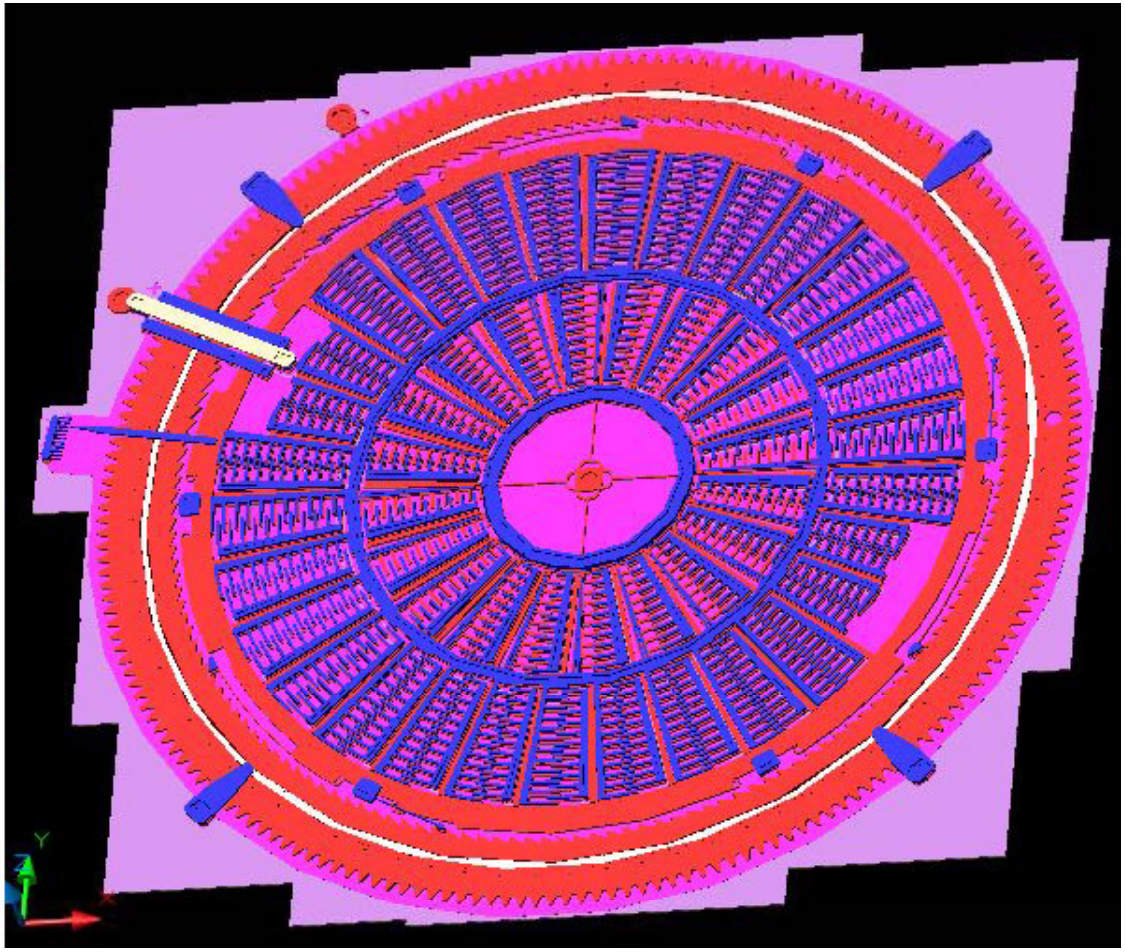
Sandia National Laboratories

MEMS 3D Modeler

Torsional Ratcheting Actuator



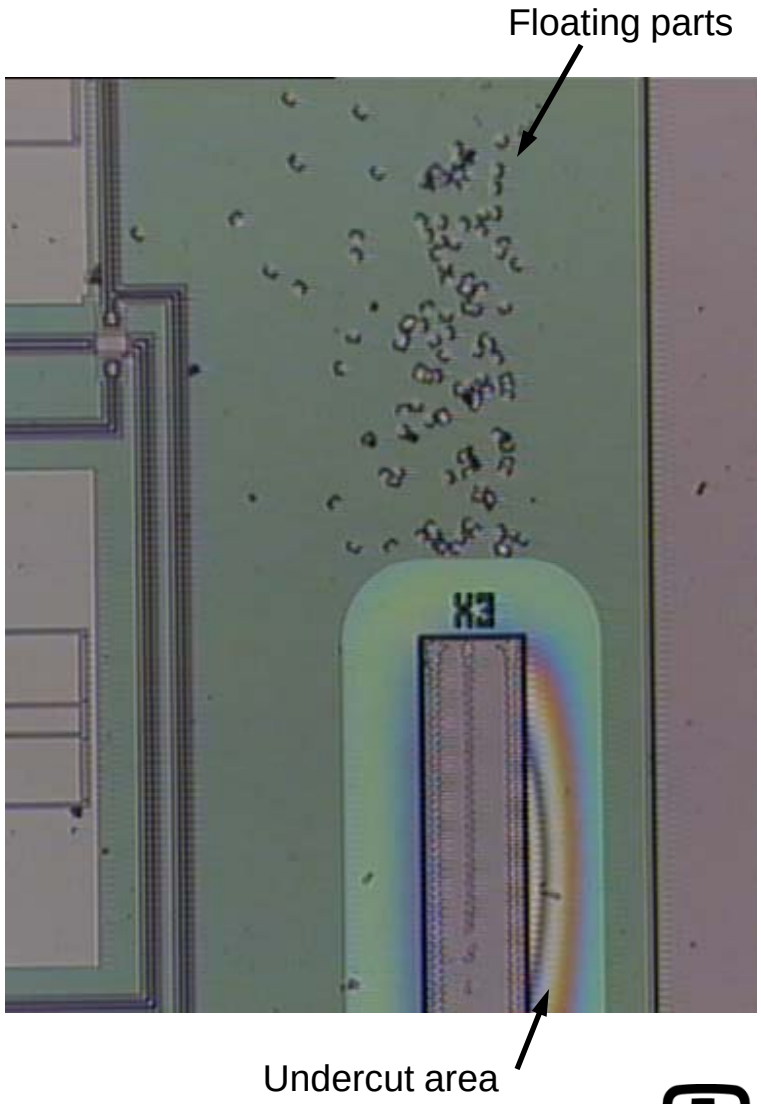




Sandia National Laboratories

MEMS Design Rule Checking

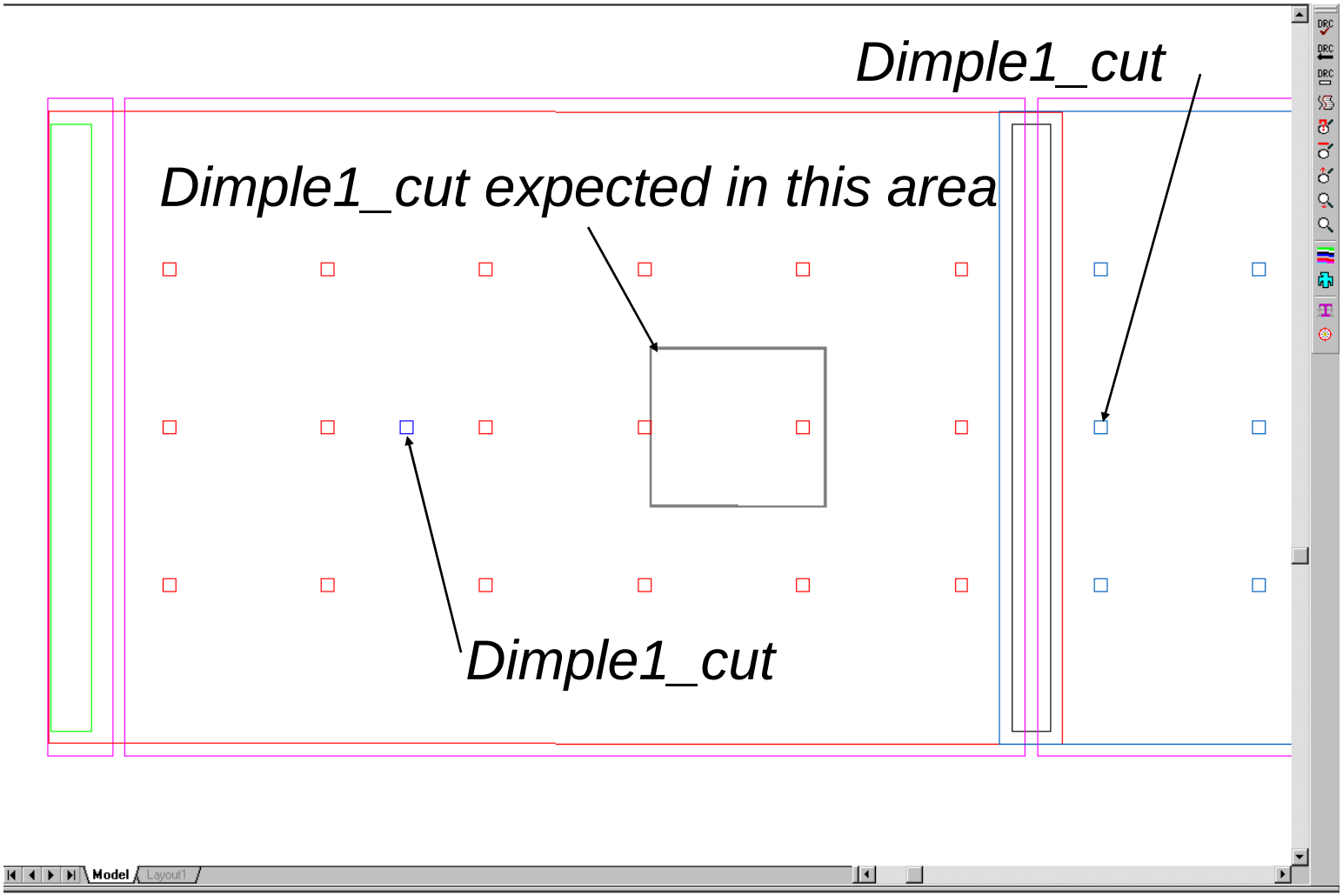
- **Helps to ensure *first pass* design success**
- **Verifies that the design can be fabricated**
- **Avoids parts floating away/onto other micromachines**



Sandia National Laboratories

MEMS DRC - Typical DRC Error report

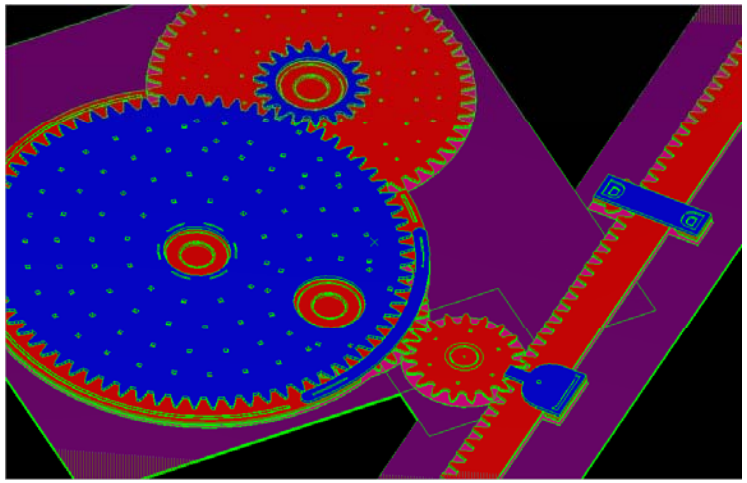
Advisory: Dimple1_cut space > 75



Sandia National Laboratories

Standard Component Library

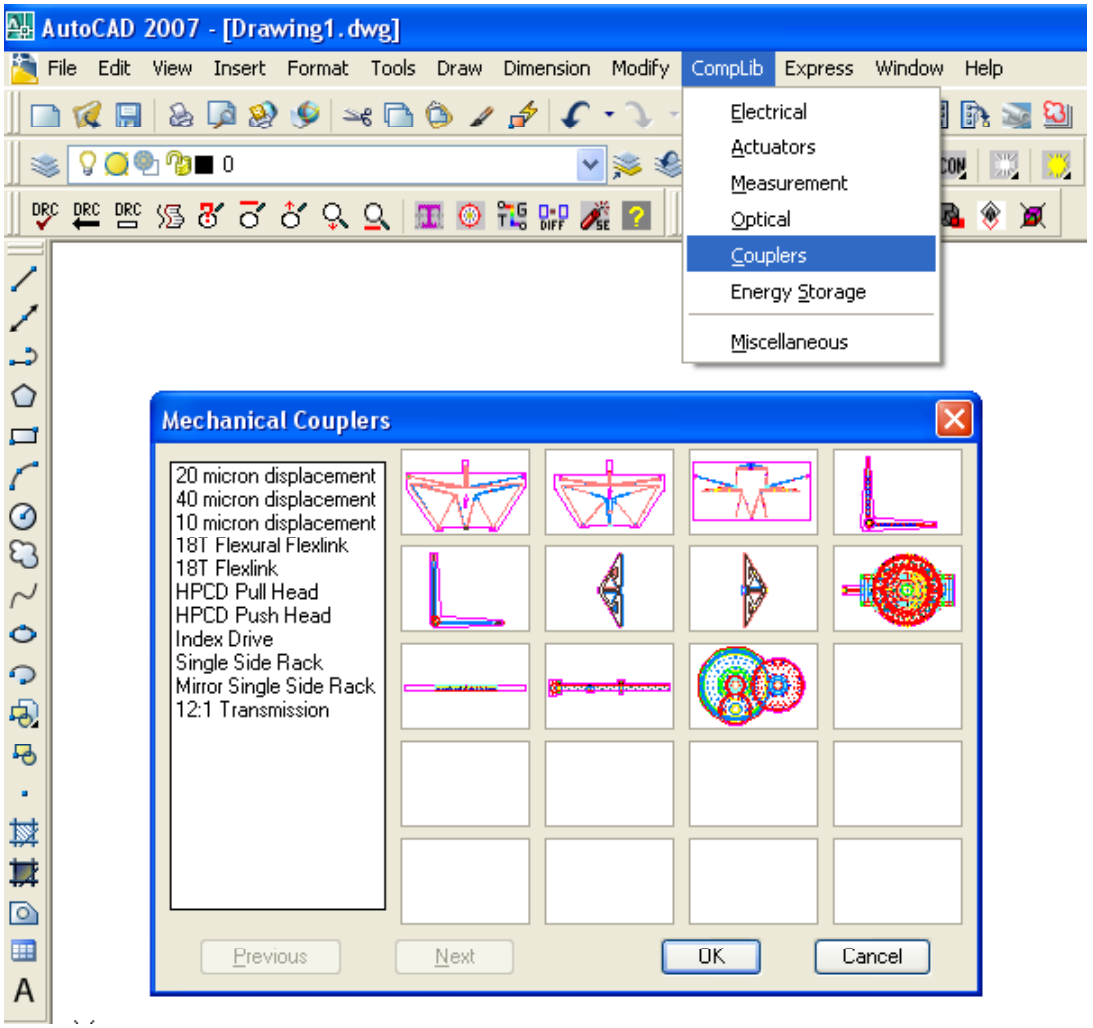
- **Components available for direct insertion into AutoCAD designs**
  - **build working devices from standard components**
  - **designed to work together**
- **Standard Component Library based on functional structure**
  - **Electrical**
  - **Actuators**
  - **Optical**
  - **Couplers**
  - **Energy storage**
  - **Misc: Gear clips, spring stops, tooth clamps**



Sandia National Laboratories

Standard Component Library

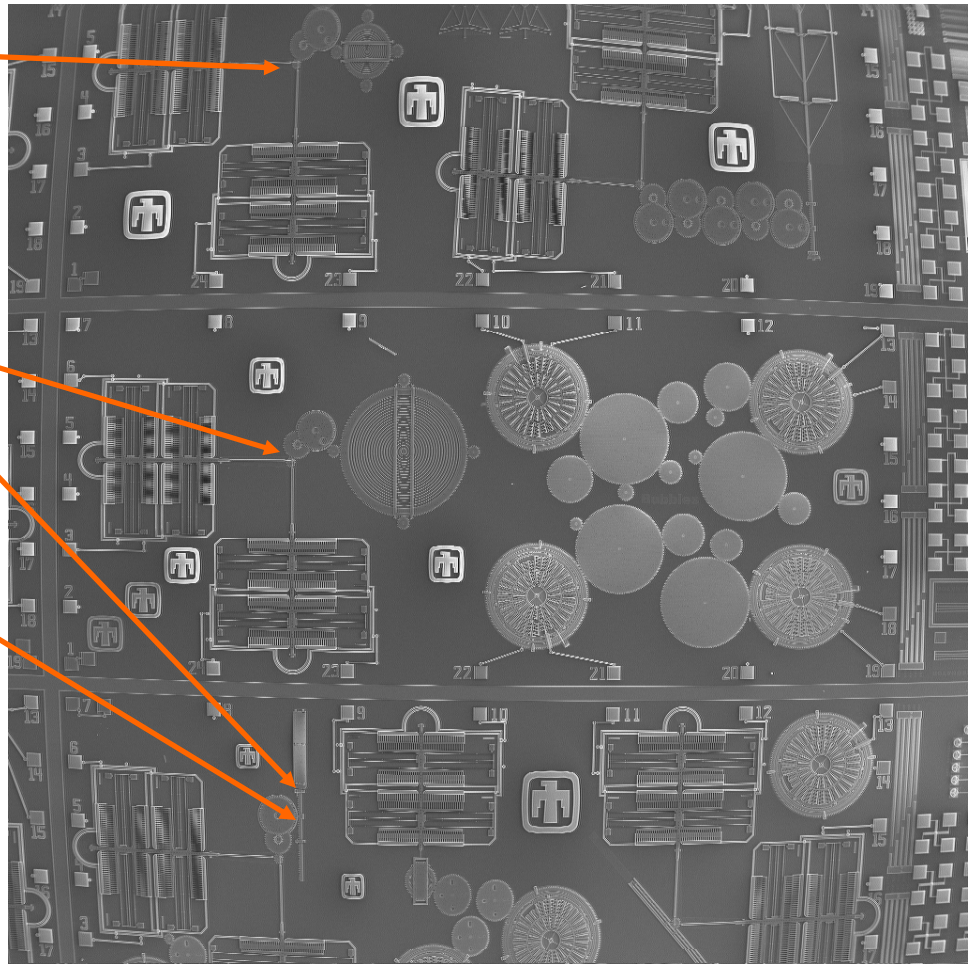
- **Available from AutoCAD using the CompLib pull-down menu.**
- **Makes pre-designed SUMMiT V™ Process components easy to access.**
- **Components are listed by function.**
- **Choose either the part name or the picture.**



Sandia National Laboratories

Building Complex Devices Using Library Components

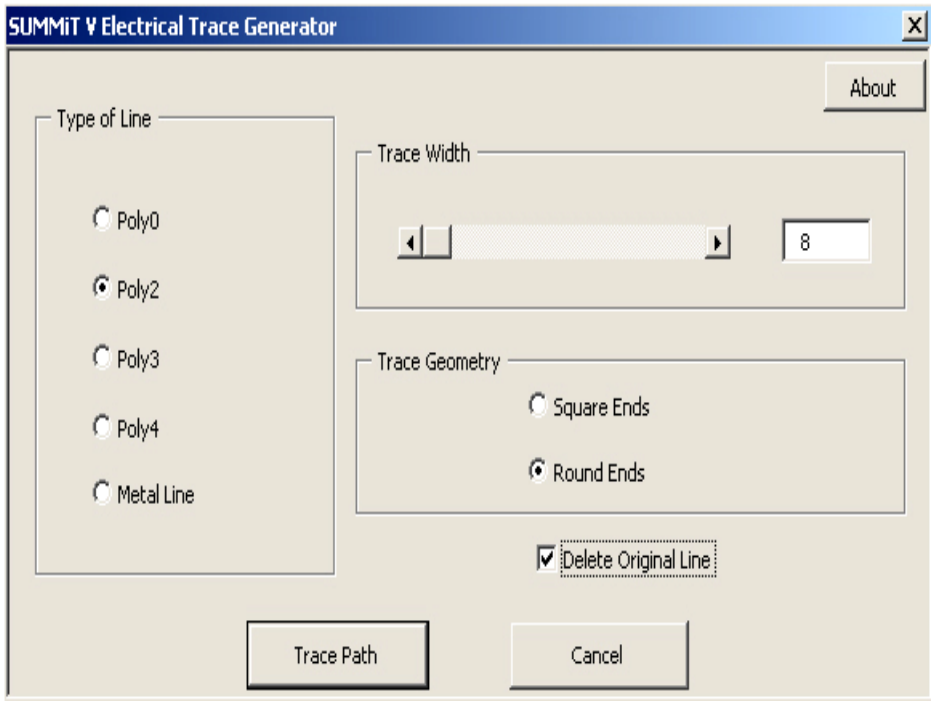
- **Electrostatic comb drives coupled to pinion gear**
- **Pinion gear coupled to multi-level gear transmission**
- **Rack gear coupled to hinged mirror**
- **Transmission coupled to rack gear**

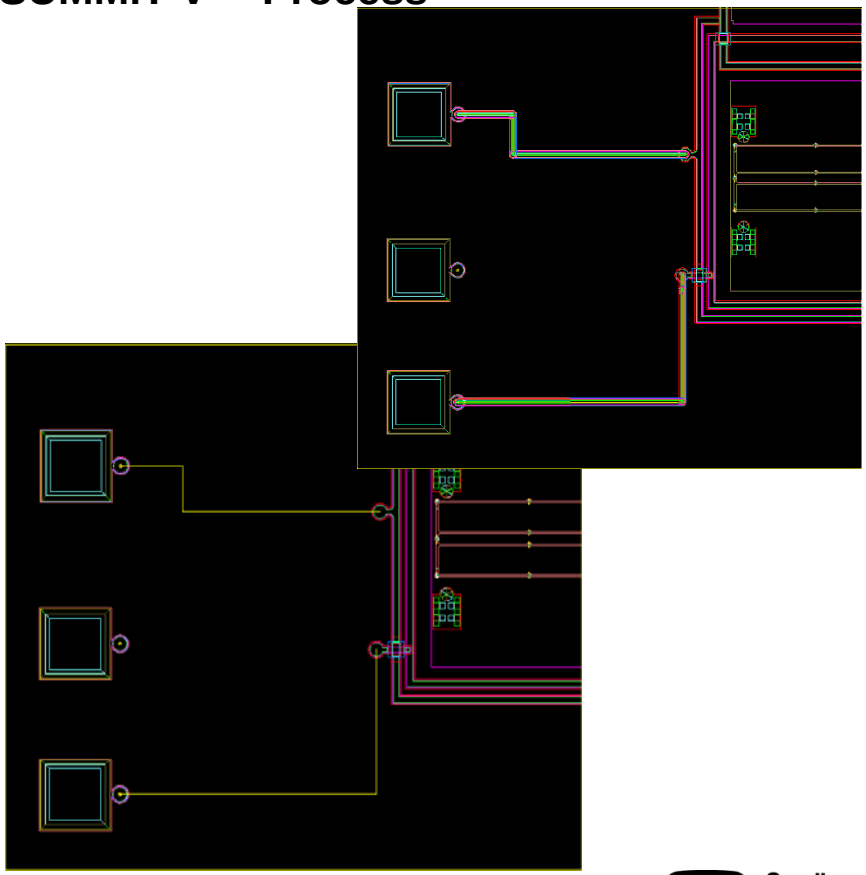


Sandia National Laboratories

Trace Generator

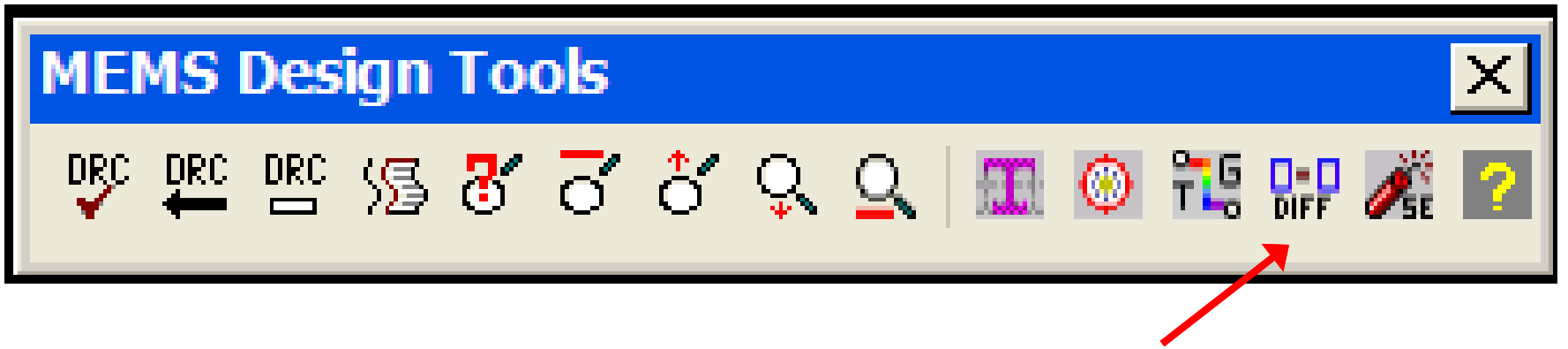
- **Creates multilayer electrical traces build according to SUMMiT V™ design rules.**
- **Uses a polyline drawn on construction layer**
- **Trace settings shown below are typical for SUMMiT V™ Process**

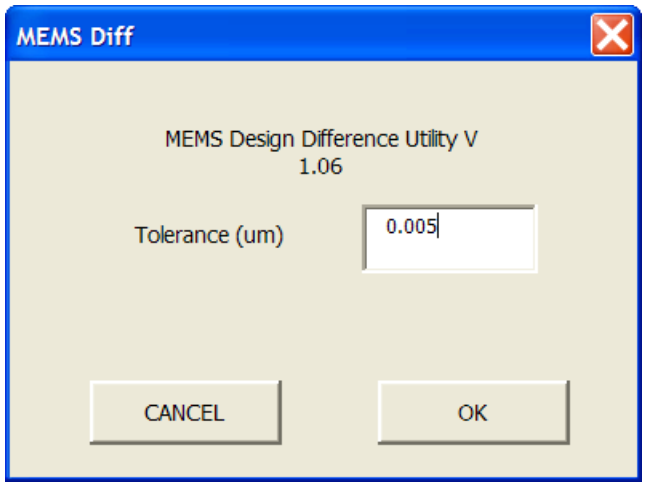




Sandia National Laboratories

MEMS Difference Utility





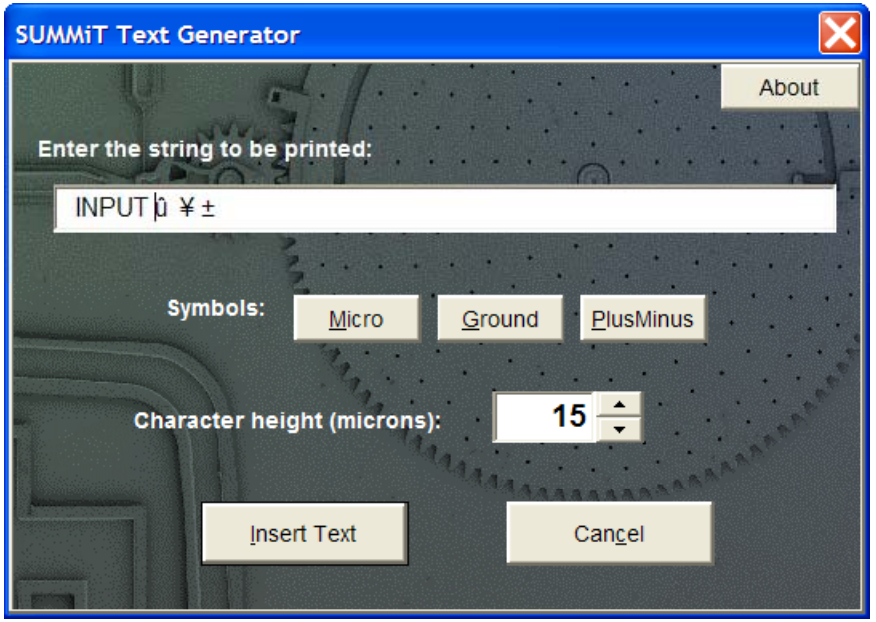
- Graphically shows the difference between two design files.
- Differences are overlaid onto the design using the DRC interface.

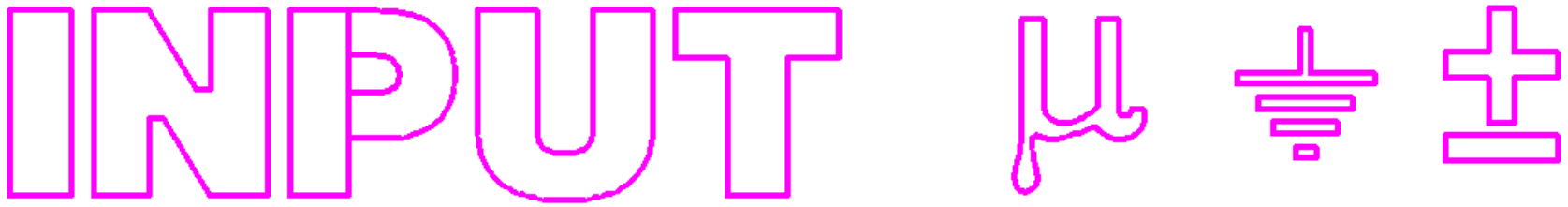
Sandia National Laboratories

Text Generator

Creates:

- Text
- Special Characters
- Symbols

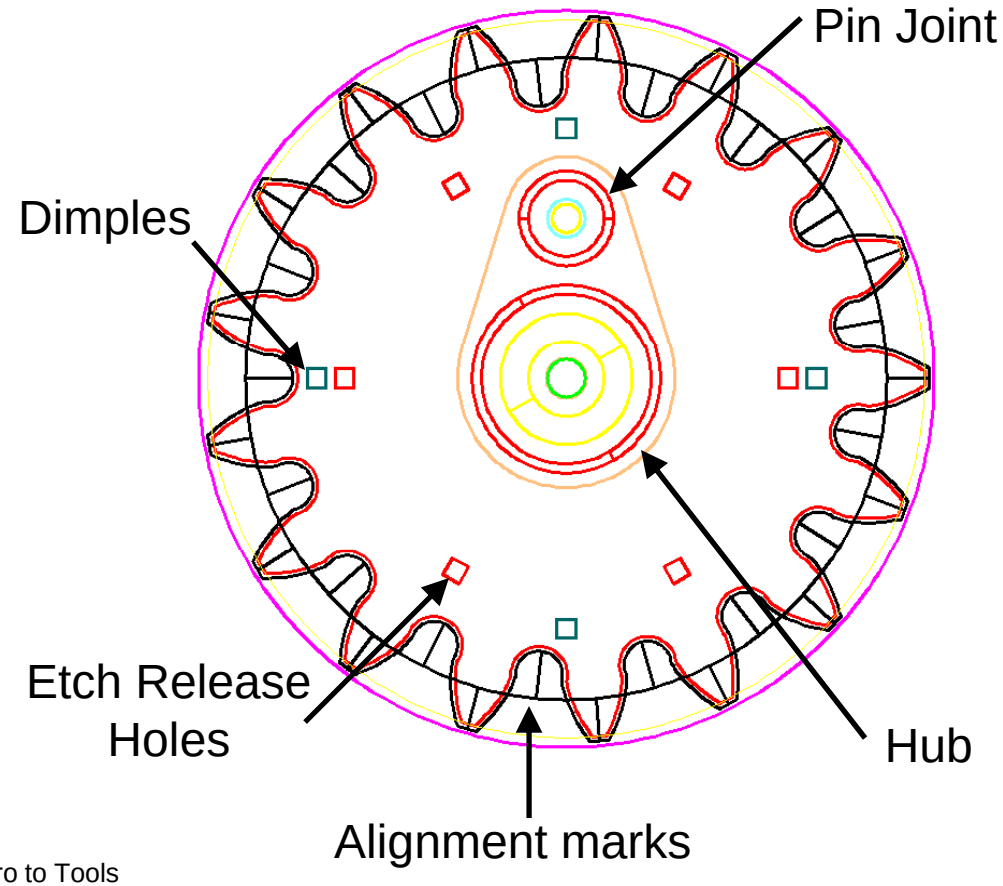


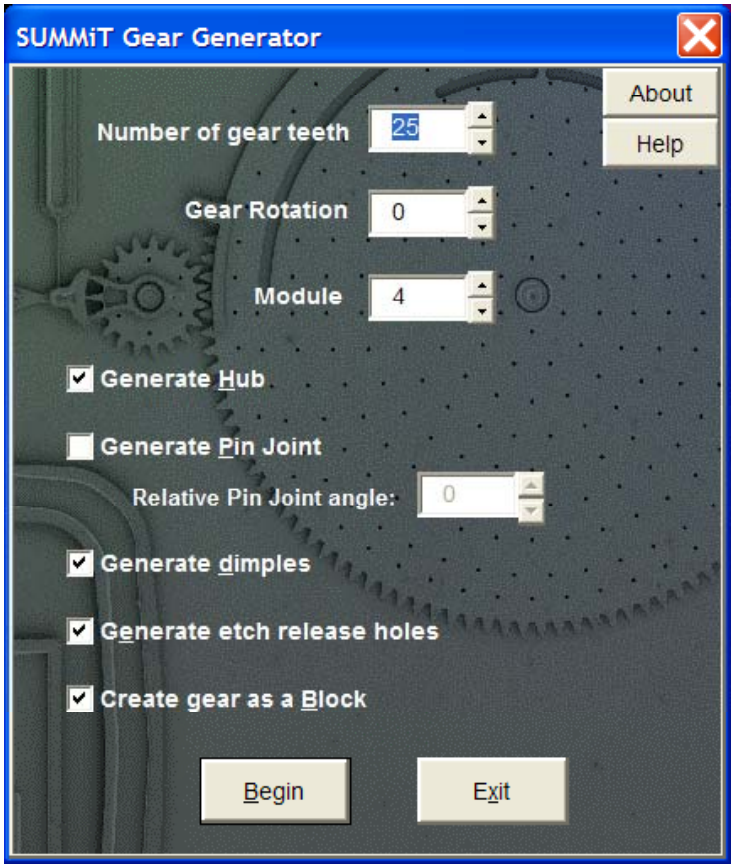


Sandia National Laboratories

SUMMiT™ Gear Generator

- **Automatically create gears by specifying features:**





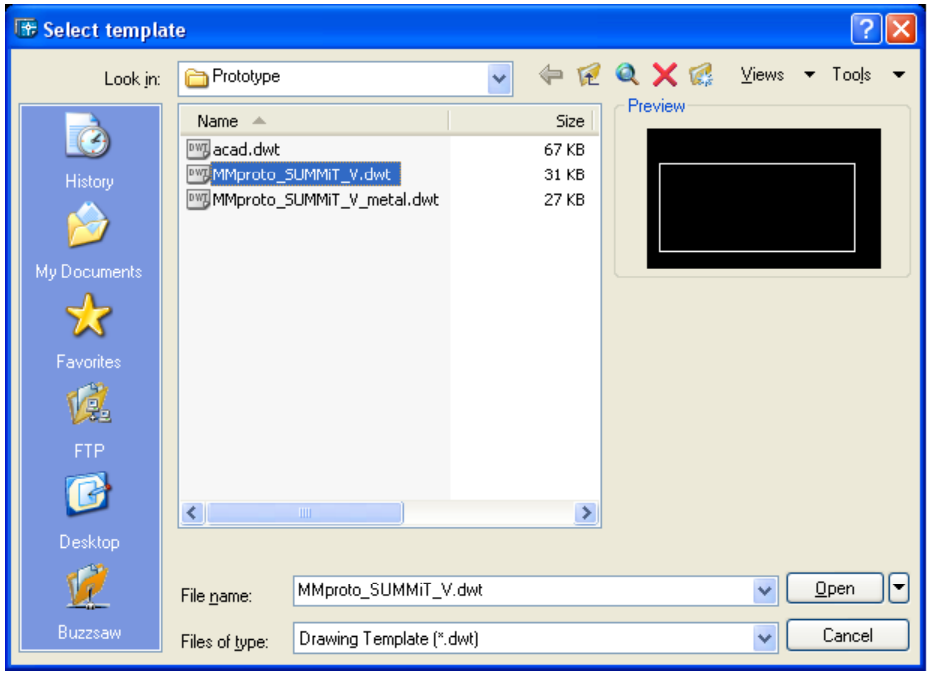
Sandia National Laboratories

Getting Started in AutoCAD

- **File/New**
- **Choose 'Mmproto_summit_v.dwt' for the drawing template**

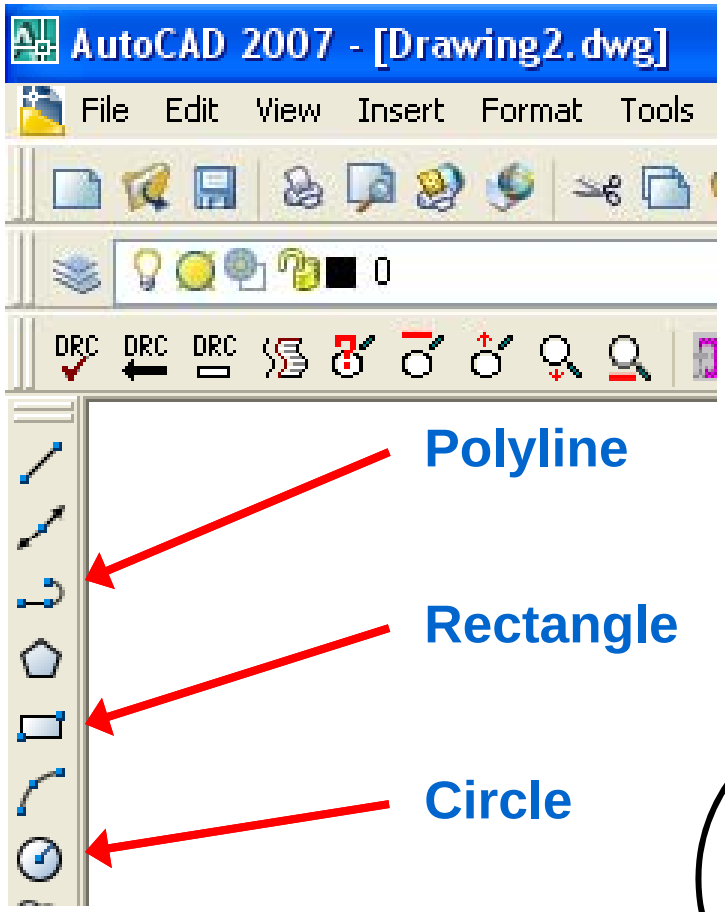
- **AutoCAD additions**
  - **DRC Toolbar**
  - **Visualization Toolbar**
  - **3D Modeler Toolbar**
  - **Standard Components Library**
  - **Module boundary**

    (6340 x 2820)

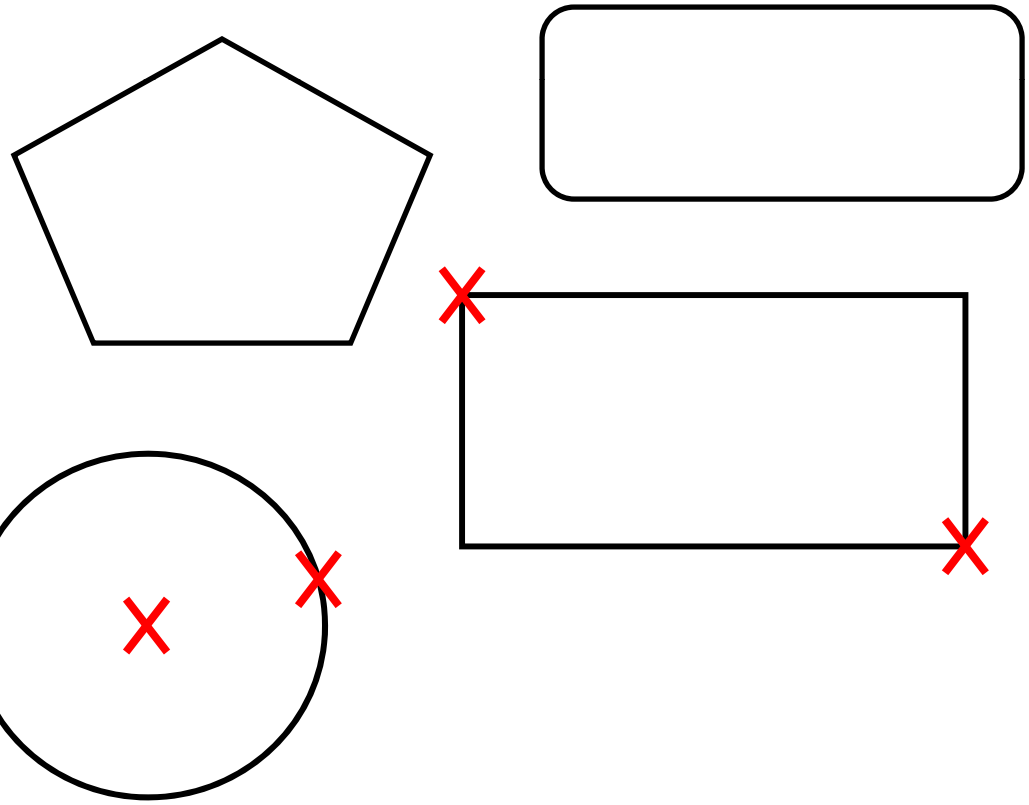


Sandia National Laboratories

Basic Creation Commands

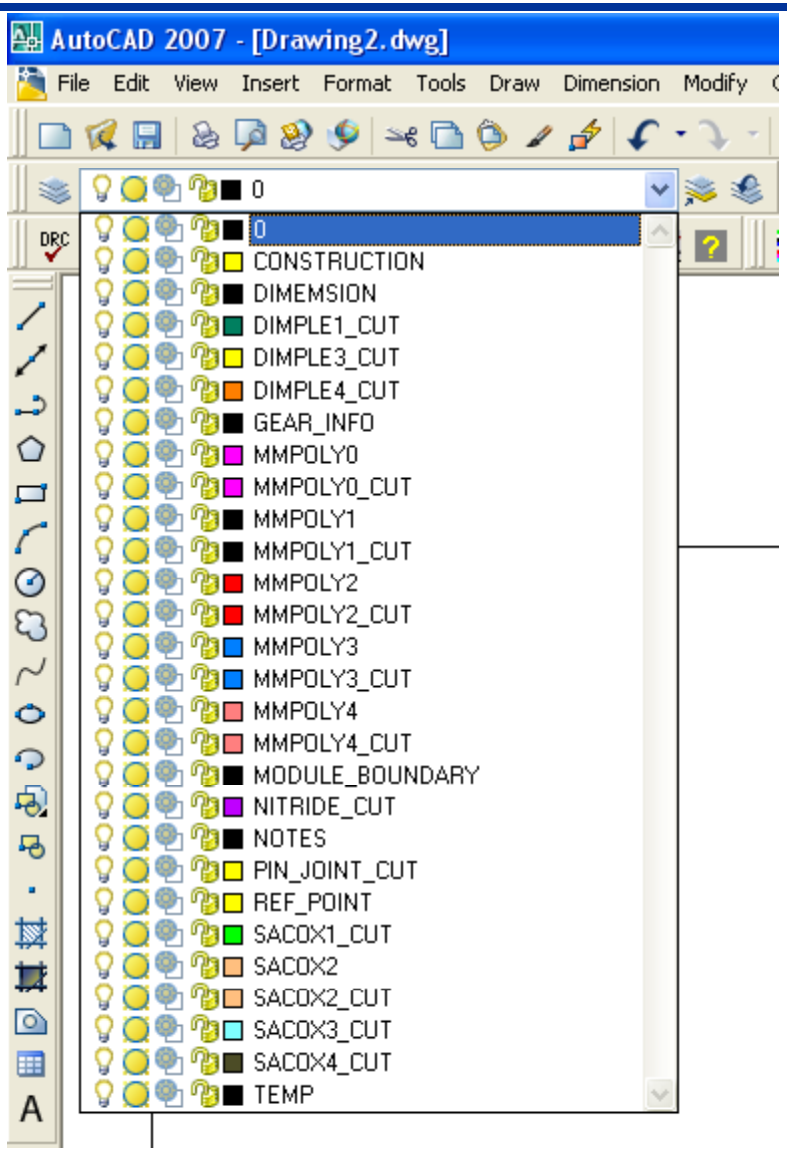


Masks require closed polygons.
Polylines may have arc fillets.



Sandia National Laboratories

Masks & AutoCAD Layers

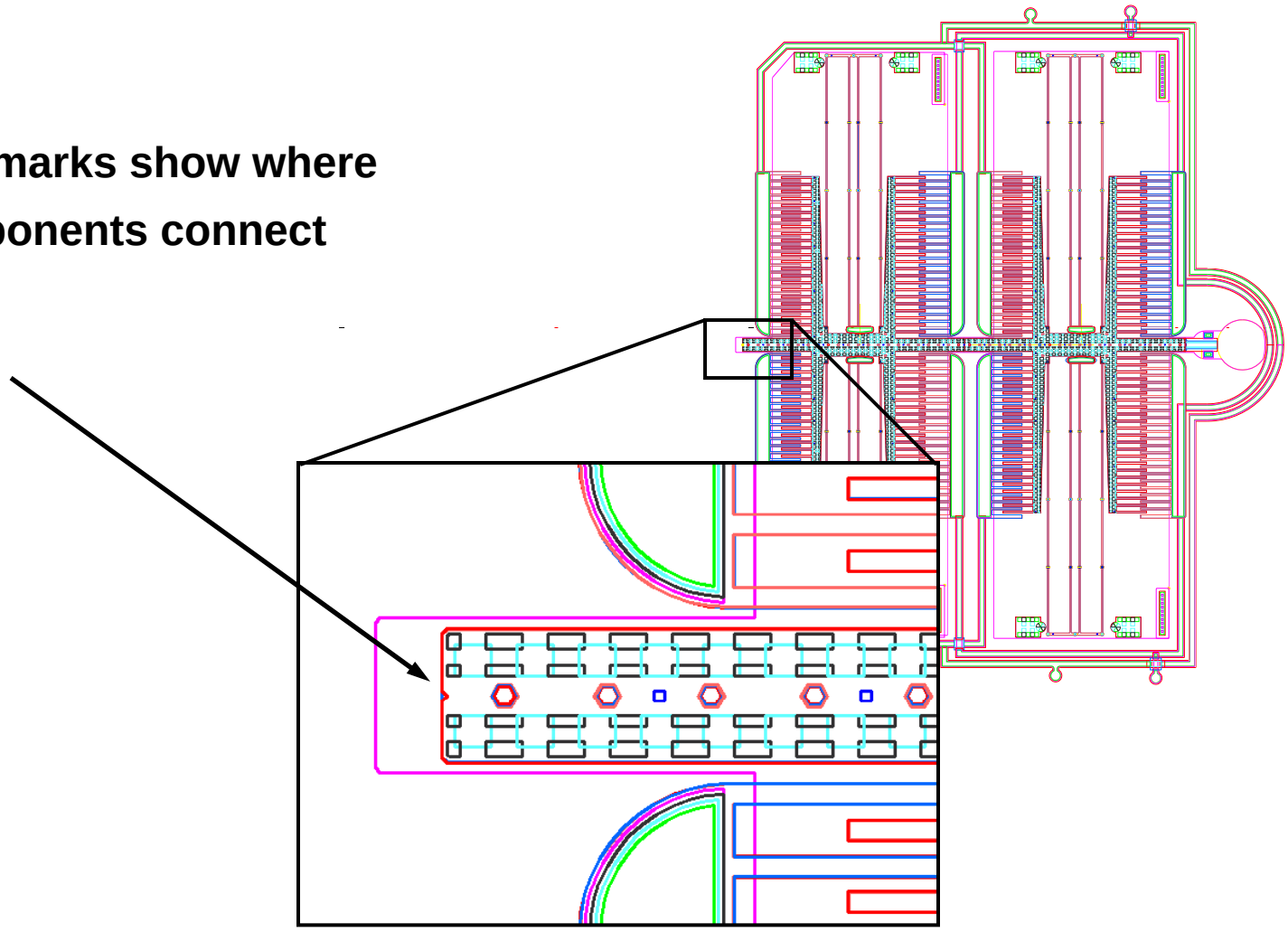


- **Mask layers and AutoCAD layers are *not* the same**
- **Drop down list shows all layers in the drawing**
- **Scroll to view complete list**

Sandia National Laboratories

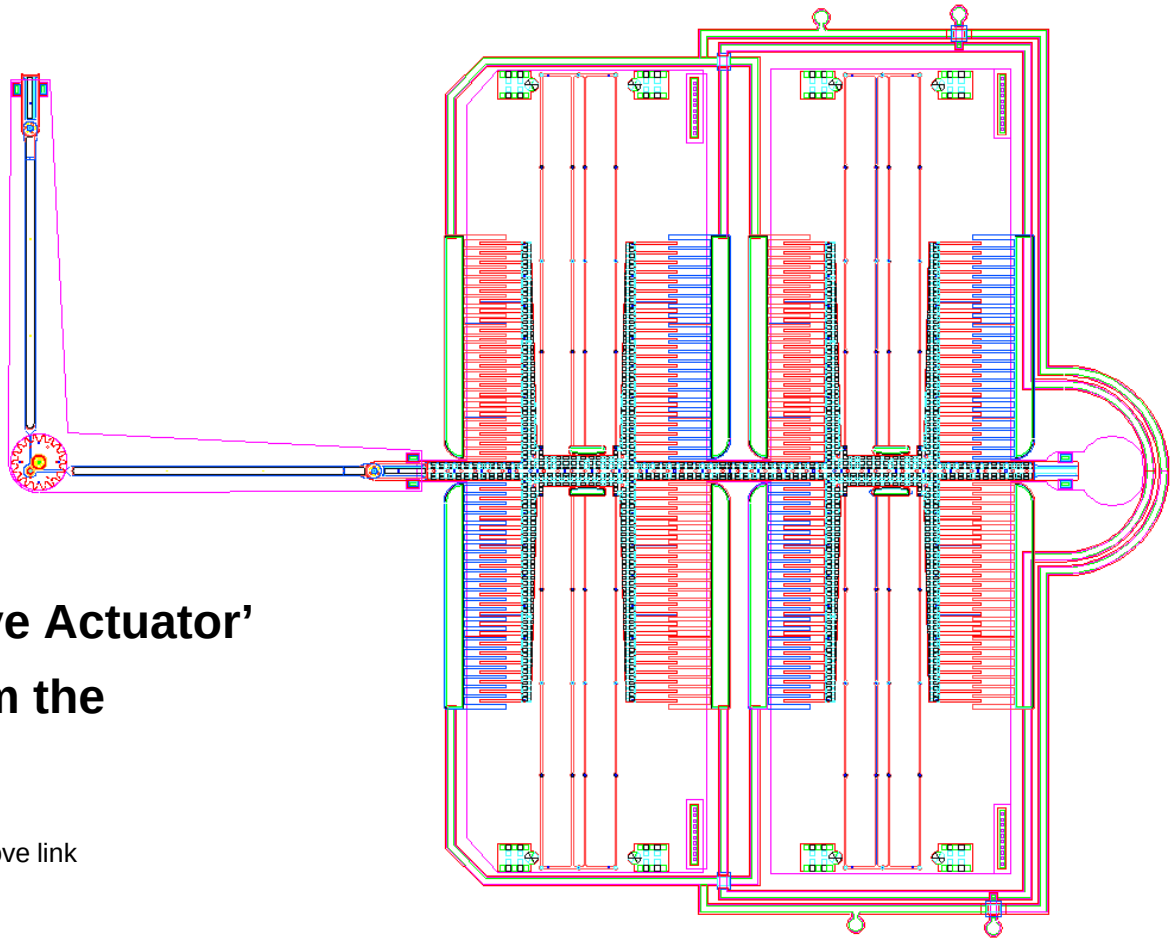
Alignment Marks

- **Alignment marks show where some components connect**



Sandia National Laboratories

AutoCAD Example 1



- **Connect ‘Symmetric Drive Actuator’ with an ‘18T flexlink’ from the CompLib**

Note: you must have AutoCAD 2008 to view above link

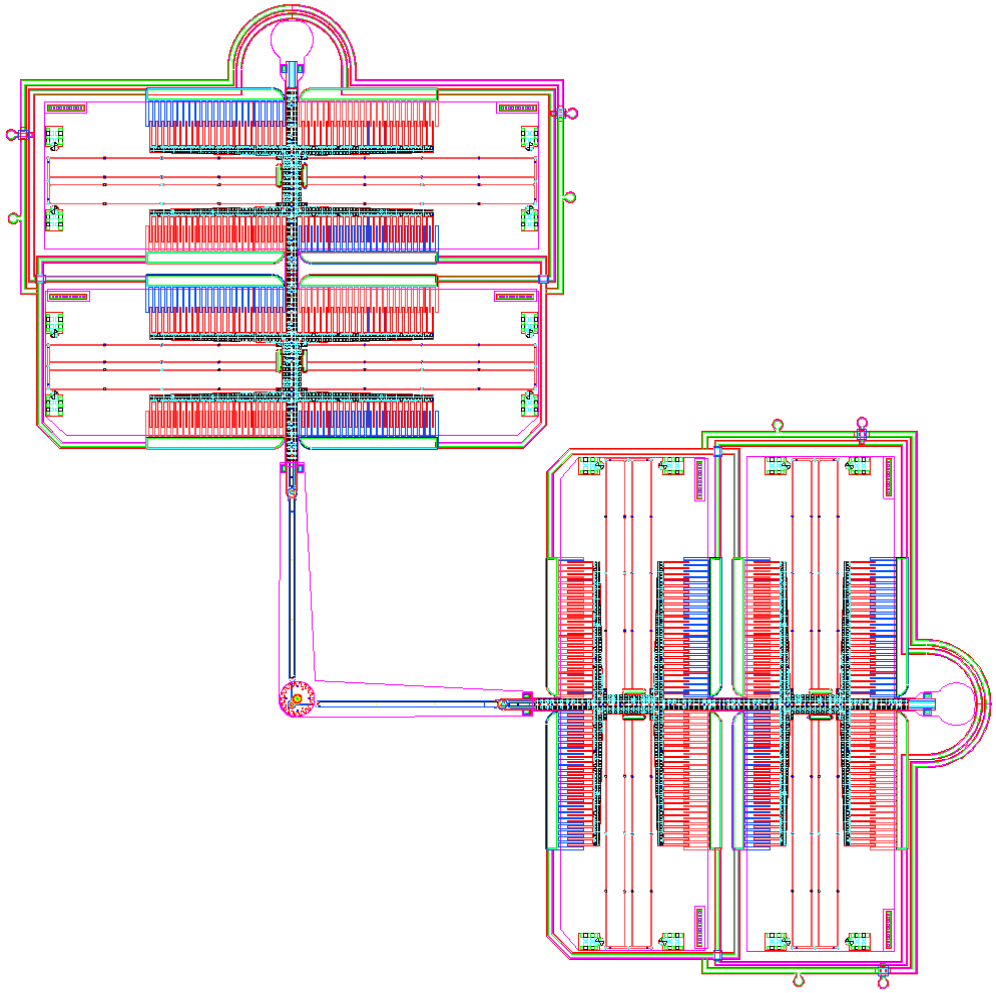
Sandia National Laboratories

AutoCAD Example 2

- **Complete the microengine by adding another comb drive**

  Note: you must have AutoCAD 2008 to view link.

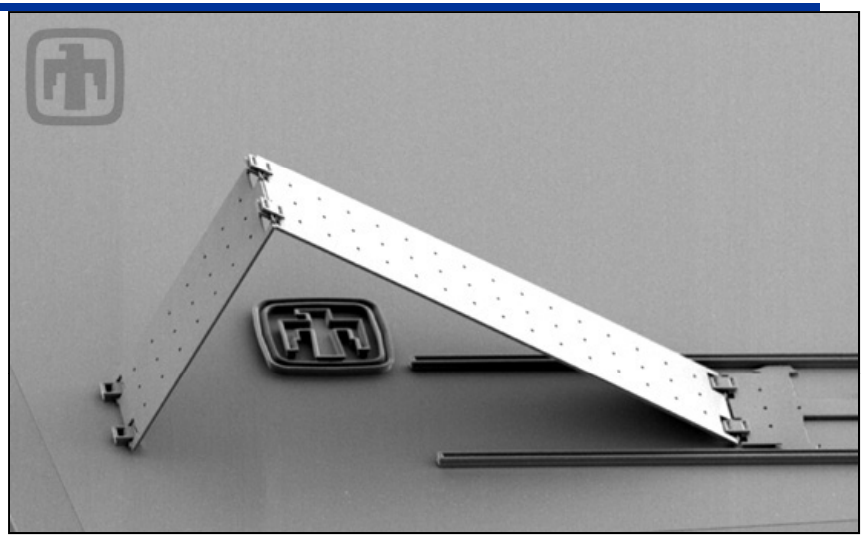
- **When inserting, specify a rotation angle of 90 degrees**

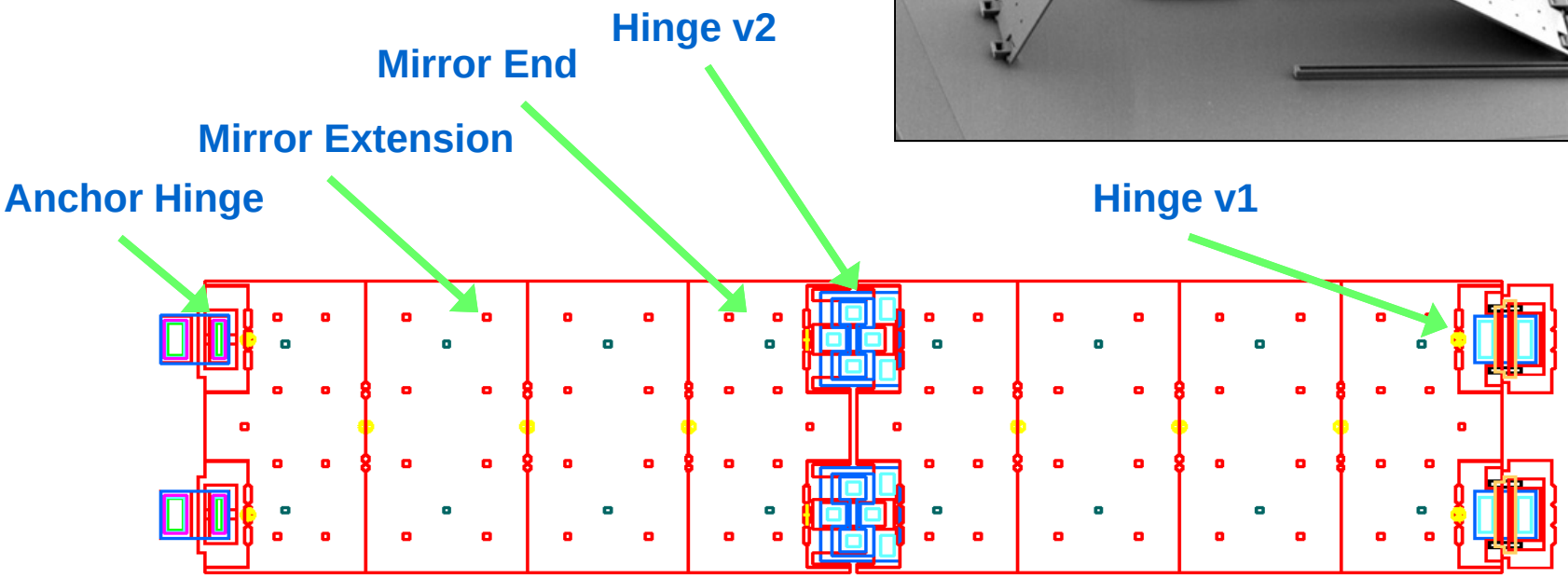


Sandia National Laboratories

Example 3: Pop-up Mirror

- **Use CompLib to create and drive a mirror**



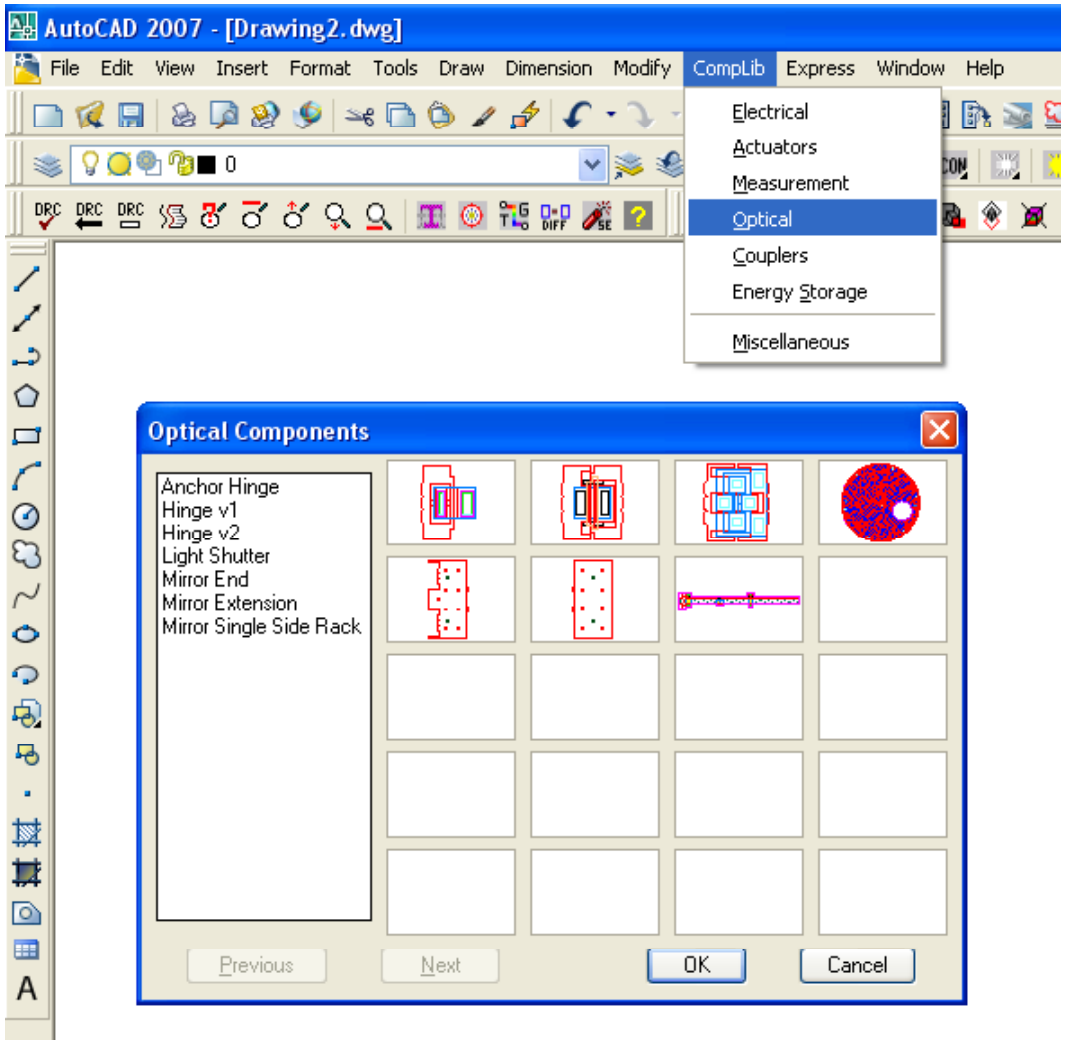


Sandia National Laboratories

Mirror Components

- **All the mirror components are in:**

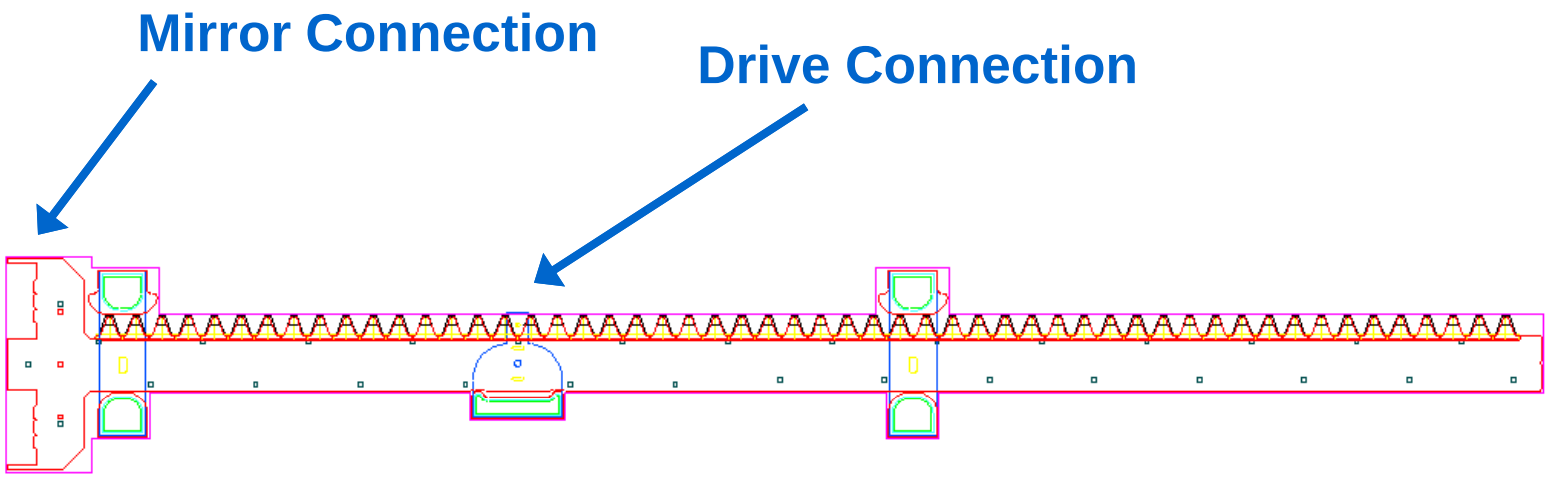
  Complib > Optical



Sandia National Laboratories

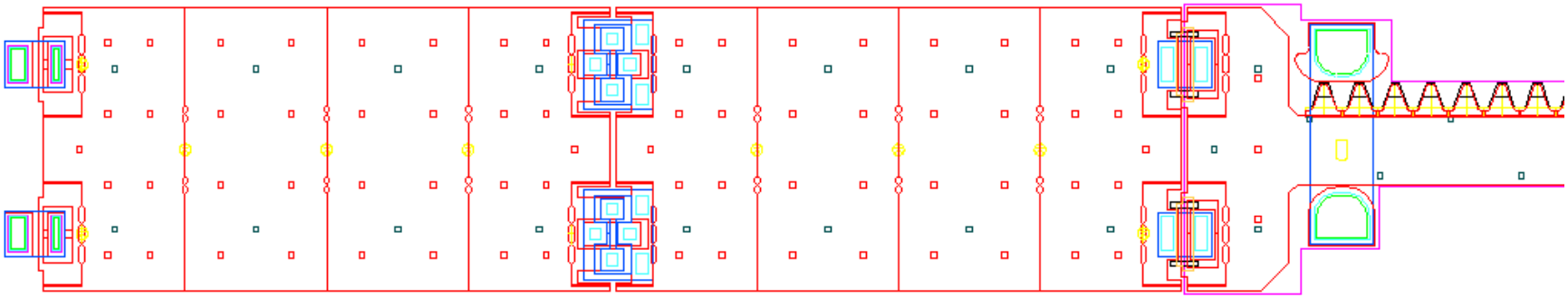
Mirror Single Side Rack

- **Once the mirror is completed, add a Mirror Single Side Race (linear) rack to drive it up.**



Sandia National Laboratories

Connected Mirror and Rack



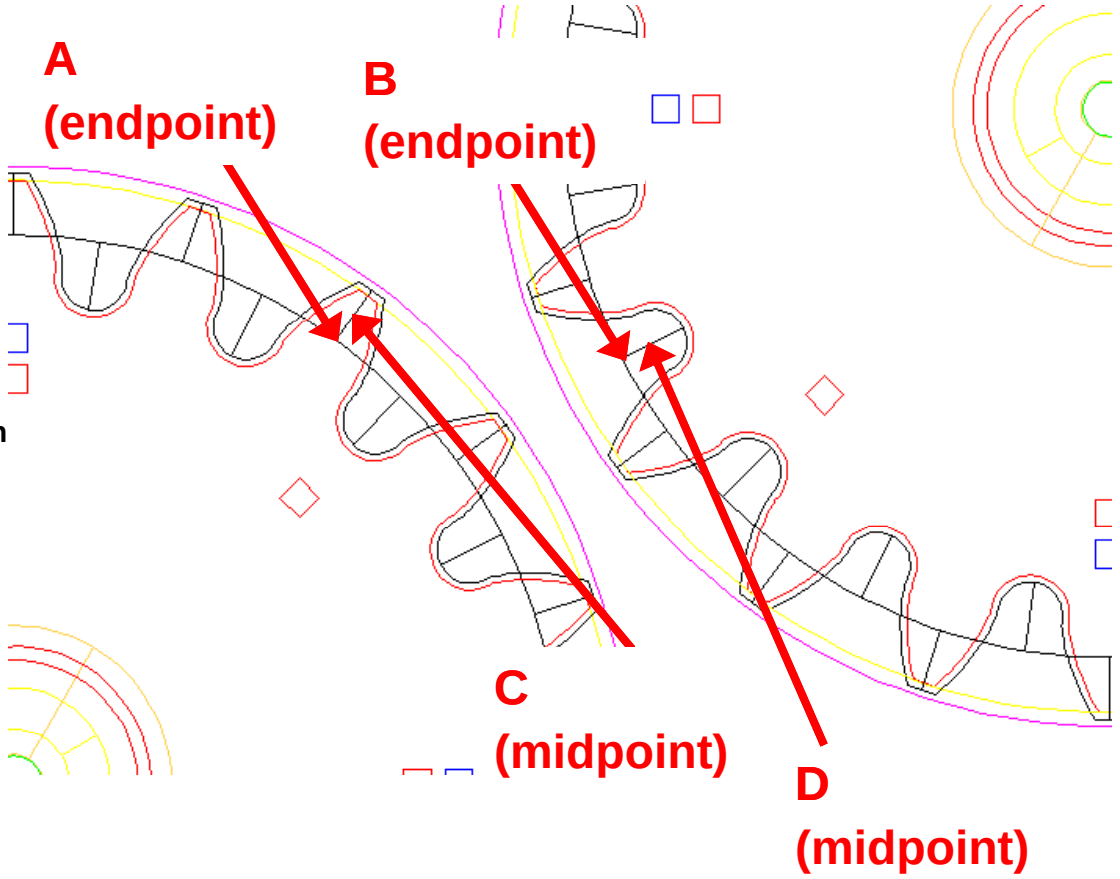
Connected mirror and rack

Note: you must have AutoCAD 2008 to view this link.

Sandia National Laboratories

Aligning Gears

1) Start the align command
2) Select all of the gear on the left
3) Press return
4) Choose point A for “Specify first source point”
5) Choose point B for “Specify first destination point”
6) Choose point C for “Specify second source point”
7) Choose point D for “Specify second destination point”
8) Press return twice



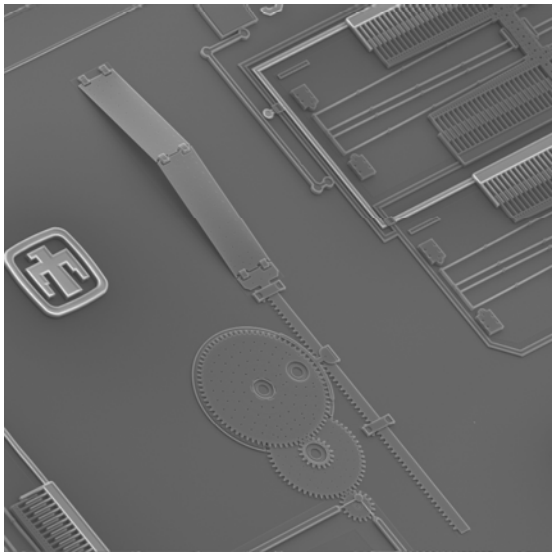
Sandia National Laboratories

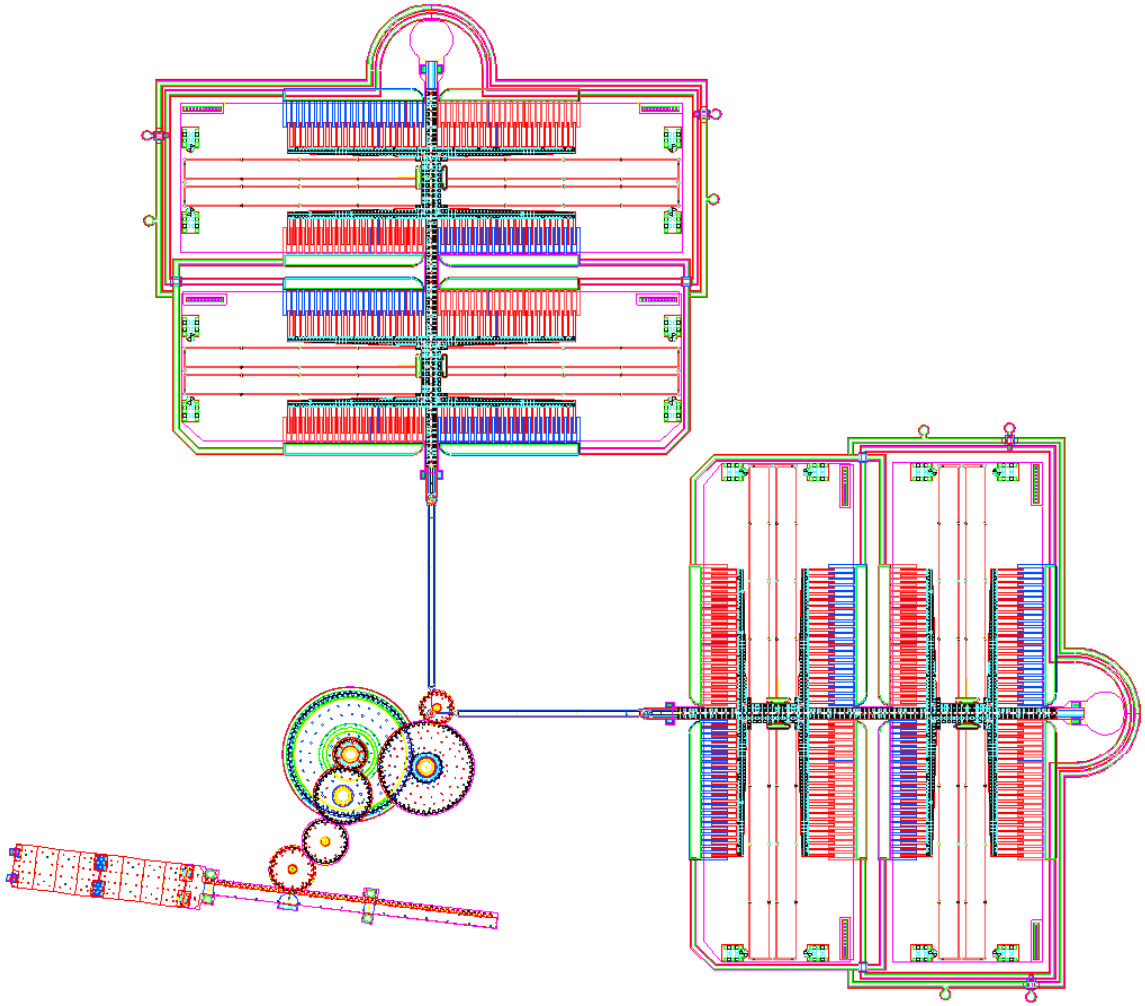
Finished Product

- **Complete the mirror assembly by adding a transmission (‘12:1 Transmission’) and then aligning everything to the microengine**

  Mirror rack with transmission and gears

  Note: you must have AutoCAD 2008 to view link.



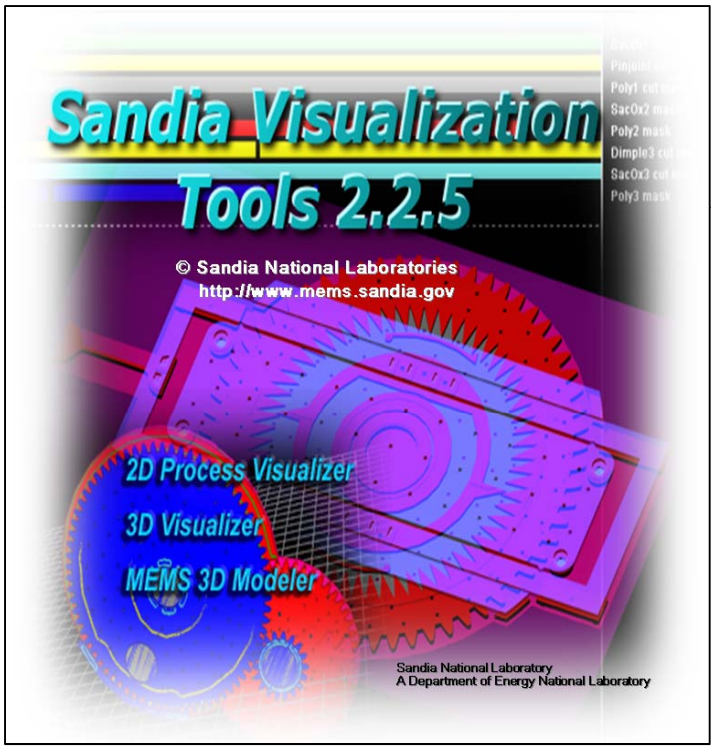


Sandia National Laboratories

Sandia MEMS Design Tools

Available on CD or Download

Design Tools CD



Visualization Tools CD

Sandia National Laboratories

Design Tools
Hardware/Software requirements

- CPU: Pentium IV or better
- Clock Speed: 3.0 GHz or faster
- Memory: 2 GBytes
- Hard Drive: 2 GB free of disk space
- Operating System: Windows XP, Windows XP x64, or Vista
- Graphics Card: Nvidia card recommended
- 128MB OpenGL-capable graphics card 24 Bit or True Color Mode
- Monitor Resolution: 1280 X 1024 or higher
- Software: AutoCAD 2007 - 2010
- Microsoft Internet Explorer 7.0