SAND98-0205 C

MEMS Design Rule Checking: a batch approach for remote operation

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ABSTRACT

This paper describes a design rule checking (DRC) tool developed as an aid for designing microelectromechanical structures (MEMS) using AutoCAD® running on a Windows NT workstation. The application suite, MEMSdrc, consists of: a graphical user interface integrated into AutoCAD® to invoke DRC, translation and interface software to communicate with a commercial IC layout design checking software package, and routines to interactively display and review the results .

The user interface provides the capability to select a checking window area and specific DRC rules to be applied to the design. The MEMS structures, defined as 2D AutoCAD® geometry are translated first into DXF format, then to GDSII format. A remote process transfers the files to a Unix workstation where Mentor Graphics ICverify is invoked to perform the layout design rule checks. Upon completion, the results are translated into DXF geometry and returned back to the Windows NT workstation to be overlaid onto the original design. A set of icons are provided for the user to interactively review the results inside of AutoCAD® using a first/next/previous technique.

Keywords: MEMS, DRC, AutoCAD, design rule check, DXF

OVERVIEW

Design rule check tools have long been used on IC layouts to ensure size, spacing, and overlap of geometry are correct for a manufacturing process. The application suite described here provides the MEMS designer the capability to check MEMS structures on a remote server yet review the results on a local workstation. This technique maximizes the use of expensive analysis tools and reduces the cost per design.

The design environment at Sandia National Labs uses AutoCAD® Release 14 running on a PC-based Windows NT 4.0 workstation for mask layout. Custom application software written in a combination of AutoLisp[1] functions and shell scripts provide a graphical user interface to invoke the DRC, translation, and interface software. The MEMS design layout, translated into AutoCAD® DXF[1] format is transferred to a remote server via FTP. A commercial translator from Artwork Conversion Software, ASM 3500[2], is used to convert the DXF file to the industry standard GDSII file for mask plotting and for use by the DRC tool. The GDSII file is processed by a commercial design rule checking tool, Mentor Graphics ICVerify[3] , running on a Sun Workstation. The DRC results are translated back into DXF geometry by a Sandia written translator. The DXF file is then transferred back to the Windows NT workstation via FTP to be overlaid onto the original design. Menu functions are provided for the user to interactively review the results inside of AutoCAD® using a first/next/previous technique to step through each error.

PROGRAM DESCRIPTION

The MEMS layout is created in AutoCAD® using 2D polygon, arcs, and circle objects placed on predefined layers on a Windows NT design workstation (Figure 1). Invoking the 'Execute DRC' menu function (Figure 2) causes a DXF file to be created and transferred to the FTP site. A program monitoring the site transfers the DXF file to the MEMS fileserver and invokes the DXF to GDSII translator, ASM 3500. This translator creates closed polygons required for DRC operations and mask generation. It will attempt to close geometry using closeness criteria and may detect objects that cannot be converted. This translator works best when all geometry is created in AutoCAD® using closed polylines or other intrinsically closed

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objects such as circles or rectangles. This technique avoids problems associated with the translator trying to complete open polygons. In addition, construction techniques must be used so that geometry does not contain self-intersecting edges as in a figure eight. The resultant GDSII file is checked for validity and any invalid geometry is translated back into DXF format and placed on an AutoCAD® layer named ERR_GDS_CVT. If GDSII conversion errors are detected, DRC processing is halted and the DXF error file is transferred back to the FTP site for review and correction by the user. These error results are displayed using the DRC error display functions described below.

After the GDSII file has been created, it is loaded into the Mentor Graphics ICverify tool and checked against a set of design rules defined for the Sandia Ultra-planar Multi-level MEMS Technology (SUMMiT)[4] process. Upon executing the DRC, ICverify creates a text file containing the rule violation results. The rule violations consist of sets of coordinates defining edges and polygons enclosing the offending object or area along with a text description of the problem (Figure 4). The results file is translated into a DXF file containing polylines tagged with the error description. The lines are assigned width and color to help the user in locating the error visually. The error description is used to create the AutoCAD® layer name on which the polyline is placed. Major error layer names are prefaced with "ERR" and advisory warnings are prefaced with "ADV". The remainder of the error text is abbreviated to create a valid layer name. A counter is also inserted into the error text identifying the violation. This count is used later when stepping through the error list.

After the rule violation DXF file is created, the file is placed back onto the FTP site. The DRC results are displayed by invoking the 'LOAD DRC results' menu function which retrieves the files from the FTP site and imports the DXF file into the current AutoCAD® drawing file. The geometry is overlaid onto the MEMS design for the user to review using the DRC error display functions..

Functions 'First DRC result', 'Next DRC result', 'Previous DRC result', and 'Last DRC result' are used to interactively step through and review the results. The function 'Query DRC result' is used to display the error text associated with a selected violation.

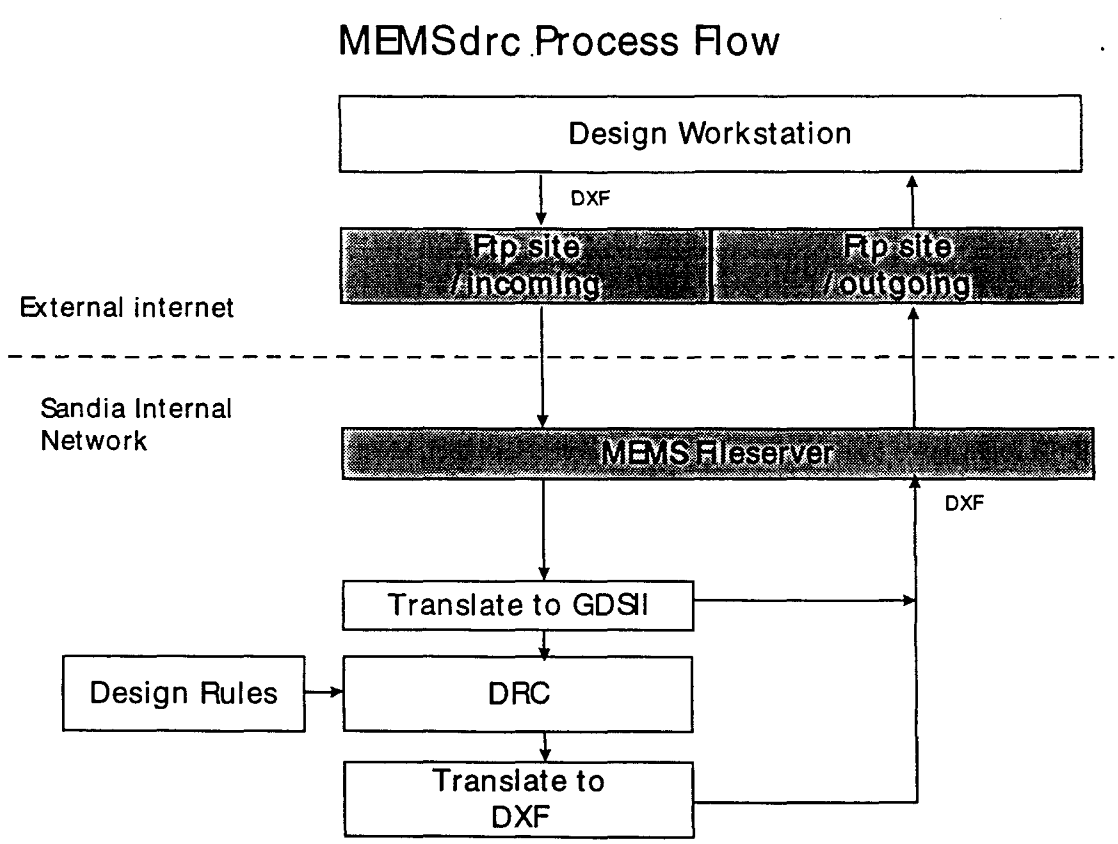


Figure 1. MEMSdrc Process Flow

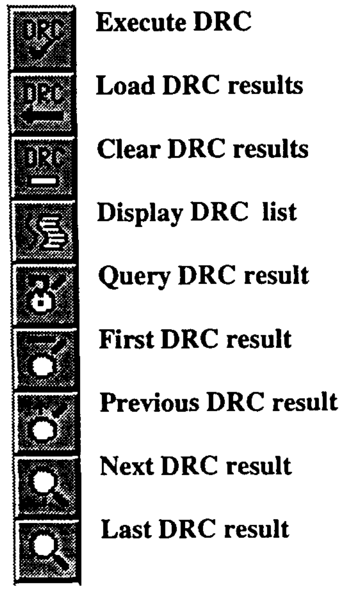


Figure 2. MEMSdrc Menu Bar

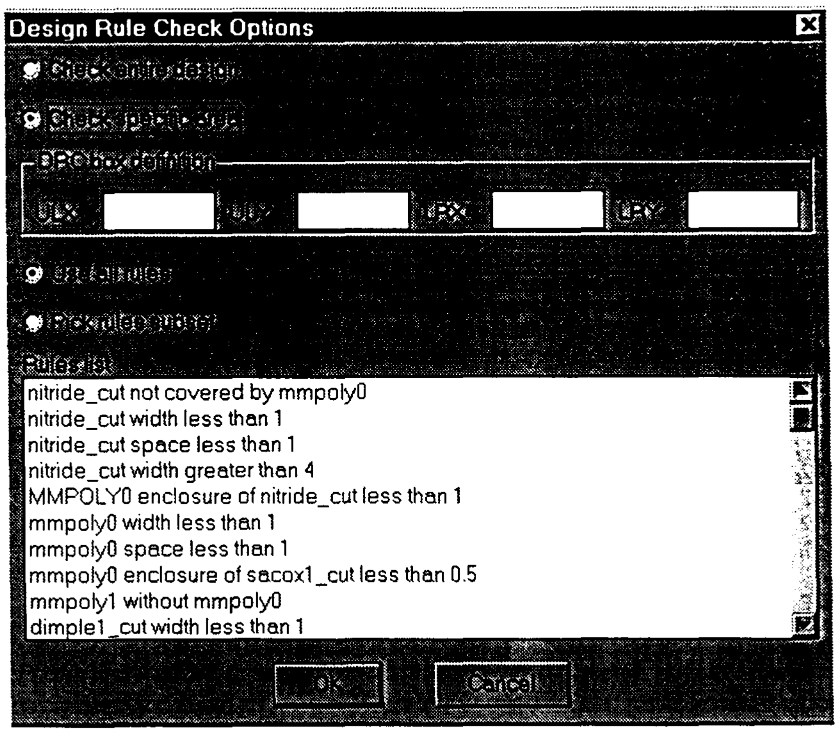


Figure 3. Design Rule Check Options Dialog Box

MEMSdrc is integrated into the AutoCAD® environment using a combination of AutoLisp functions and shell scripts. A menu bar (Figure 2) is provided to activate each of the MEMSdrc functions. Each of the menu buttons is described below:

 **Execute DRC** - This button invokes the design rule check dialog box (Figure 3.). There are two options:

1. `Check entire design / Check specific area`. This option allows the user to enter the window boundary by coordinates of the upper left and lower right corners. If the coordinates are not provided, the user will be prompted to graphically pick the upper left and lower right box corners.

2. `Use all rules / Pick rules subset.` This option allows the user to choose the default rule set or select a subset of the rules listed. All the design rules are listed in the dialog box and can be scrolled up for down to

 **Load DRC results** - This button loads the results into the current AutoCAD® drawing. These results are contained in a DXF file and are separated onto named layers corresponding to the rule names. Wide gray lines are used to display advisory rule violations and orange lines are used to display major rule violations.

 **Clear DRC results** - This button erases the DRC result geometry from the AutoCAD® drawing.

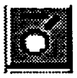
 **Display DRC list** - This button invokes notepad to display the raw ASCII text file of DRC results provided by executing ICverify. An example file is shown in Figure 4. The first line in the listing indicates the total number of DRC results. Each of the following sections contain a DRC result consisting of the following items:

DRC rule name, date, total number of results for this rule,
sequential result number, graphical result type
DRC rule filename
DRC rule file title
DRC rule text description
XY coordinate pairs

```
Total DRC Results:  615
DRC RULECHECK ERR_X1C_WITHOUT_P1_OR_P2  Jan  8 14:10:20 1998 (contains 2 DRC results)
Result number 1  4-vertex polygon
Rule File Pathname: pmem.rules
Rule File Title: MEMS RULES VERSION 11/10/97
sacox1_cut without mmpoly1 or mmpoly2

2356.101 2302.742
2358.101 2302.742
2358.101 2304.742
2356.101 2304.742

DRC RULECHECK ERR_X1C_WITHOUT_P1_OR_P2  Jan  8 14:10:20 1998 (contains 2 DRC results)
Result number 2  4-vertex polygon
Rule File Pathname: pmem.rules
Rule File Title: MEMS RULES VERSION 11/10/97
sacox1_cut without mmpoly1 or mmpoly2

2437.21 989.66
2437.707 973.93
2438.7 958.224
2440.188 942.558
```

Figure 4. DRC Results ASCII list example

 **Query DRC result** - This button allows the user to pick a DRC result and display identifying information about the result: the result number, the DRC rule name, and a text explanation of the rule violation. This information is displayed in the AutoCAD® text window.

 **First DRC result** - This button invokes a dialog box (Figure 5.) that allows the user to select and filter which DRC violations to view. The view window is automatically centered about the violation area (Figure 6-8).

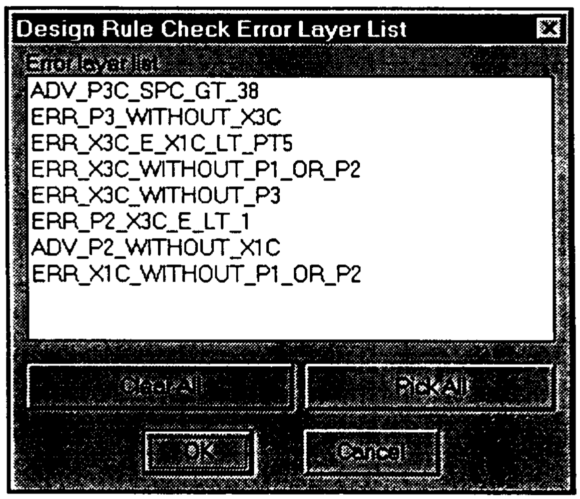
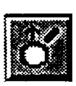


Figure 5. DRC Error Layer List example

 **Previous DRC result** - This button selects the previous DRC violation for viewing. This button can only be used after the DRC filter is selected using the 'First DRC result' button.

 **Next DRC result** - This button picks the next DRC violation for viewing. This button can only be used after the DRC filter is selected using the 'First DRC result' button.

 **Last DRC result** - This button selects the last DRC violation in the sequence. This button can only be used after the DRC filter is selected using the 'First DRC result' button.

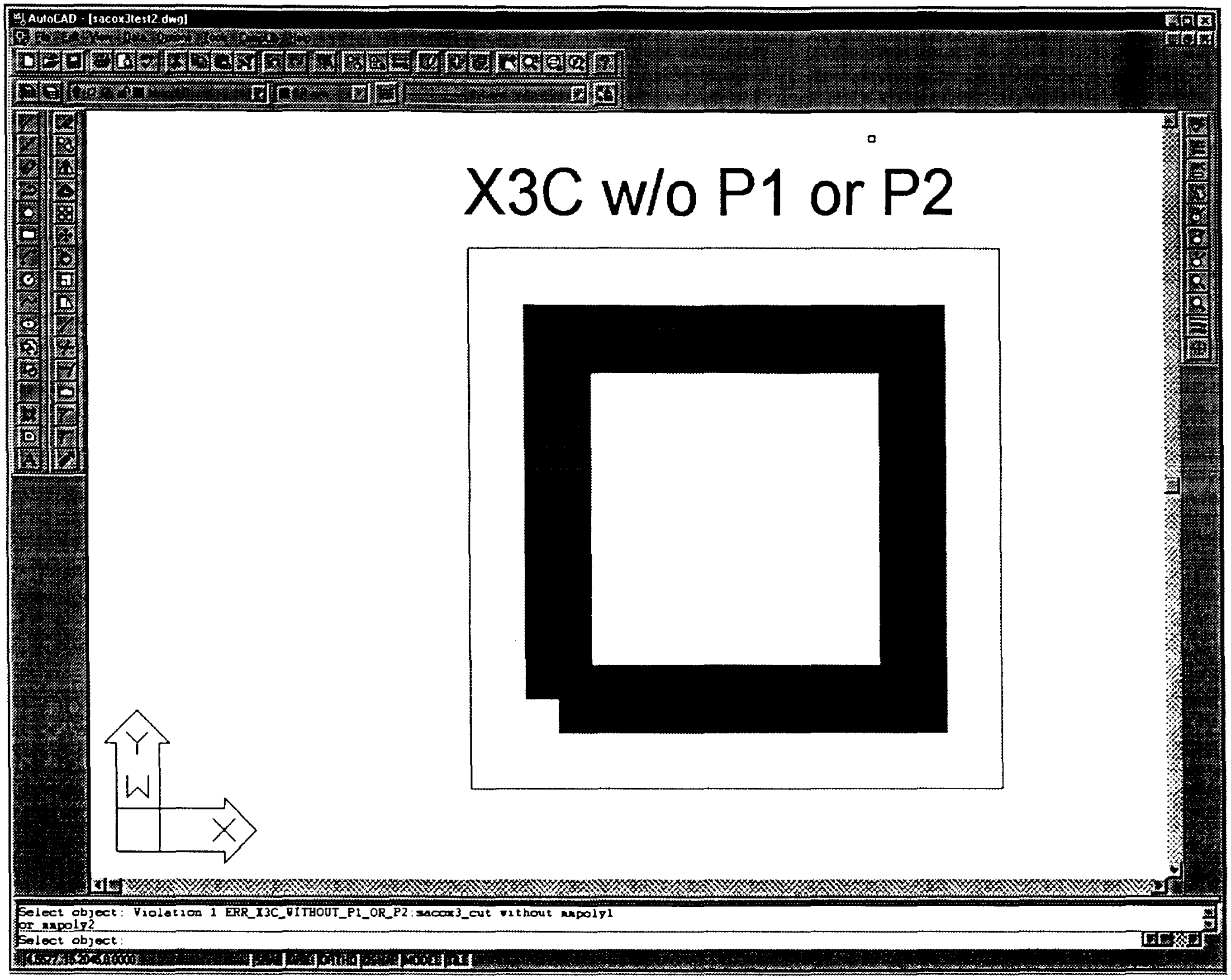


Figure 6. DRC Result Example - Missing Geometry

The example in Figure 6 shows the result of a rule that detected geometry missing from a layer. The SUMMiT process requires specific layer combinations when geometry is present. The wide polygon outlines where the missing geometry was expected.

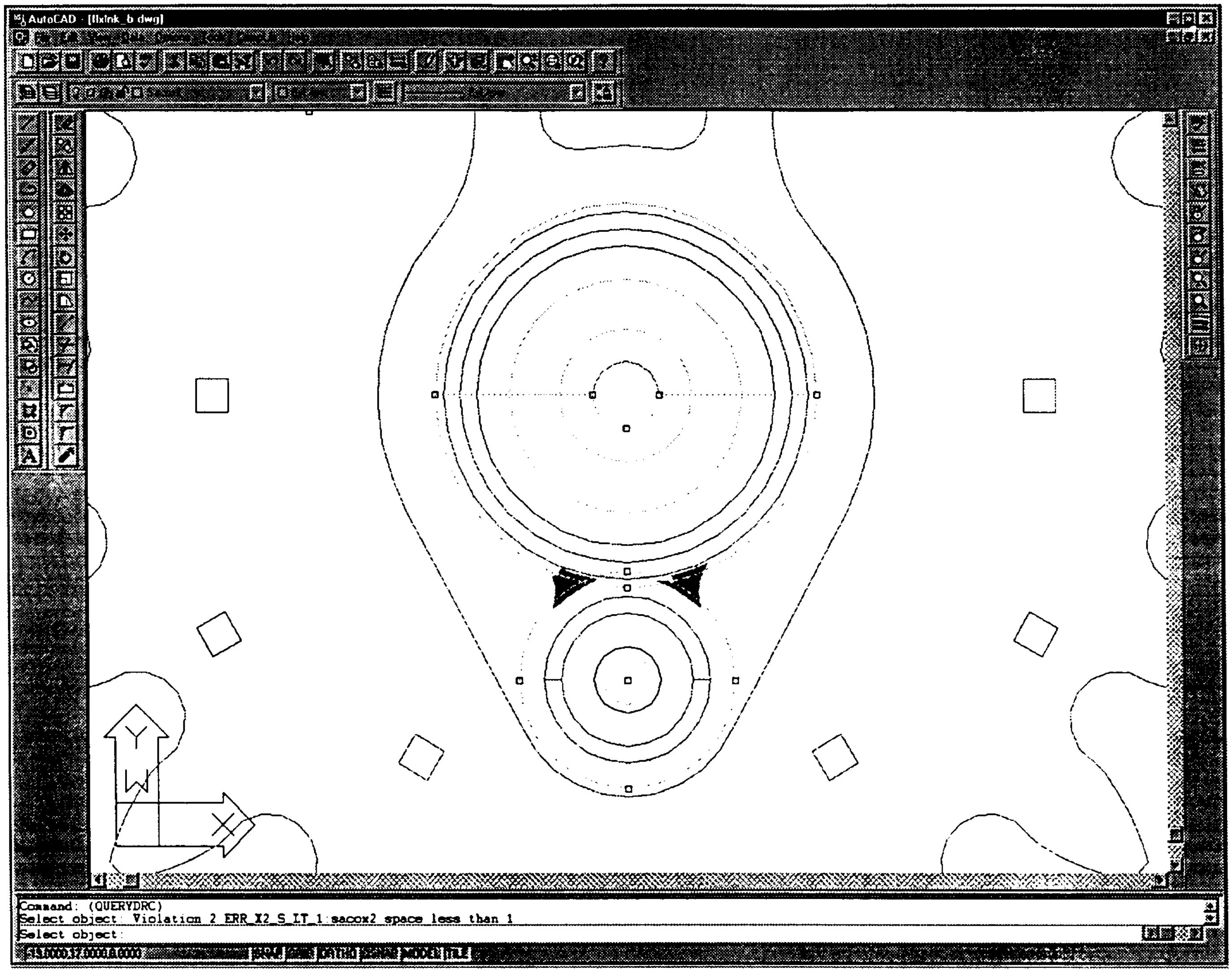


Figure 7. DRC Result Example - Space Violation

The example in Figure 7 shows the result of a rule that detected a space violation. The filled areas designate the problem area. In this example, overlapping two circles created the space violation. This error can be corrected by joining the two circles with a fillet

FUTURE WORK

Future work in this area includes extensions for:

- connectivity extraction - an aid to identify polygons that are electrically and mechanically connected.
- a stand-alone interface to provide access for AutoCAD® LT or other CAD tools that can read and write DXF files.

ACKNOWLEDGEMENTS

This work was supported by the United States Department of Energy under Contract DE-AC04-94AL85000. Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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