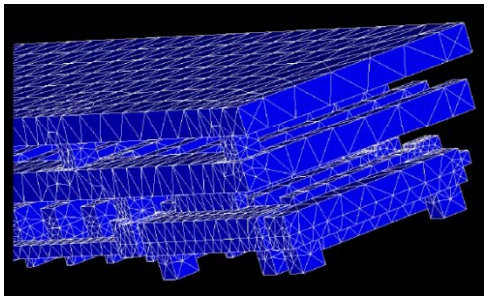
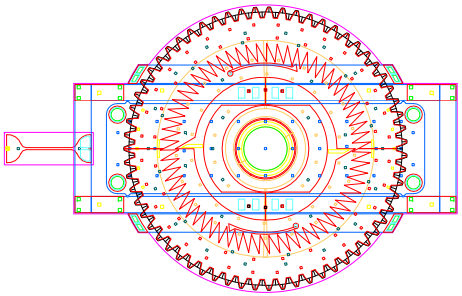
Sandia MEMS Design Tools

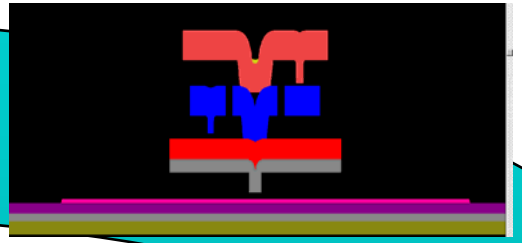
SAND Number 2010-8117 W



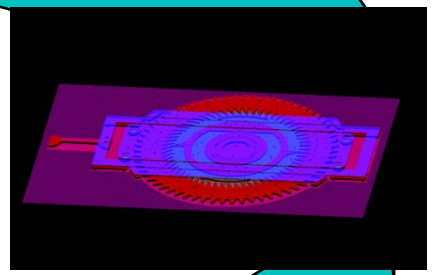
Design & Analysis



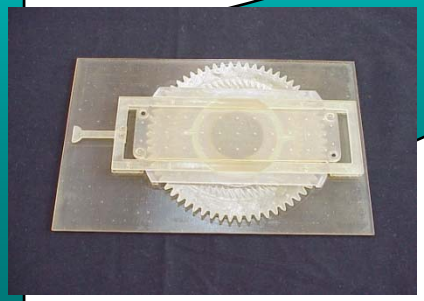
Layout

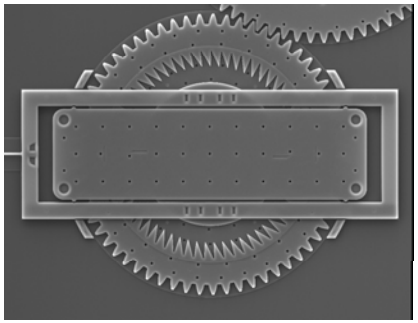


Visualization



Verification





First pass success!

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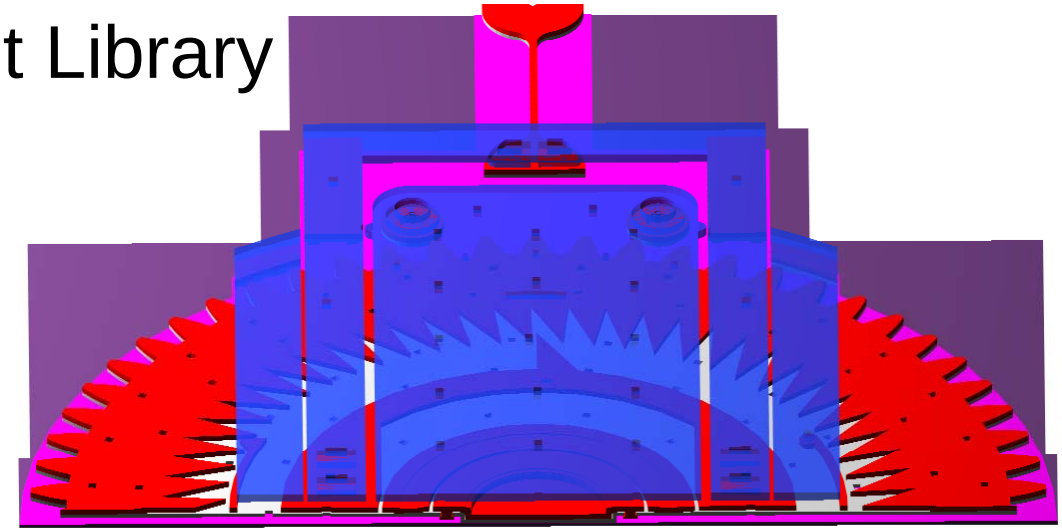
Sandia MEMS Design Tools Overview

- 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



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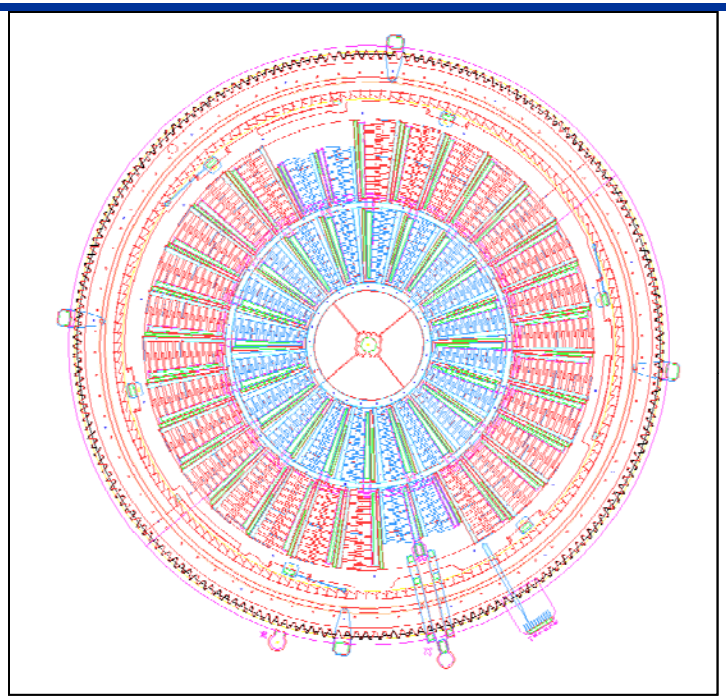
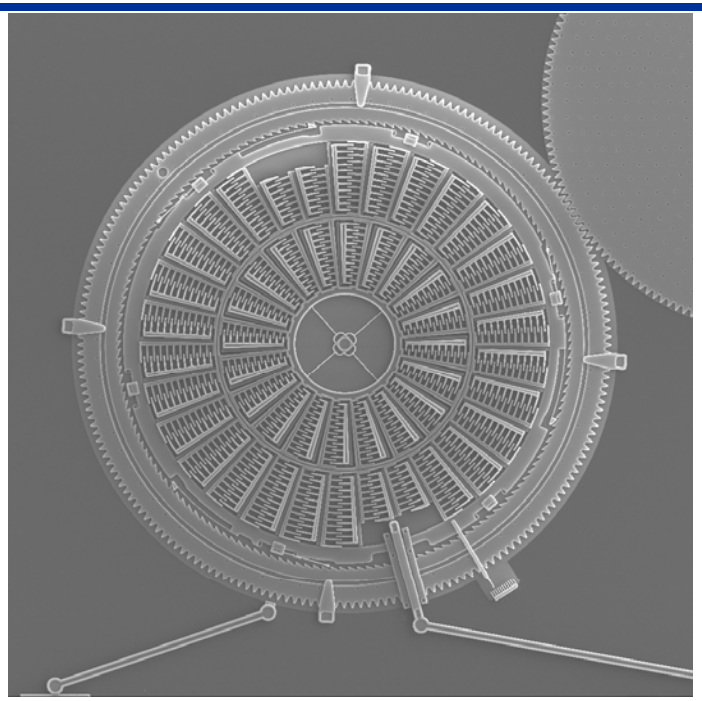
MEMS Design

Why do we need specialized MEMS Design Tools?





2-D mask layers

+

Fabrication process

→

difficult-to-visualize

3-D

systems with complex shapes

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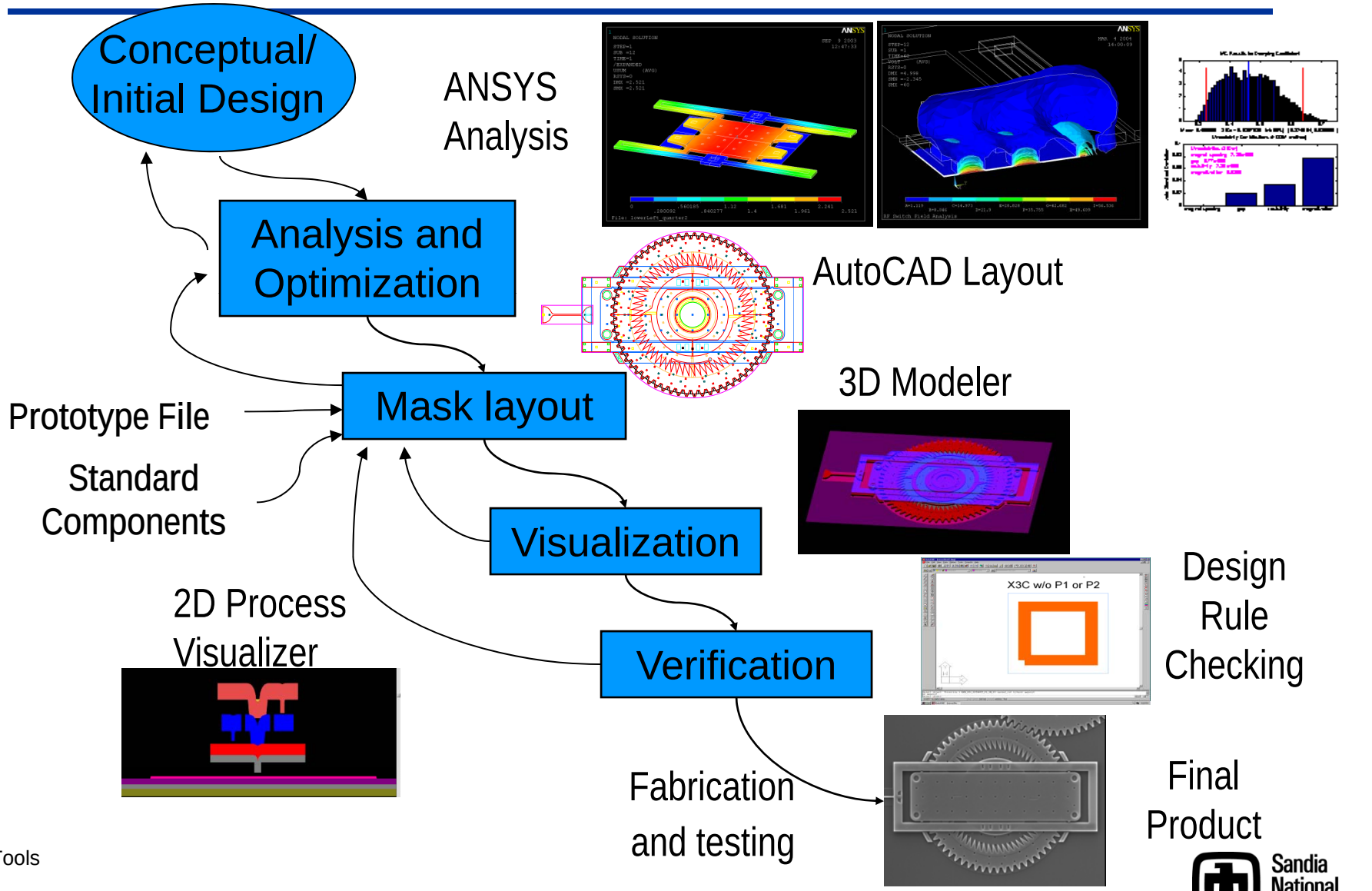
MEMS Design Process Flow



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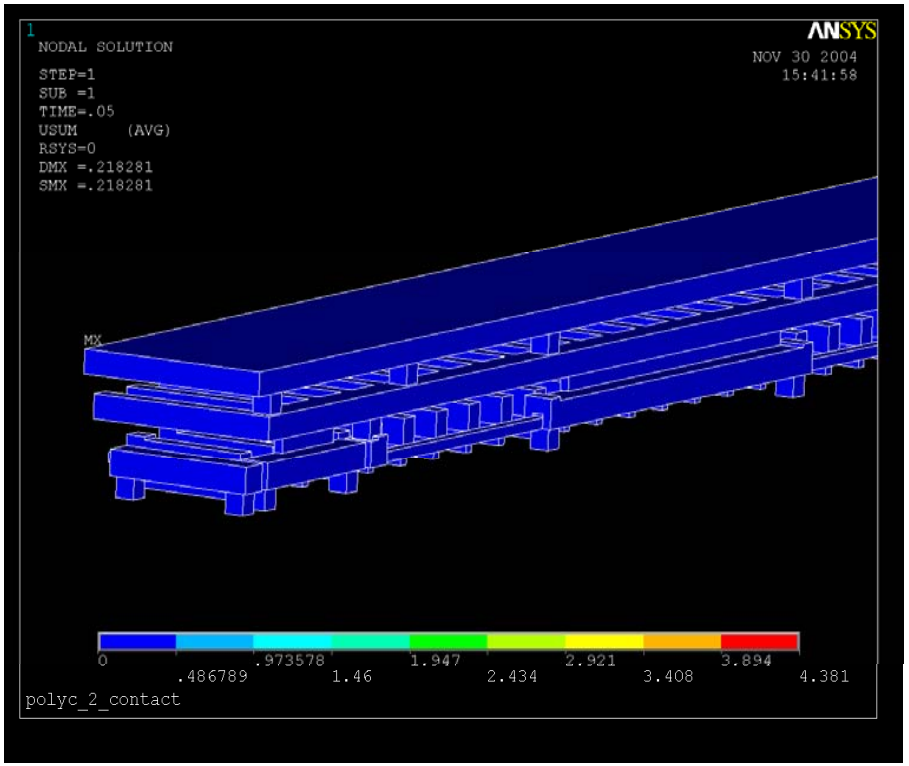
MEMS Analysis
Current Capabilities

- 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)



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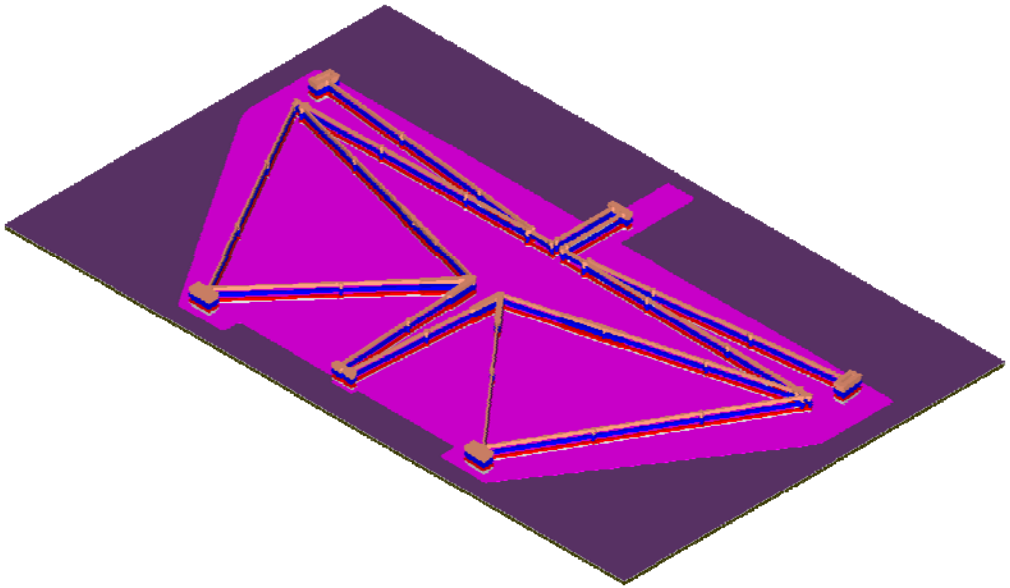
MEMS Design Tools Summary For AutoCAD

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

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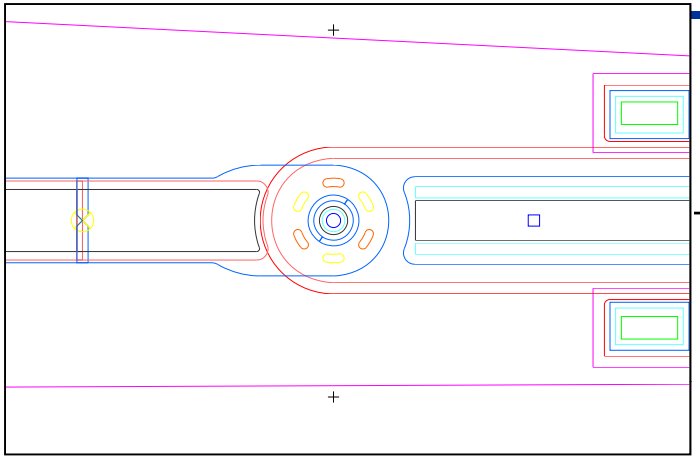
2D Process Visualizer

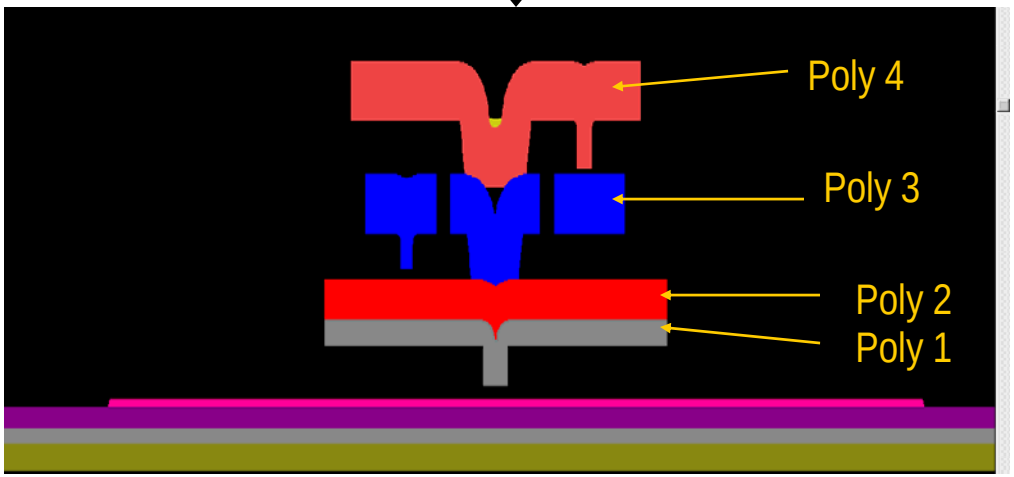


AutoCAD 2D Mask geometry

SUMMiT V Process definition file

2D Process Visualizer

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



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2D Process Visualizer

Example - Flex Link Pivot

Nitride Cut Mask
MMpoly0 Mask
Dimple1 Cut Mask
Sacox1 Mask
Pin Joint Cut Mask
MMpoly1 Mask
Sacox2 Mask
MMpoly2 Mask
Dimple3 Cut Mask
Sacox3 Mask
MMpoly3 Mask
Dimple4 Cut Mask
Sacox4 Mask
Poly4 Mask

MMpoly4
Sacox4
MMpoly3
Sacox3
MMpoly2
Sacox2
MMpoly1
Sacox1
MMpoly0
Nitride
Oxide
Substrate

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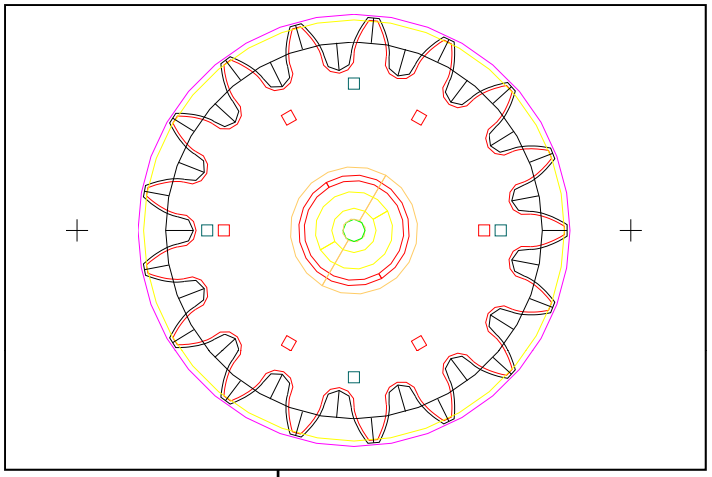
MEMS 3D Model Generation



AutoCAD
2D Mask
Geometry

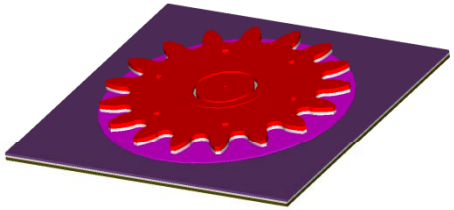
SUMMiT V Process
Definition File

3D Geometry
Modeler

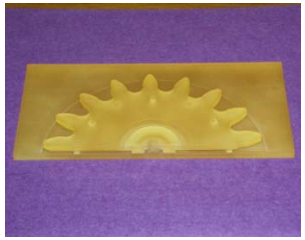
Automatically creates 3D Model of AutoCAD MEMS device layout based upon process steps and mask geometry.

ACIS
SAT
File

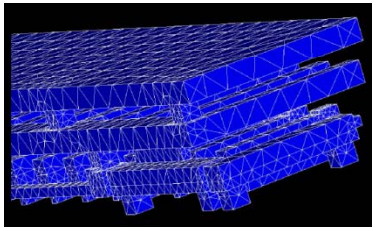
3D Visualization
(in AutoCAD)



Stereo
Lithography
Prototype



ANSYS
Analysis



CFDRC
Analysis

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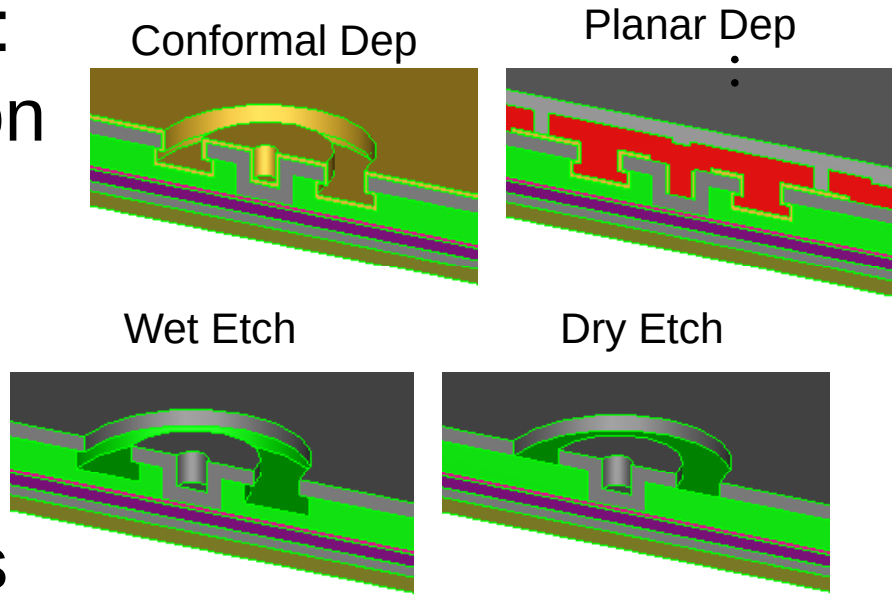
MEMS 3D Modeler

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)



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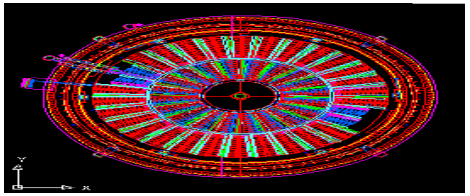
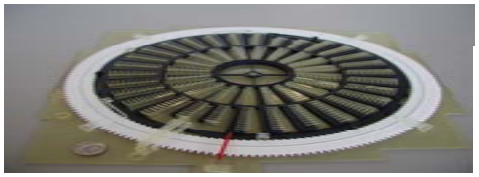
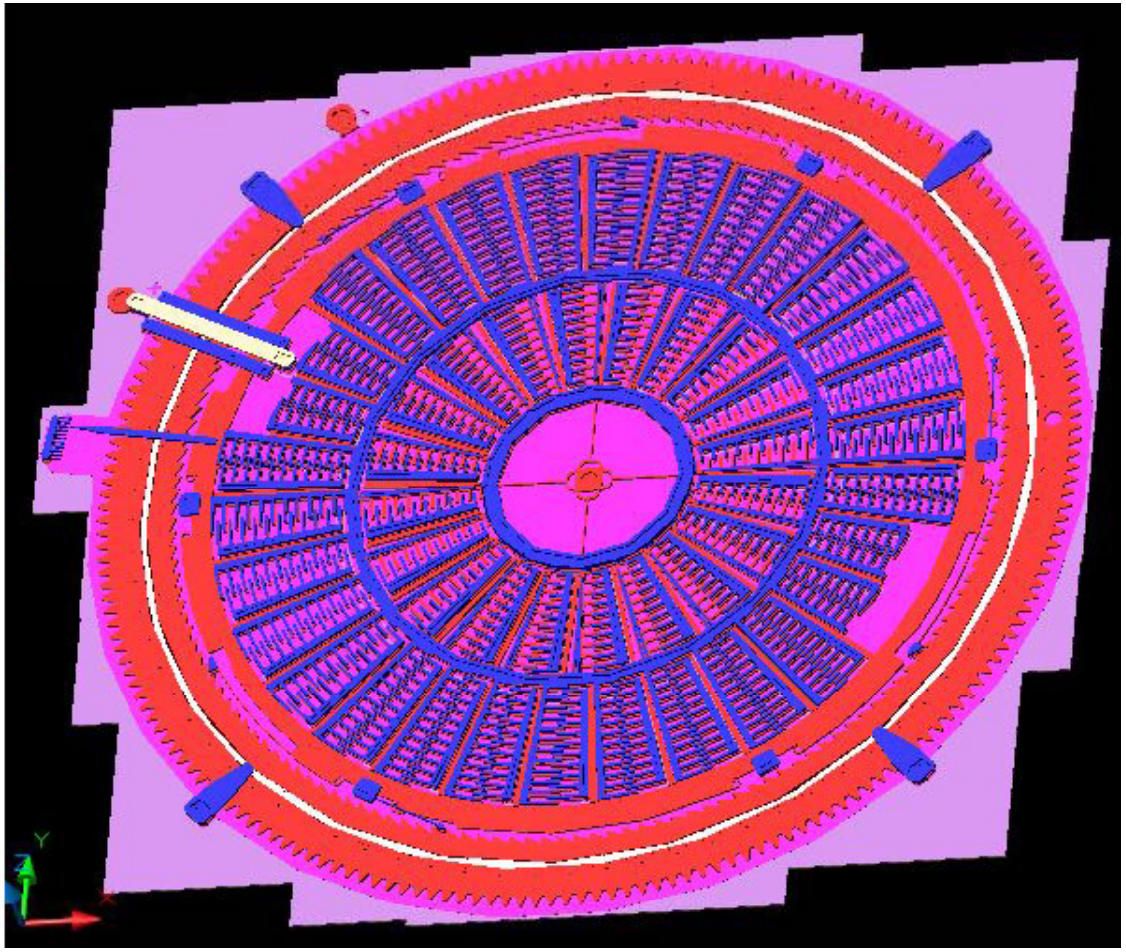
MEMS 3D Modeler

Torsional Ratcheting Actuator







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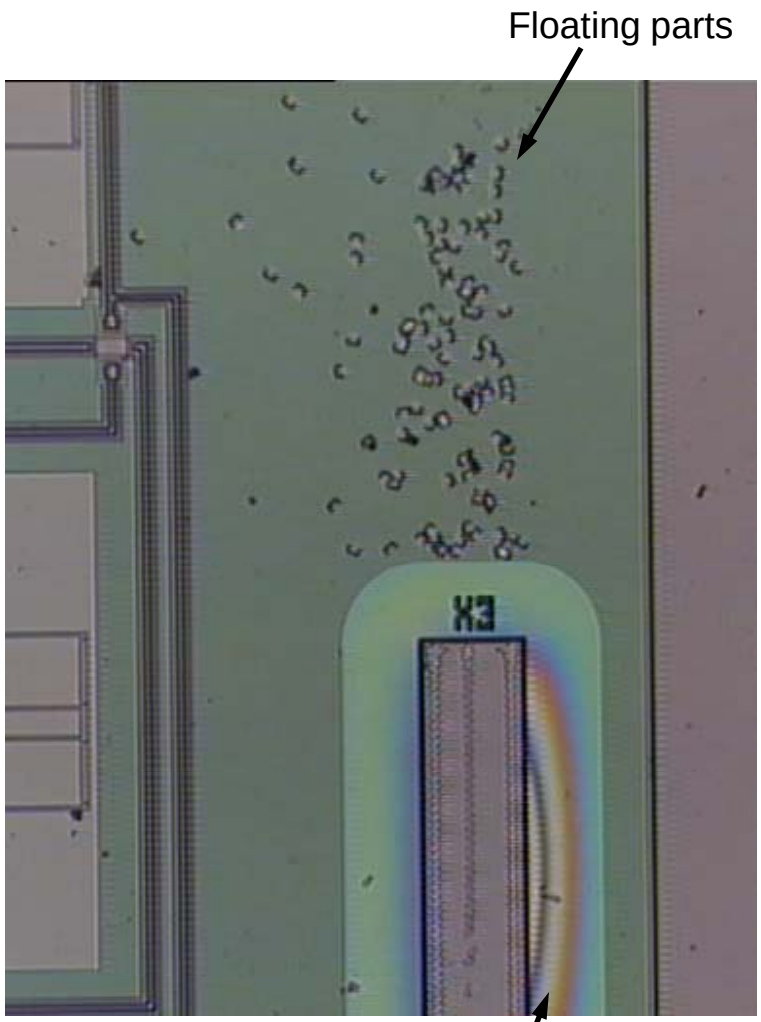
MEMS Design Rule Checking

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



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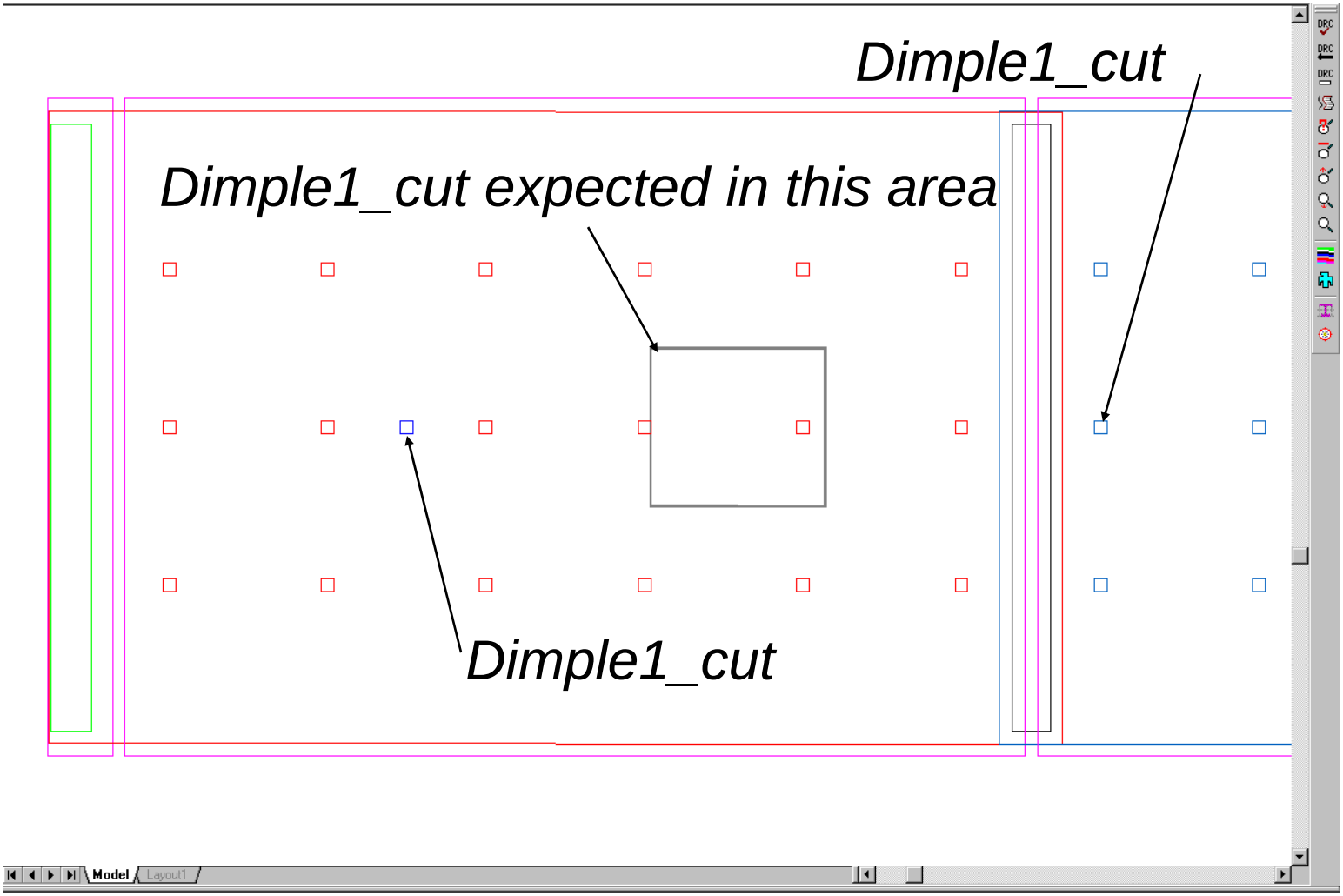
MEMS DRC - Typical DRC Error report

Advisory: Dimple1_cut space > 75



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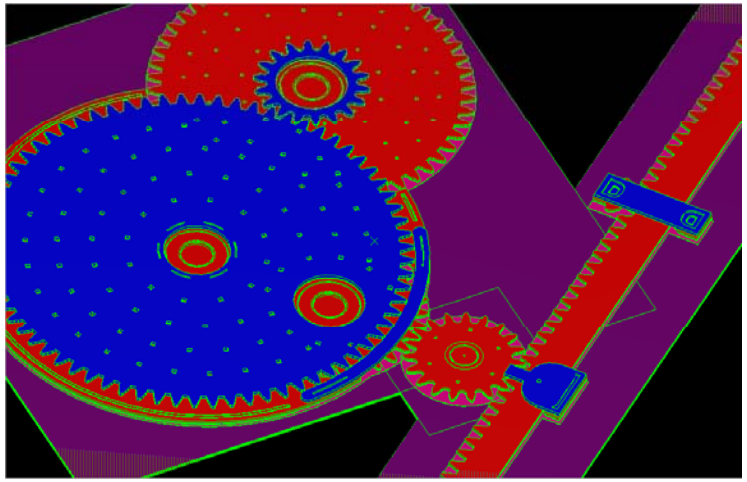
Standard Component Library

- **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**



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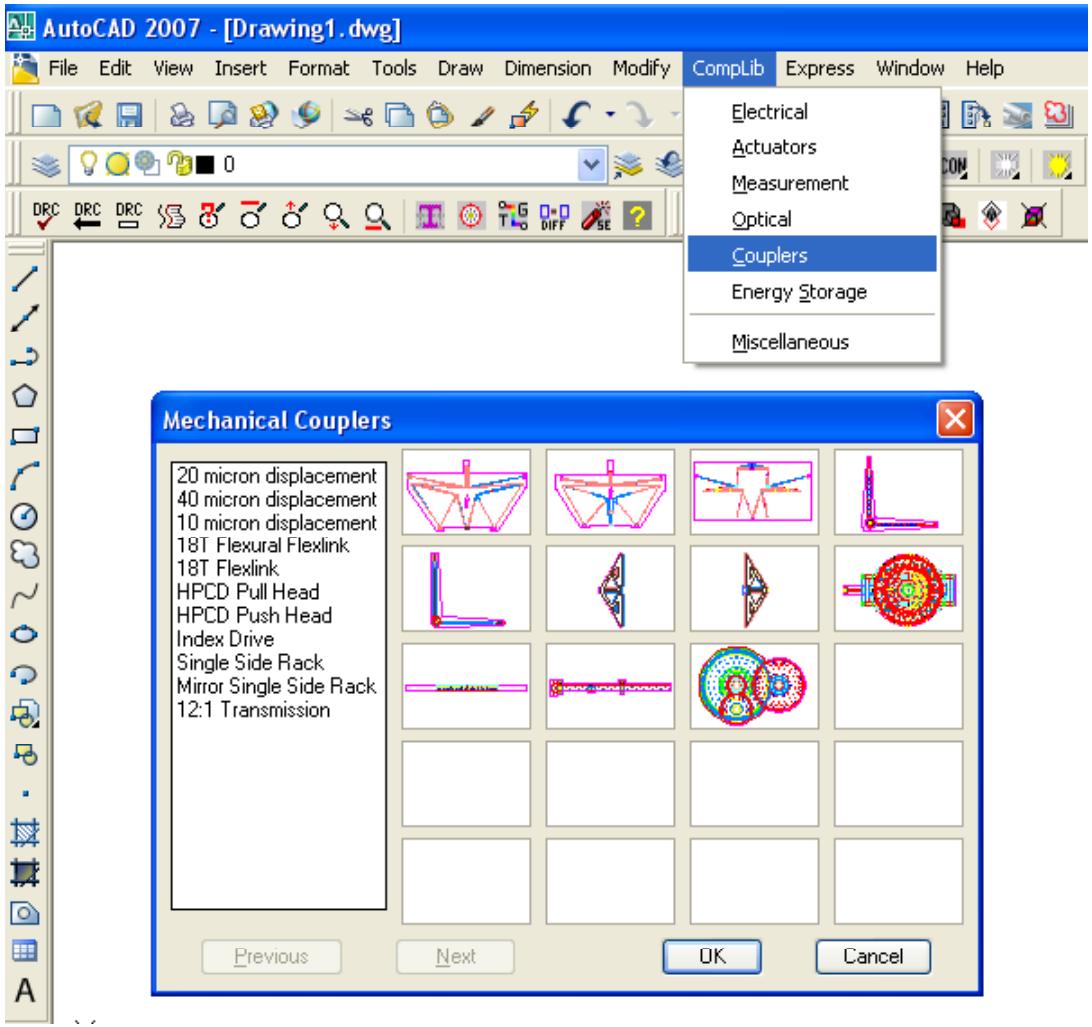
Standard Component Library

- **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.**



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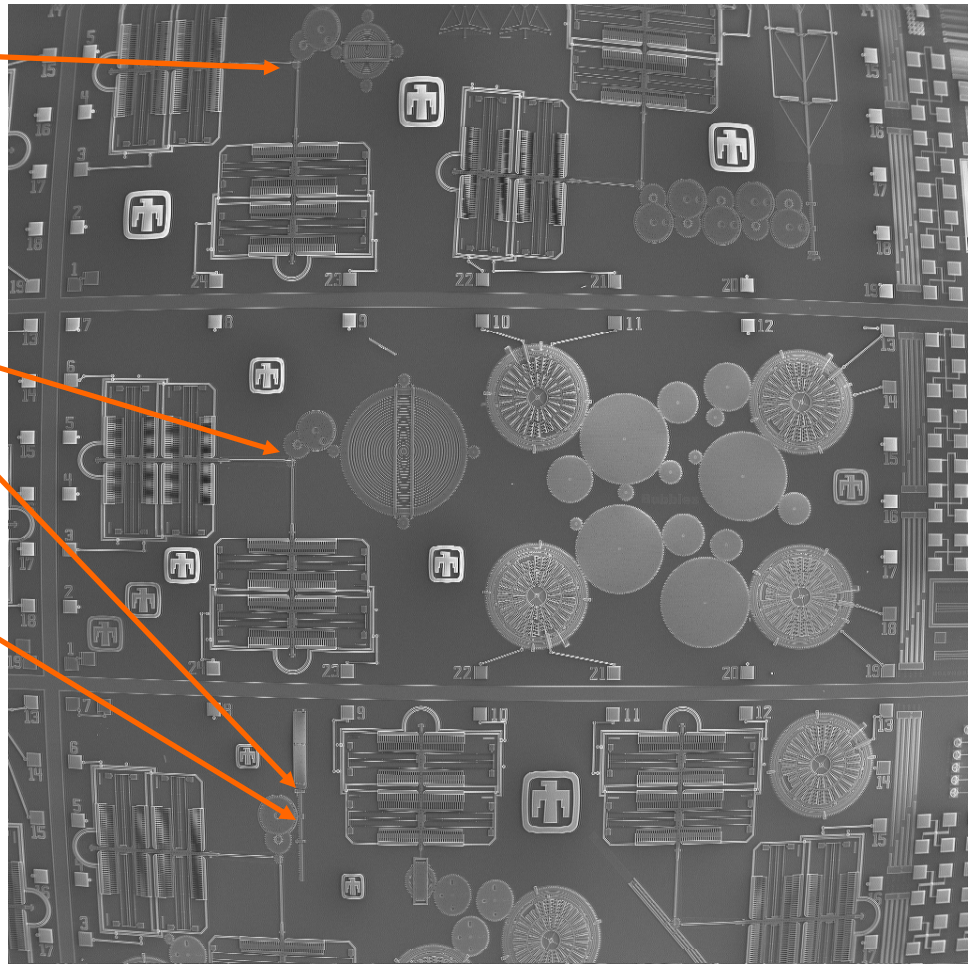
Building Complex Devices Using Library Components

- **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**



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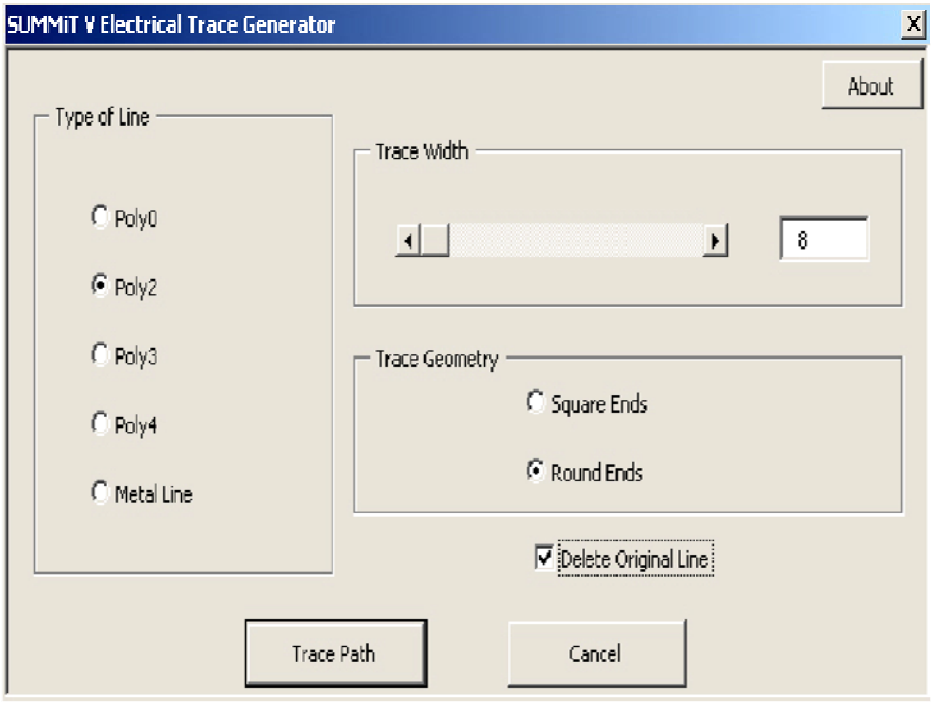
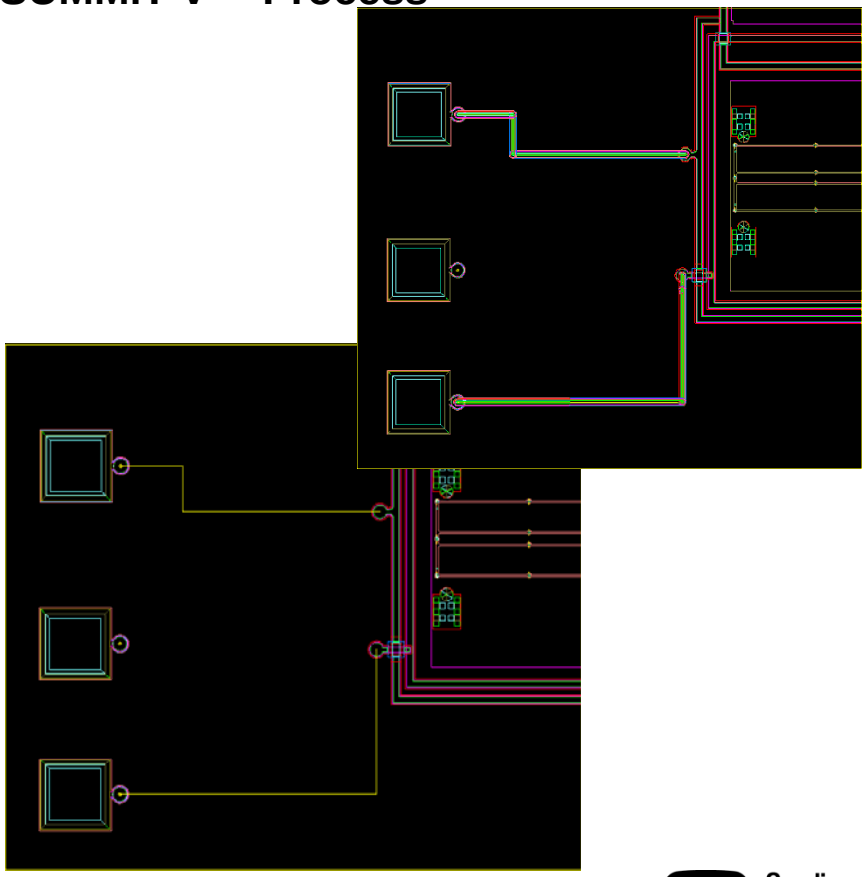
Trace Generator

- **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**





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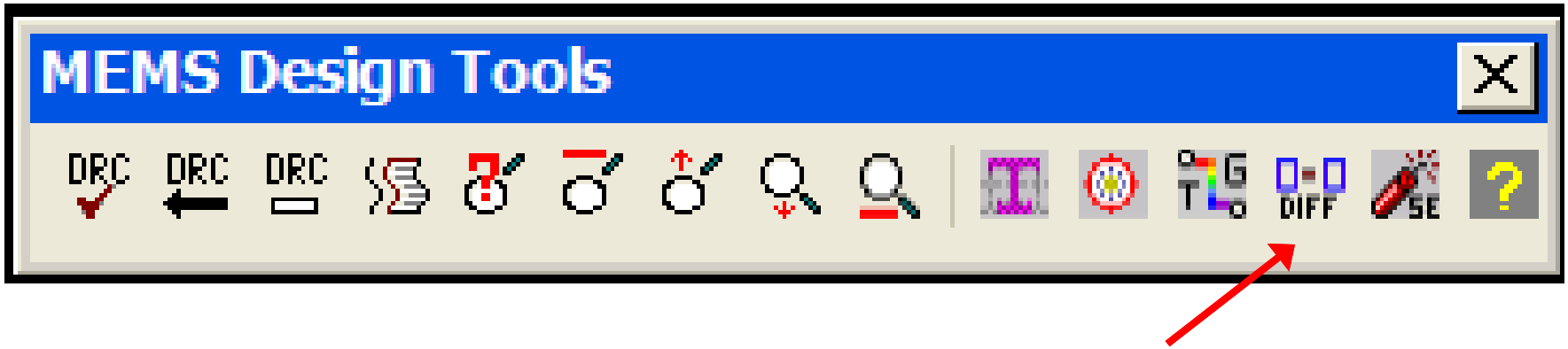
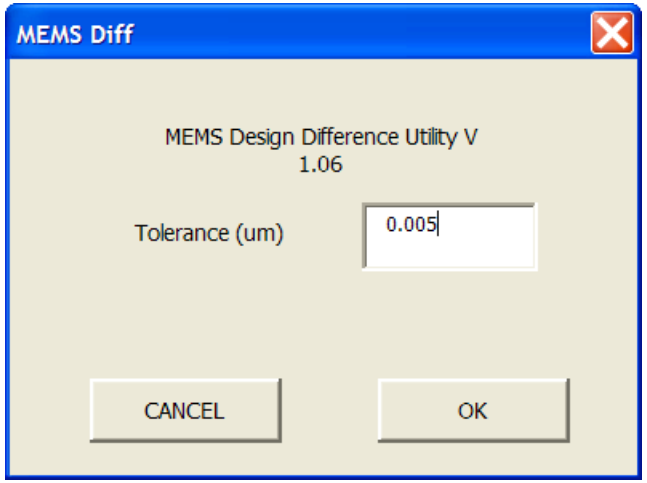
MEMS Difference Utility





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

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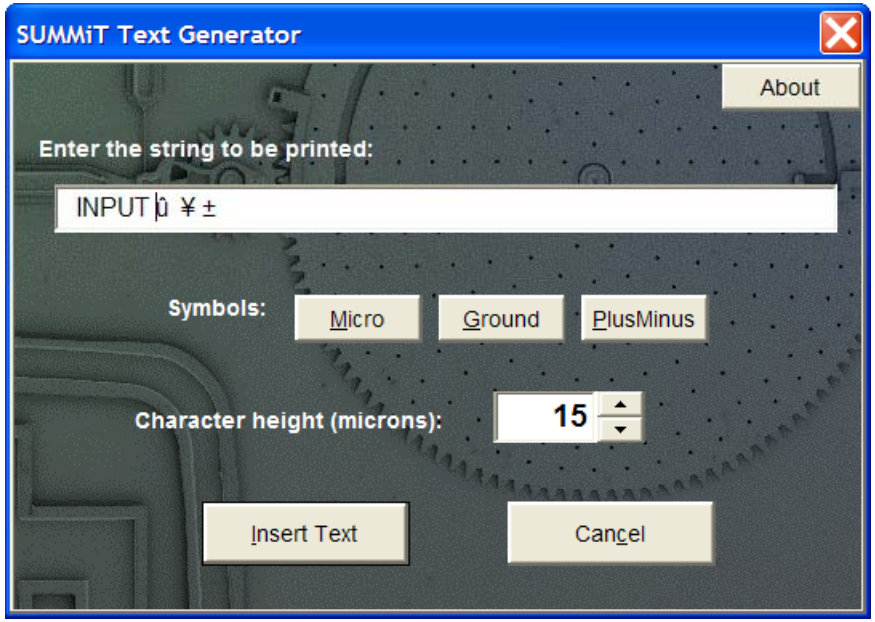
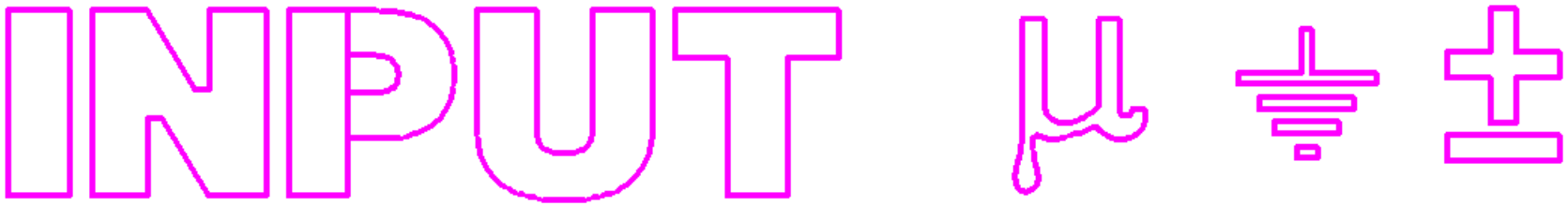
Text Generator

Creates:

- Text
- Special Characters
- Symbols





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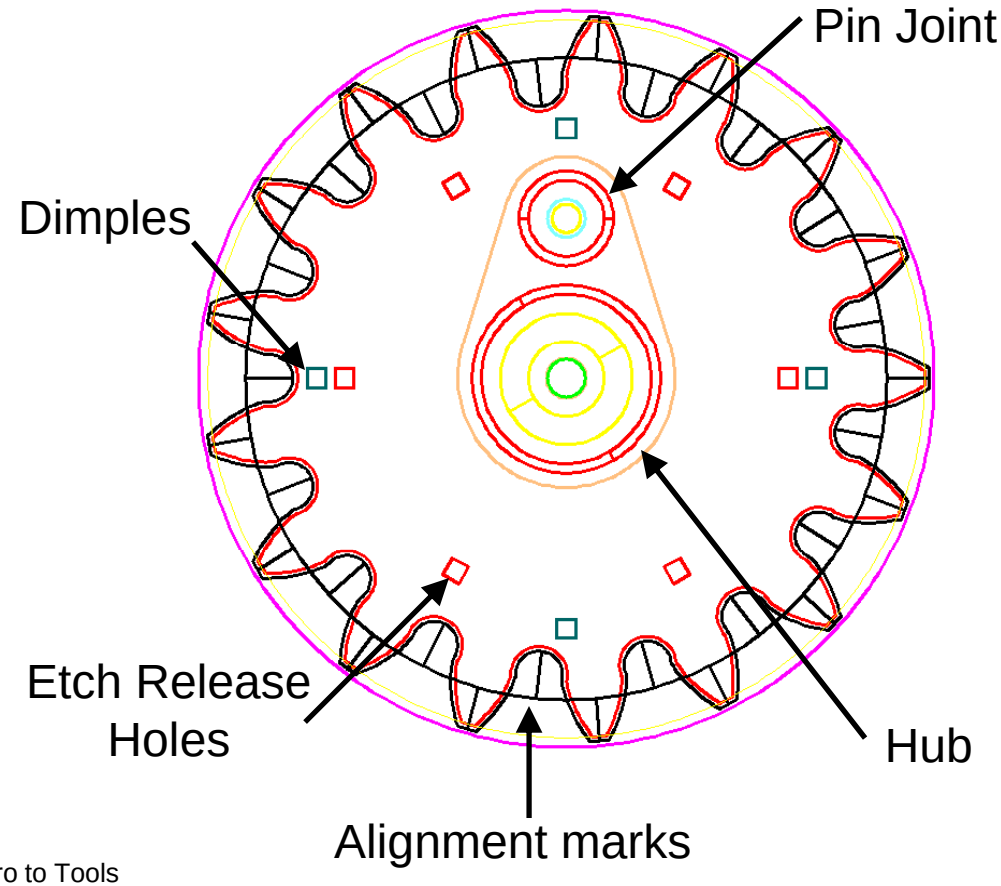
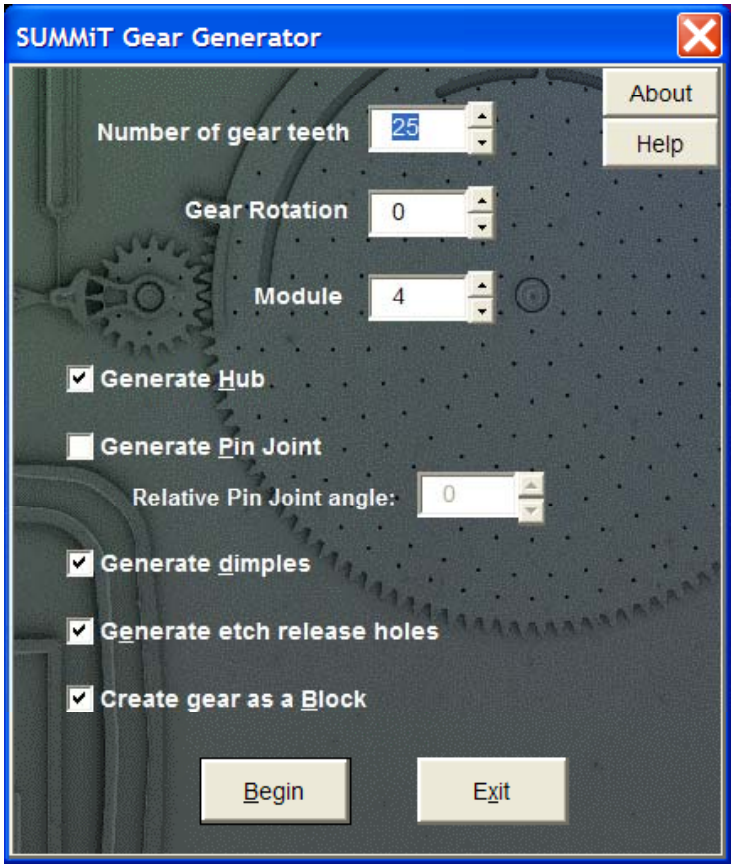
SUMMiT™ Gear Generator

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





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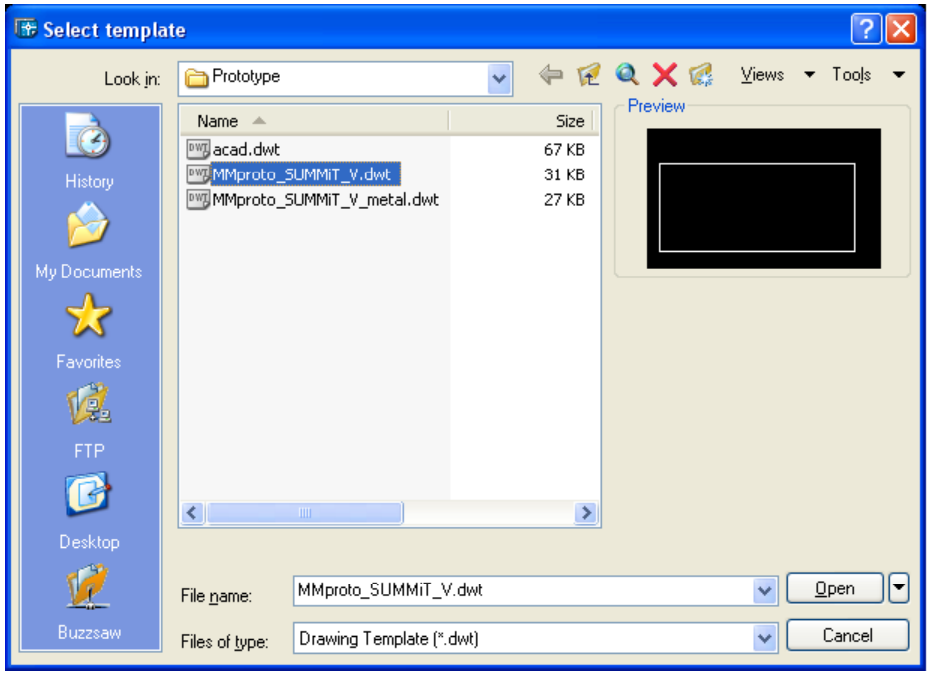
Getting Started in AutoCAD

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



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

    (6340 x 2820)

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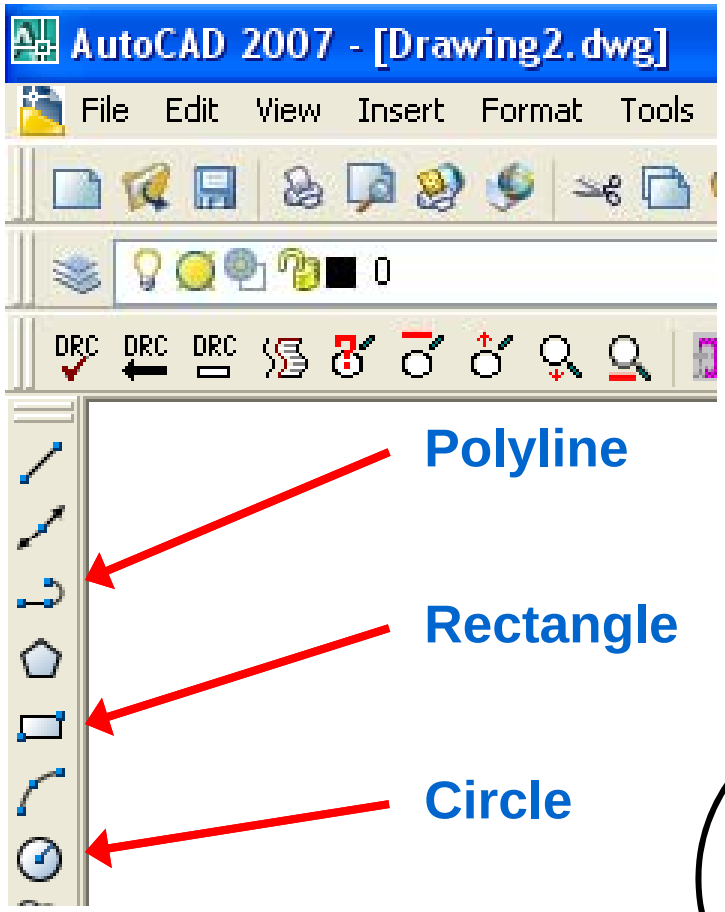
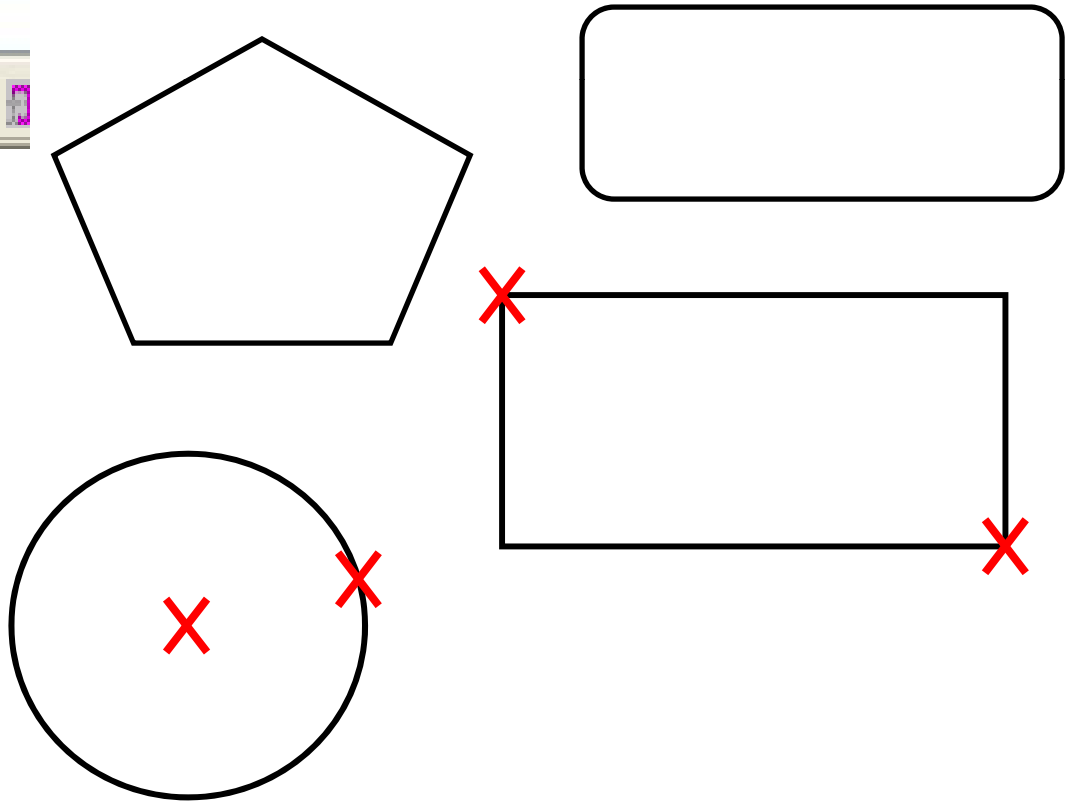
Basic Creation Commands



Masks require closed polygons.
Polylines may have arc fillets.



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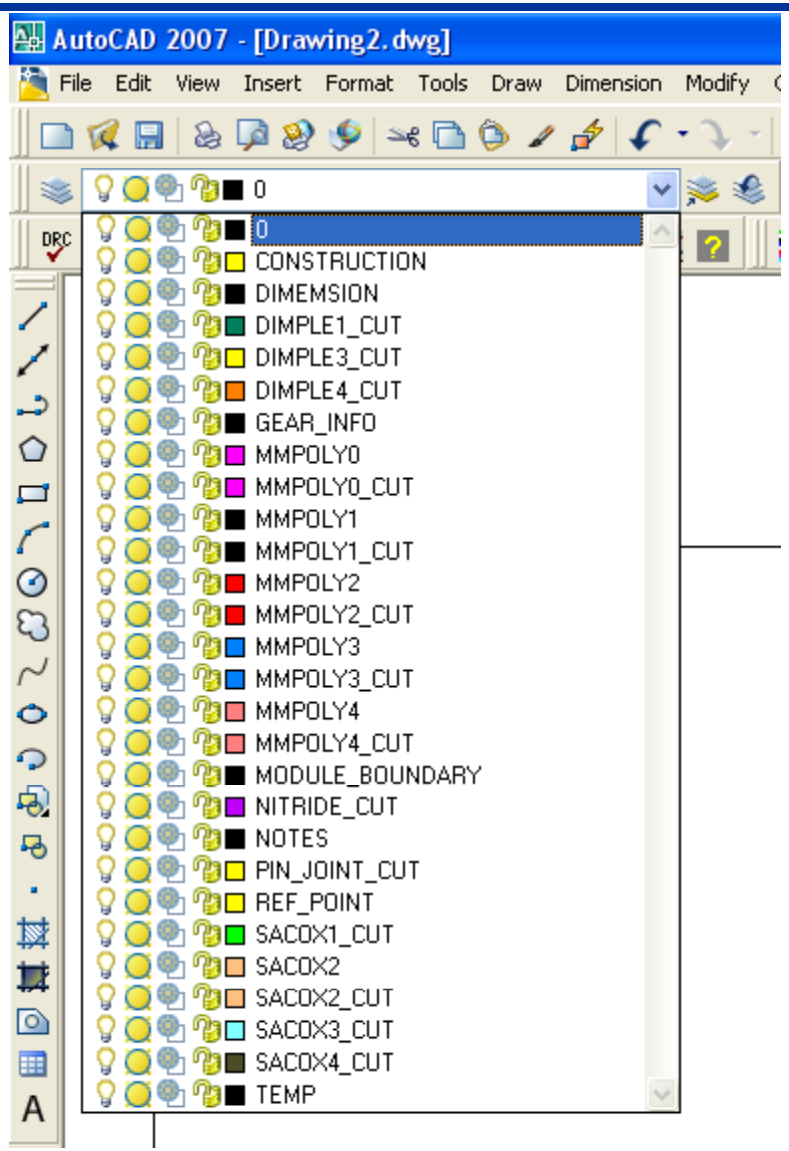
Masks & AutoCAD Layers



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

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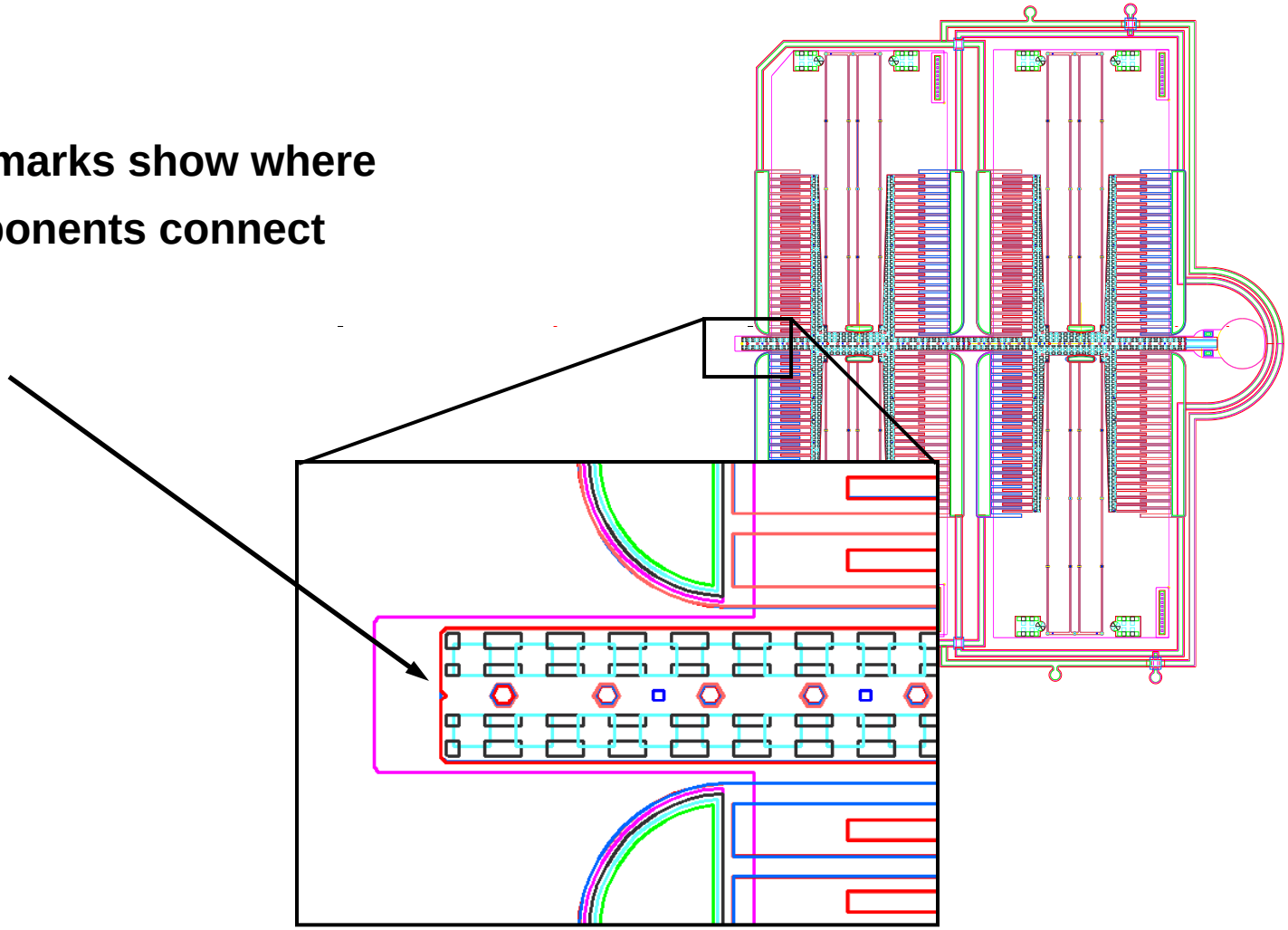
Alignment Marks

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



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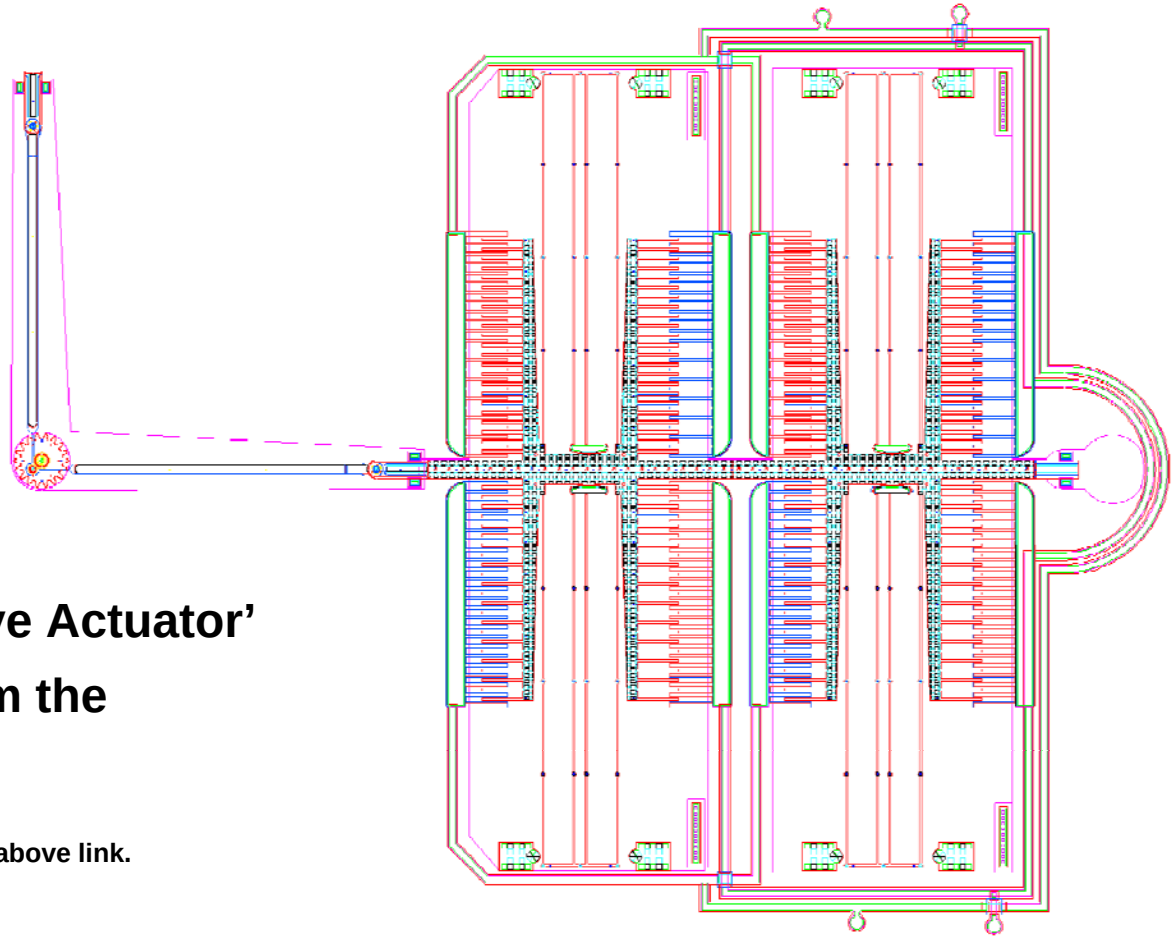
AutoCAD Example 1



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

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

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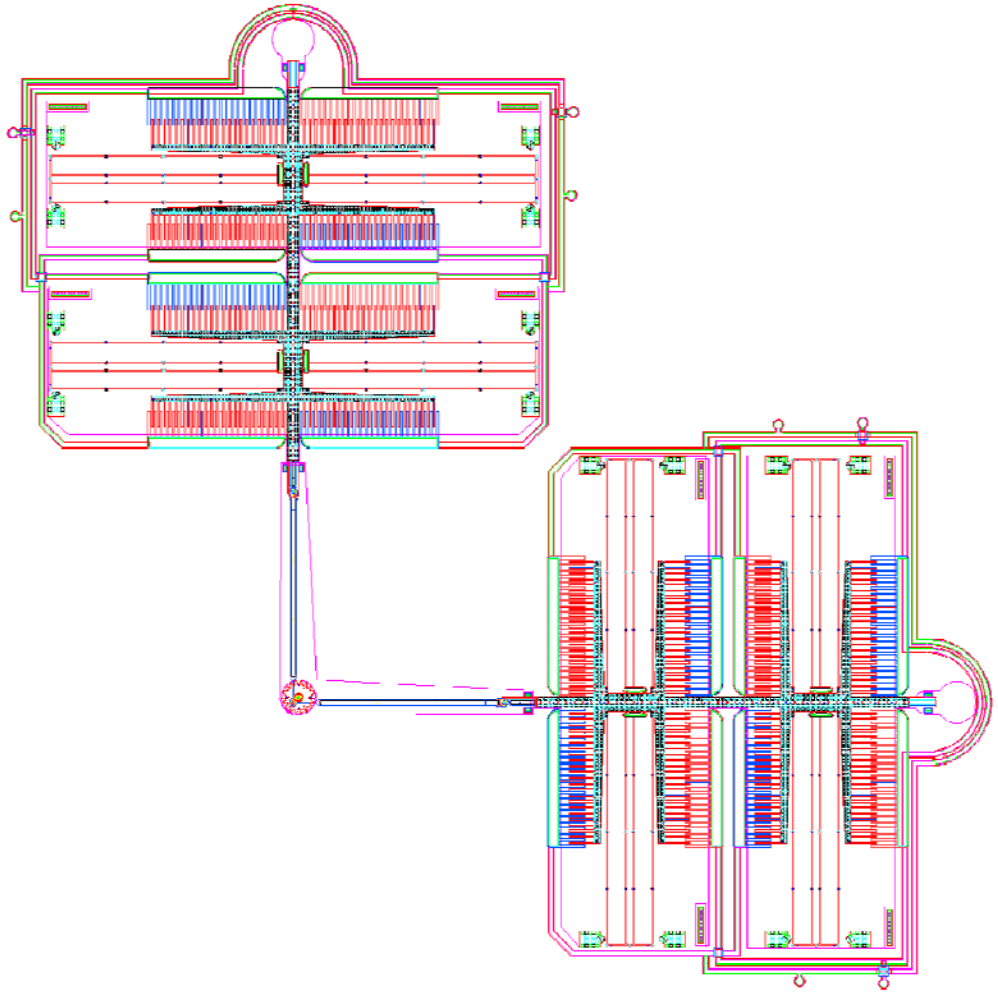
AutoCAD Example 2

- **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**



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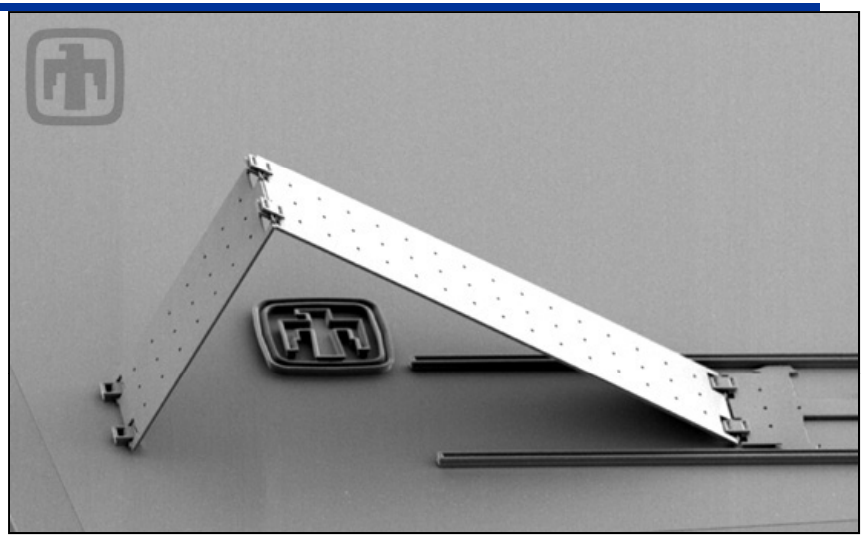
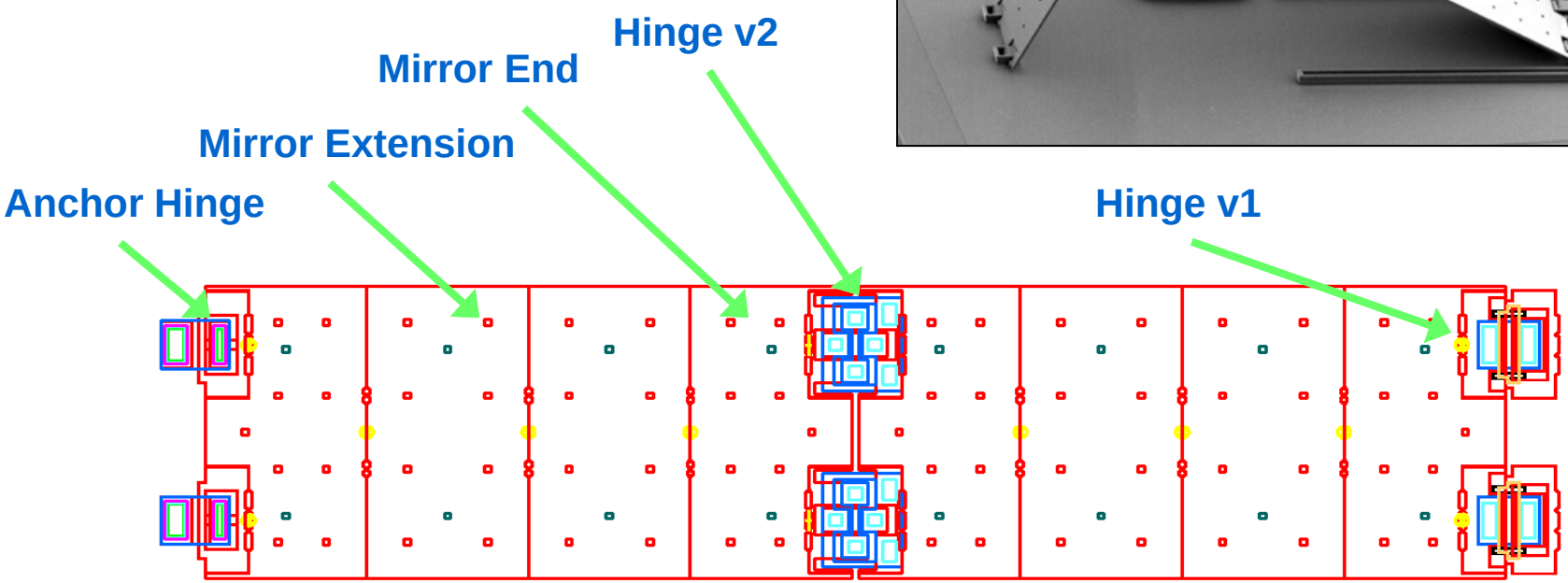
Example 3: Pop-up Mirror

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





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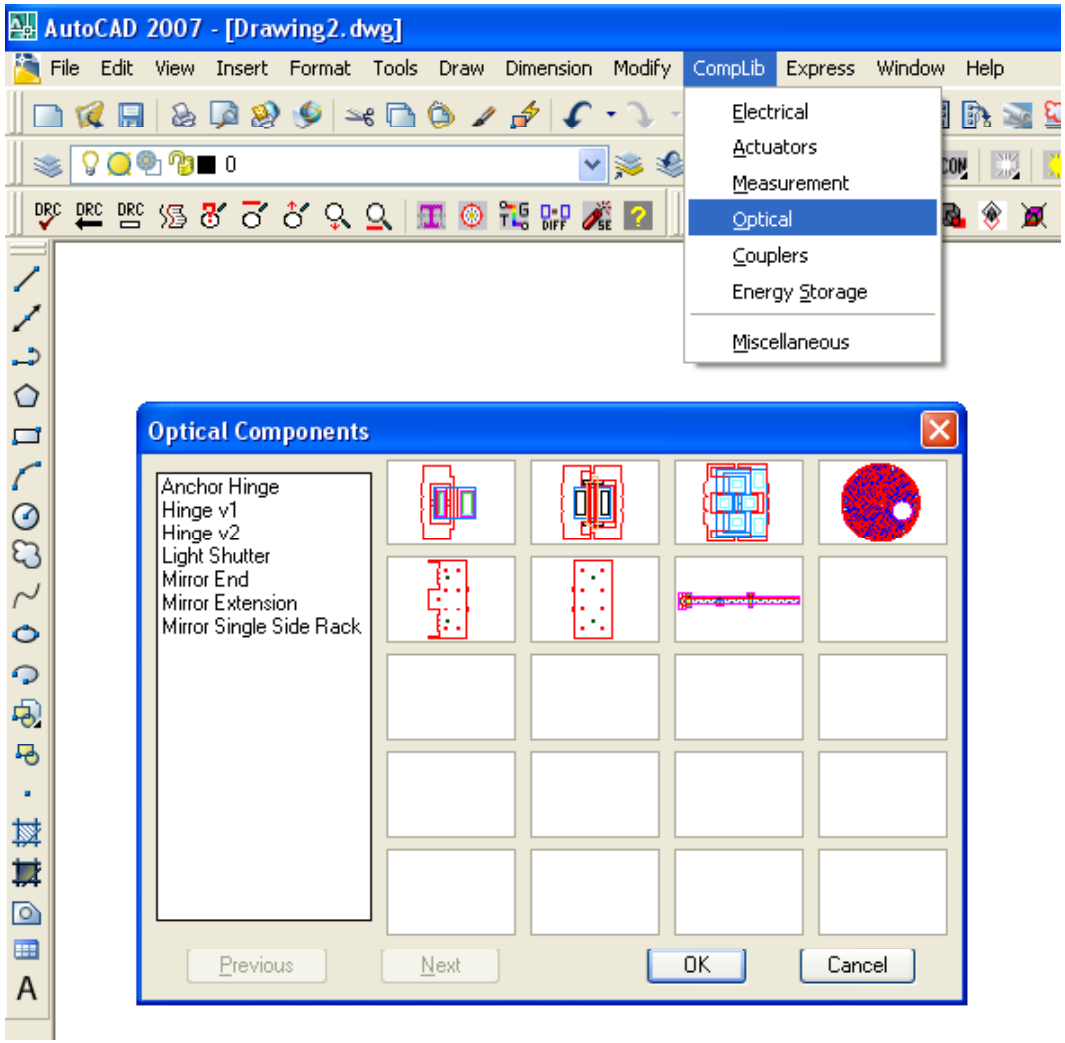
Mirror Components

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

  Complib > Optical



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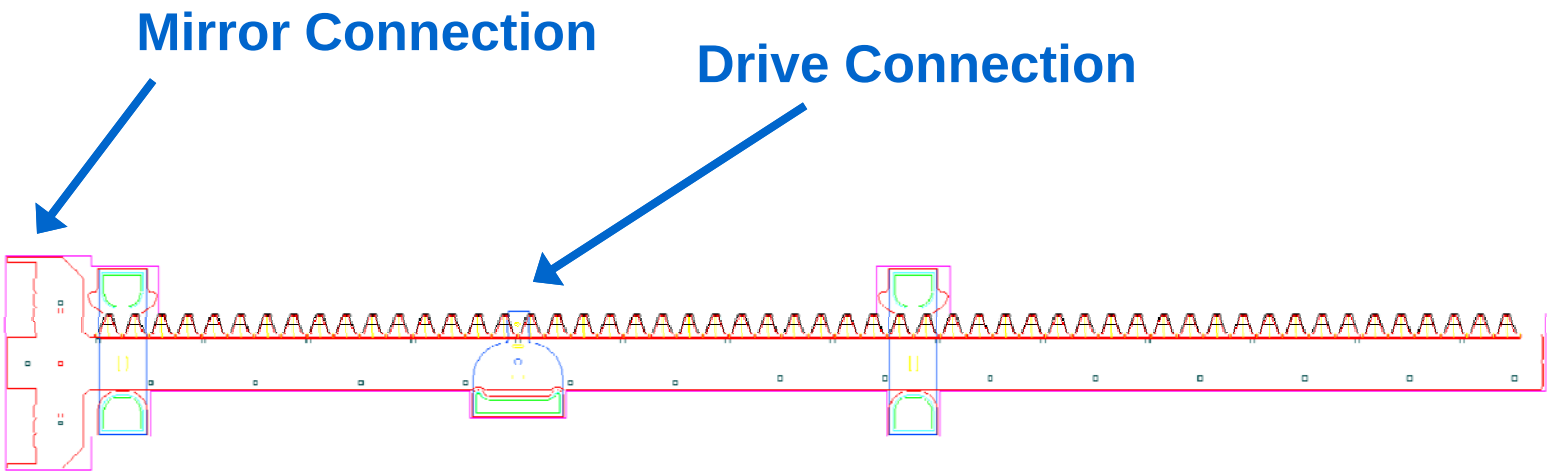
Mirror Single Side Rack

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



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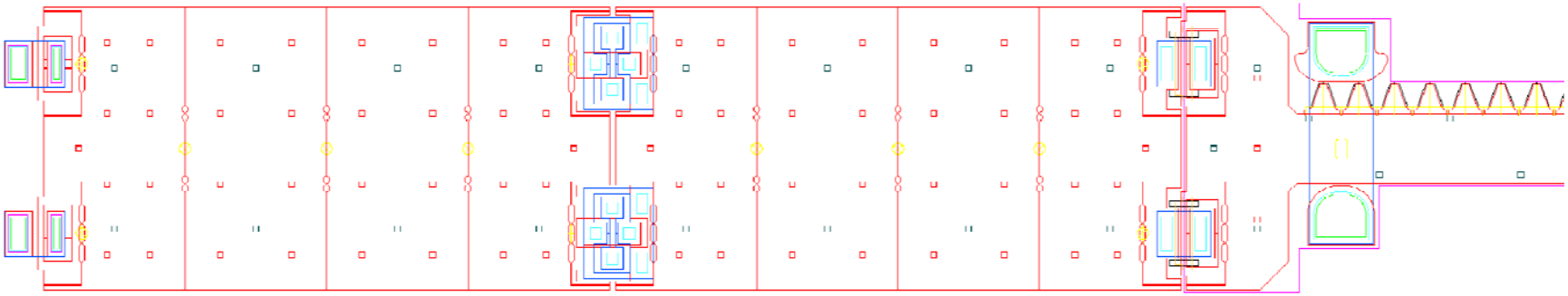
Connected Mirror and Rack



Connected mirror and rack

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

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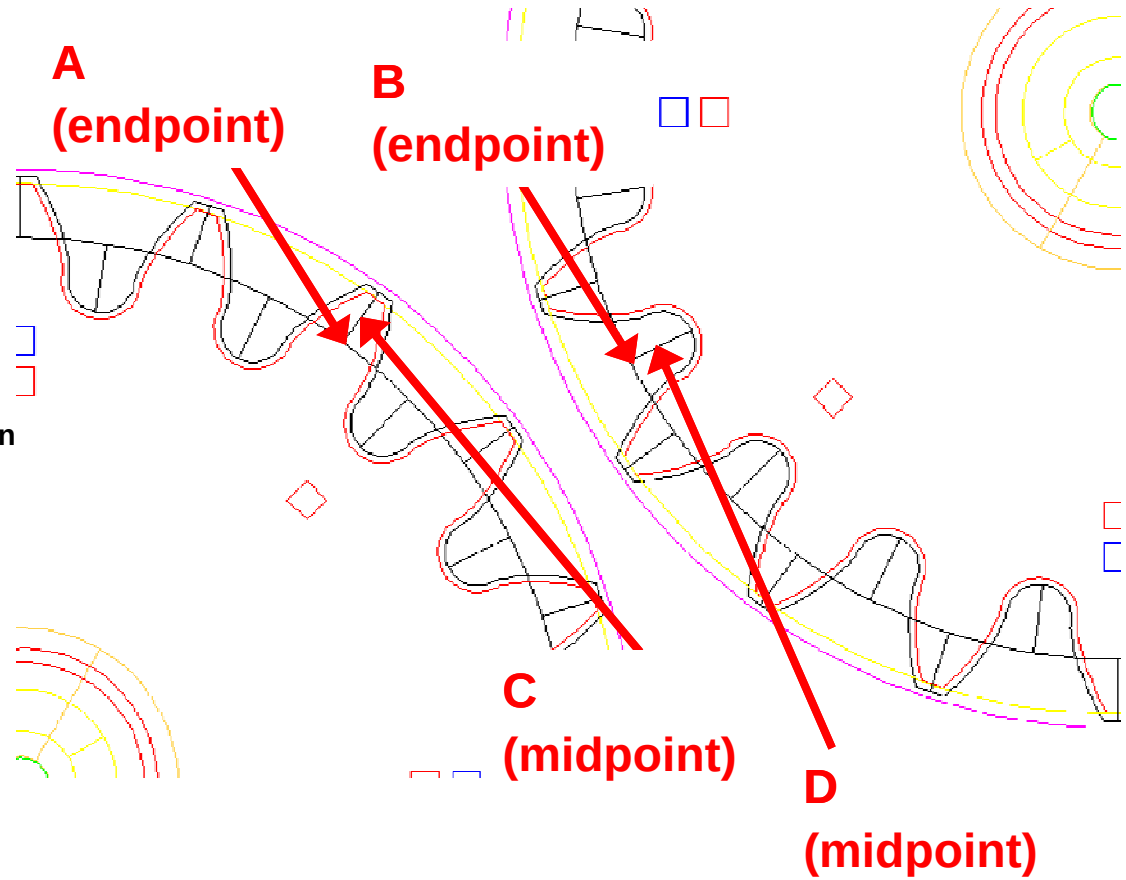
Aligning Gears

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



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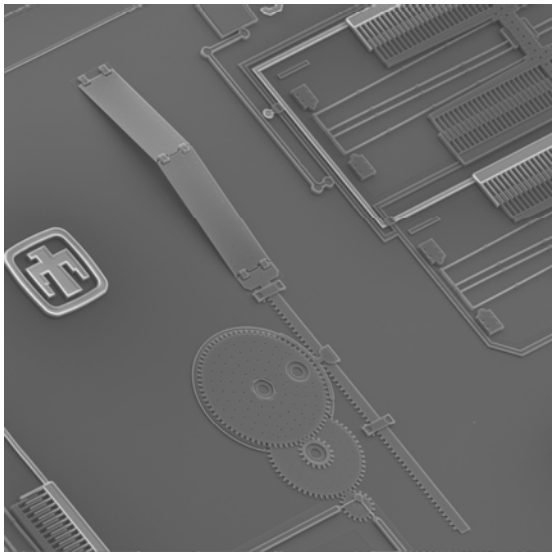
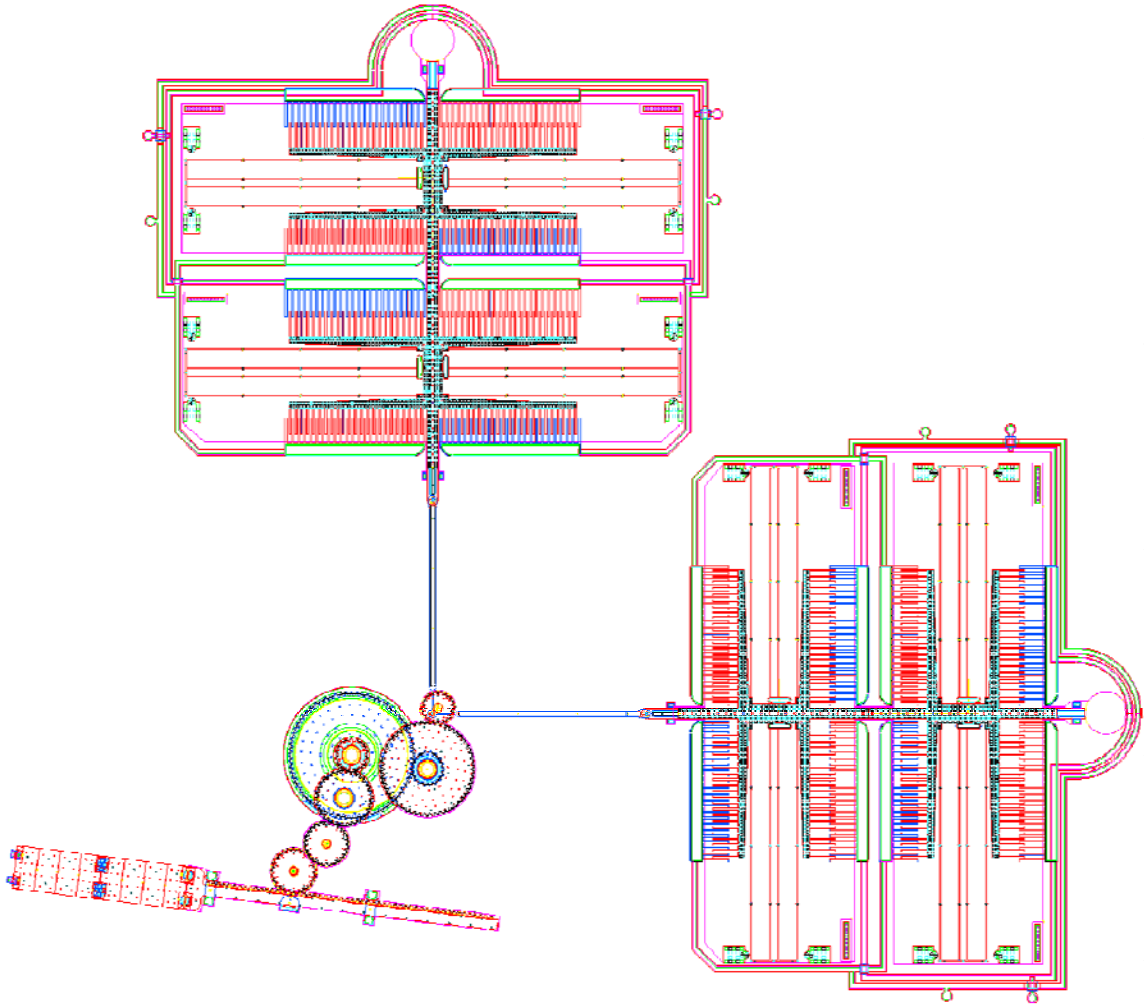
Finished Product

- **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.





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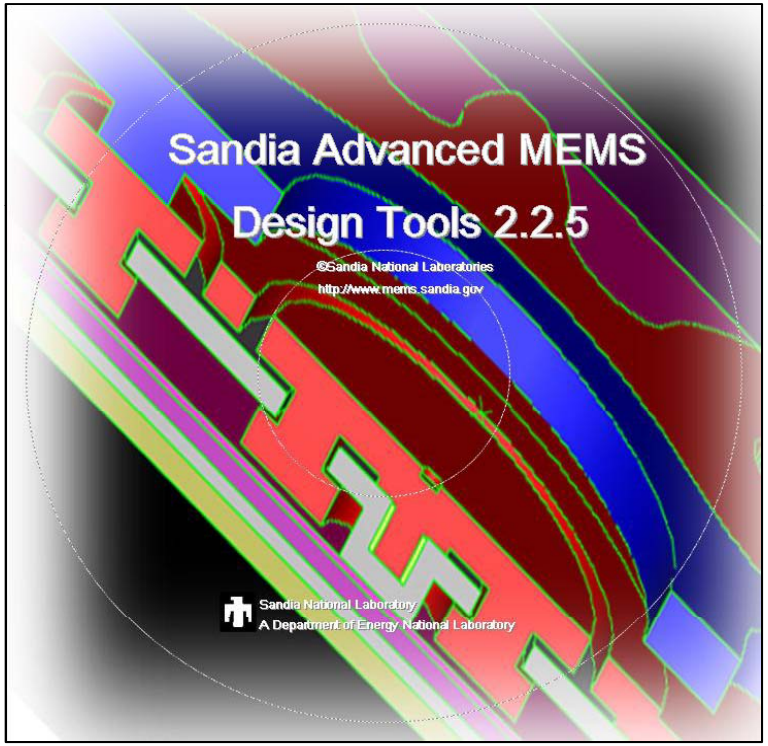
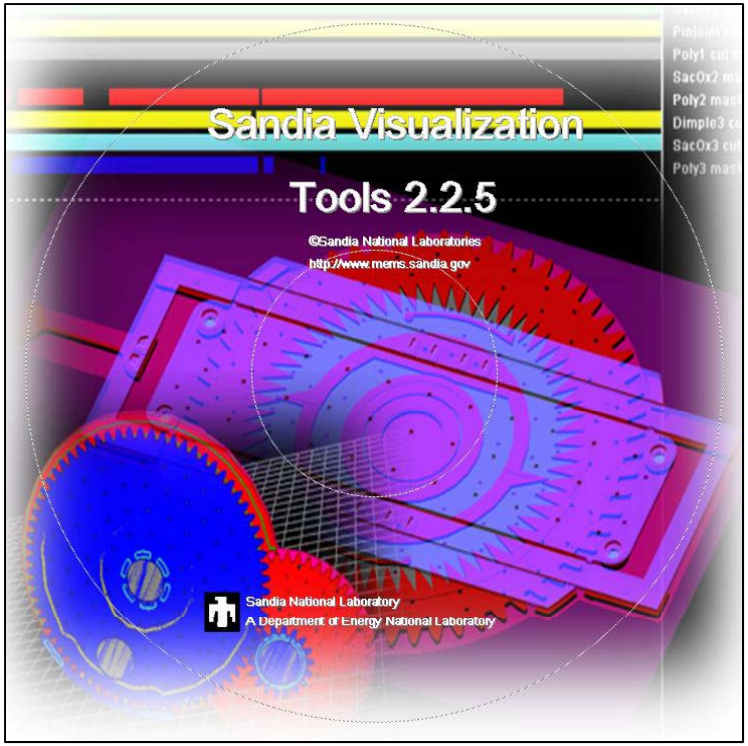
Sandia MEMS Design Tools

Available on CD or Download



Design Tools CD



Visualization Tools CD

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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

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