THE OFF-LINE PROGRAMMING SYSTEM (OLPS)
A Prototype STEP-Based NC-Program Generator

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TOPICS TO BE COVERED

1. OVERVIEW OF OLPS

2. SNAPSHOTS FROM A SESSION WITH OLPS

3. TECHNICAL DETAILS OF OLPS

4. QUESTIONS AND ANSWERS

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DISCLAIMERS

1. NO ENDORSEMENT OF ANY COMMERCIAL PRODUCT IS INTENDED IN THIS TALK
2. THE OPINIONS EXPRESSED IN THIS TALK ARE MINE ONLY AND NIST DOES NOT NECESSARILY CONCUR
3. OLPS IS A RESEARCH SYSTEM, NOT A PRODUCTION SYSTEM

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WHAT IS OLPS?

1. OLPS IS A SYSTEM FOR AUTOMATICALLY GENERATING NC-PROGRAMS FOR A MACHINING CENTER

2. OLPS IS AN ACRONYM FOR "**O**FF-**L**INE **P**ROGRAMMING **S**YSTEM"

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HOW IS OLPS RELATED TO STEP?

1. OLPS USES SIX TYPES OF INPUT DATA, ALL OF WHICH COME FROM STEP PHYSICAL FILES

2. THE USE OF OLPS SERVES TO TEST VIABILITY OF EXISTING STEP DATA MODELS

3. OLPS DATA REQUIREMENTS REVEAL NEEDS FOR MORE DATA MODELS

4. OLPS SHOULD BE USEFUL AS A TEST CASE IN BUILDING A STEP APPLICATION PROTOCOL FOR MACHINING

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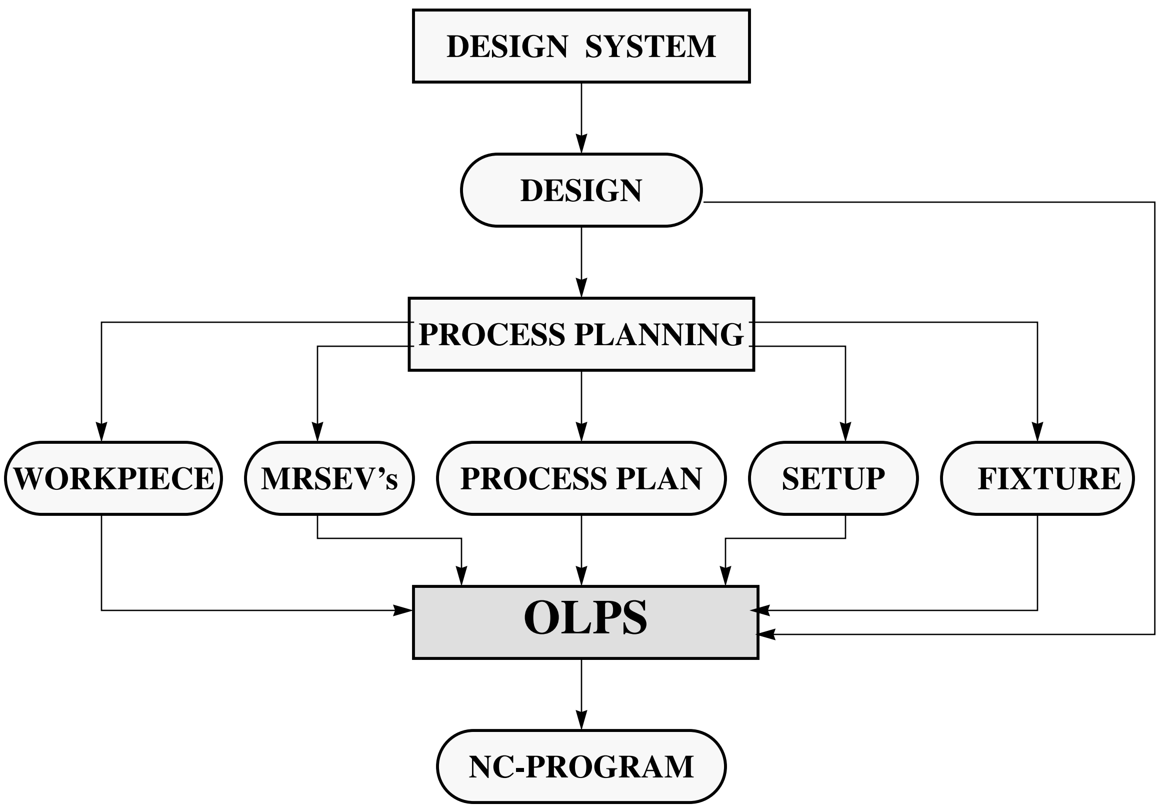
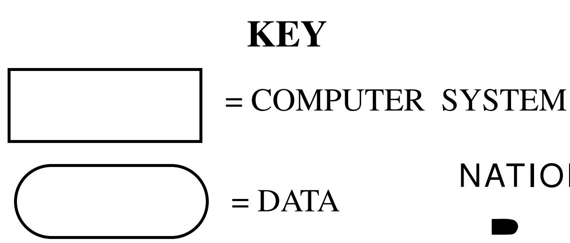
WHAT IS THE CONTEXT FOR OLPS?





WHAT ARE OLPS INPUTS?

ALL INPUTS ARE CONTAINED IN STEP FILES

1. DESIGN OF FINISHED PART
2. DESIGN OF WORKPIECE
3. DESIGN OF FIXTURE
4. MATERIAL REMOVAL VOLUMES
5. PROCESS PLAN
6. SETUP

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WHAT ARE OLPS TOOLING DATABASES?

1. CUTTER CATALOG

2. TOOL HOLDER CATALOG

3. CURRENT TOOLING (CUTTER + HOLDER)

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WHAT ARE OLPS OUTPUTS?

1. NC-PROGRAM IN PSEUDOCODE
2. NC-PROGRAM FOR GE2000 CONTROLLER FOR MONARCH VERTICAL MACHINING CENTER
3. MODELING PROGRAM IN LISP FOR PARASOLID SOLID MODELER
4. TEXT AND PICTURES ON SCREEN FOR USER

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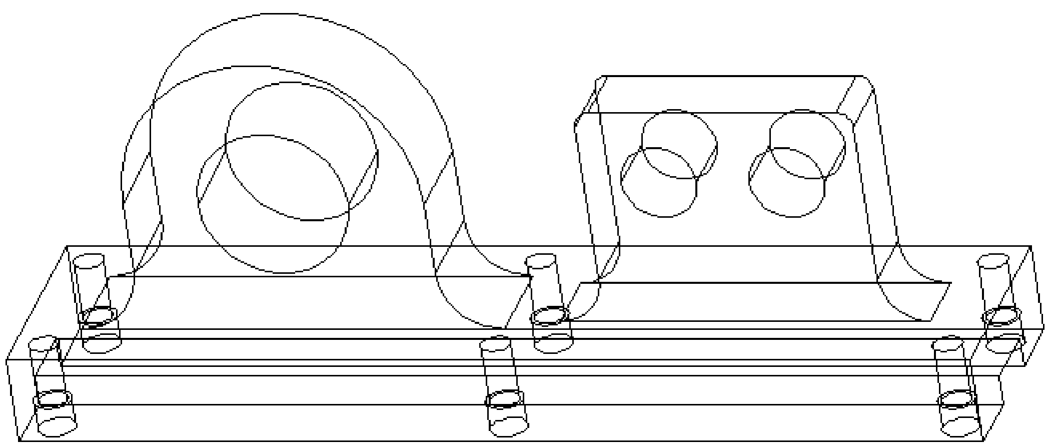
WHAT PARTS DOES OLPS HANDLE?

1. PRISMATIC PARTS
2. SURFACES MUST BE PLANAR, CYLINDRICAL, OR CONICAL
3. EDGES MUST BE STRAIGHT LINES OR ARCS OF CIRCLES (including complete circles)



EXAMPLE PART

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WHAT COMPUTER SYSTEM RUNS OLPS?

1. OLPS RUNS ON SUN3 COMPUTERS

2. OLPS RUNS UNDER THE SUN OPERATING SYSTEM, RELEASE 4.1

3. OLPS USES THE SUNVIEW WINDOW SYSTEM

4. OLPS REQUIRES AT LEAST 6 MEGABYTES OF RAM MEMORY

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WHAT IS OLPS SOFTWARE?

1. OLPS IS WRITTEN IN ALLEGRO COMMON LISP - ABOUT 12,000 LINES OF CODE AND 2,000 LINES OF DATA

2. OLPS USES SUNCORE GRAPHICS

3. OLPS USES THE PARASOLID SOLID MODELING SYSTEM OFF-LINE

4. A PARASOLID-TO-STEP CONVERTER HAS BEEN WRITTEN IN C FOR OFF-LINE USE

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HOW IS OLPS DIFFERENT?

1. TOTALLY STEP-BASED - ***UNIQUE***

2. USES PROCESS PLAN DEFINED IN A NON-PROPRIETARY LANGUAGE (ALPS +) DEFINED IN A FORMAL INFORMATION MODELING LANGUAGE (EXPRESS) - ***RARE***

3. USES MATERIAL REMOVAL VOLUMES DEFINED INDEPENDENTLY FROM PART DESIGN - ***RARE***

WHAT ARE OLPS LIMITATIONS?

1. MODEST RANGE OF PARTS
2. OBSOLETE INADEQUATE GRAPHICS
3. NO APT
4. MODELER NOT FULLY INTEGRATED
5. NO VERIFICATION SYSTEM
6. DOES NOT HANDLE FULL MRSEV LIBRARY
7. NO INTERACTIVE NC-PROGRAMMING
8. NO ERROR RECOVERY CAPABILITY
9. HELP SYSTEM HAS LITTLE TO SAY
10. LIMITED AUTOMATIC-MANUAL SWITCH

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WHAT IS THE FUTURE OF OLPS?

1. OLPS WILL BE DOCUMENTED

2. OLPS MIGHT BECOME PART OF A STEP-BASED MACHINING WORKSTATION IN CONNECTION WITH PDES TESTBED WORK AT NIST

3. OLPS MIGHT BE RECODED IN C OR C++

4. FUTURE WORK MIGHT BE DIRECTED TO REMOVING LIMITATIONS

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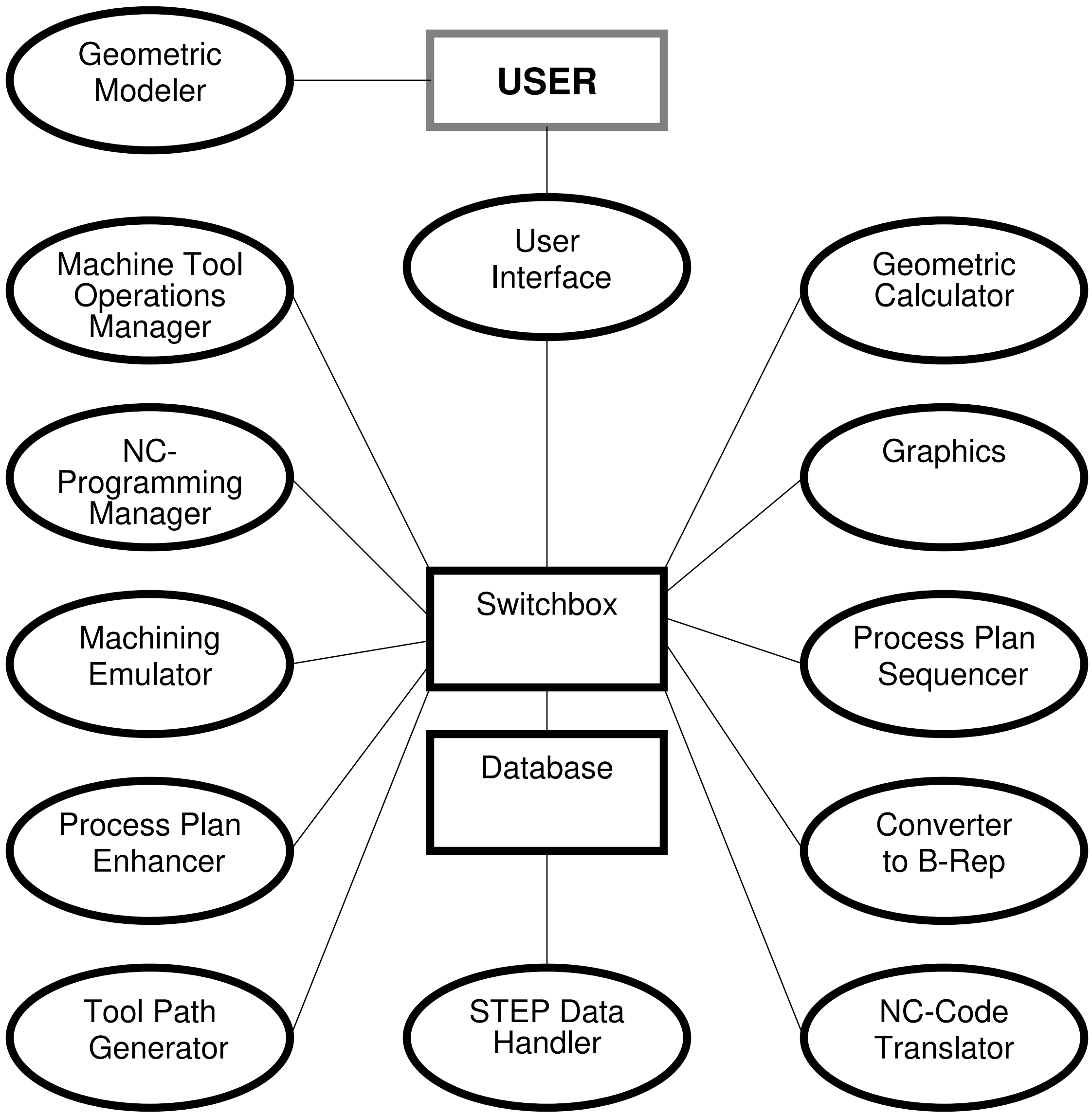
OLPS MAJOR COMPONENTS



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WHAT IS A PROCESS PLAN FOR OLPS?

1. A PROCESS PLAN FOR OLPS IS A LIST OF MACHINING PROCESSES TO BE CARRIED OUT, PLUS DATA FOR DETERMINING THE SEQUENCE OF THE PROCESSES

2. PROCESS PLANS ARE READ IN FROM STEP PHYSICAL FILES PREPARED ACCORDING TO AN EXPRESS SCHEMA FOR THE ALPS PROCESS PLANNING LANGUAGE, WITH MACHINING PROCESSES ADDED

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WHAT MACHINING PROCESSES DOES OLPS SUPPORT?

1. CENTER-DRILL

2. COUNTERBORE

3. FINISH-MILL

4. ROUGH-MILL

5. SET-0-CORNER

6. TWIST-DRILL

WHAT INFORMATION IS IN ONE STEP?

Step 12 From Second Cut on Clevis2

FROM ALPS

type	rough_mill
node_name	"ROUGH POCKET 31"
node_number	"12"
node_type	"ROUGH_MILL"
checkpoint_flag	"1"
qualified_by	nil
preceded_by	(step 8)
succeeded_by	nil
work-element	"ROUGH_MILL"
requires	nil
duration	10
earliest_start	nil
latest_start	nil
earliest_completion	nil
latest_completion	nil
tool-type-id	ruf-mill-0.625-4
mrsev	"OTHER_POCKET31"
spindle_speed	3500
feed-rate	17.0
pass-depth	0.625
stepover	0.375

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WHAT IS A MRSEV?

1. A MRSEV DESCRIBES THE SHAPE OF A VOLUME OF SPACE ASSOCIATED WITH A MACHINING PROCESS

2. WHEN THE MACHINING PROCESS IS COMPLETE, THERE MUST BE NO MATERIAL REMAINING IN THE VOLUME

3. NO MATERIAL OUTSIDE OF THE VOLUME MAY BE REMOVED BY THE PROCESS

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WHAT MRSEV TYPES ARE USED IN OLPS?

1. HOLE

2. RECTANGULAR POCKET

3. OTHER POCKET

4. RECTANGULAR POCKET WITH ISLANDS

5. OTHER POCKET WITH ISLANDS

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WHAT DATA DEFINES A MRSEV?

1. MRSEV'S ARE READ IN FROM STEP PHYSICAL FILES PREPARED ACCORDING TO AN EXPRESS SCHEMA FOR MRSEV's BUILT ON TOP OF THE STEP GEOMETRY, TOPOLOGY, AND FORM FEATURES MODELS

2. THIS IS SAMPLE FILE DATA USED TO DEFINE A MRSEV WHICH IS A HOLE

```
@2  = DIRECTION ( , 0.0, 0.0, 1.0);
@3  = DIRECTION ( , 1.0, 0.0, 0.0);
@301  = CARTESIAN_POINT ( , 1.8, 1.5, 0.3);
@305  = AXIS2_PLACEMENT ( , #301, #2, #3);
@306  = HOLE (#305, 0.8, , 0.5);
@307  = MATERIAL_REMOVAL_VOLUME
          ('HOLE30', (#306), );
```

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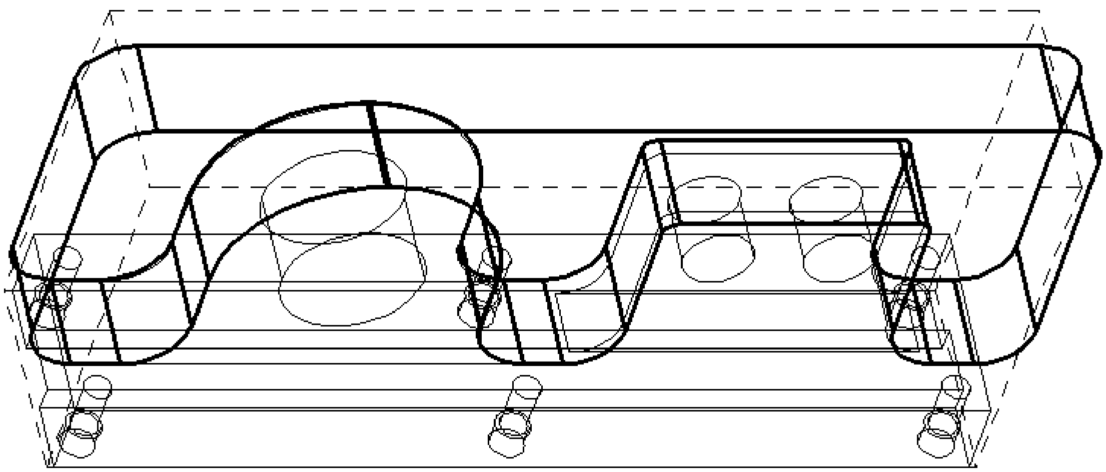
WHAT DOES A MRSEV LOOK LIKE?

An Other Pocket MRSEV



In this figure, the MRSEV "other_pocket31" is shown with a heavy outline, superimposed on a picture of the design (light solid outline) and the workpiece (light dashed lines).

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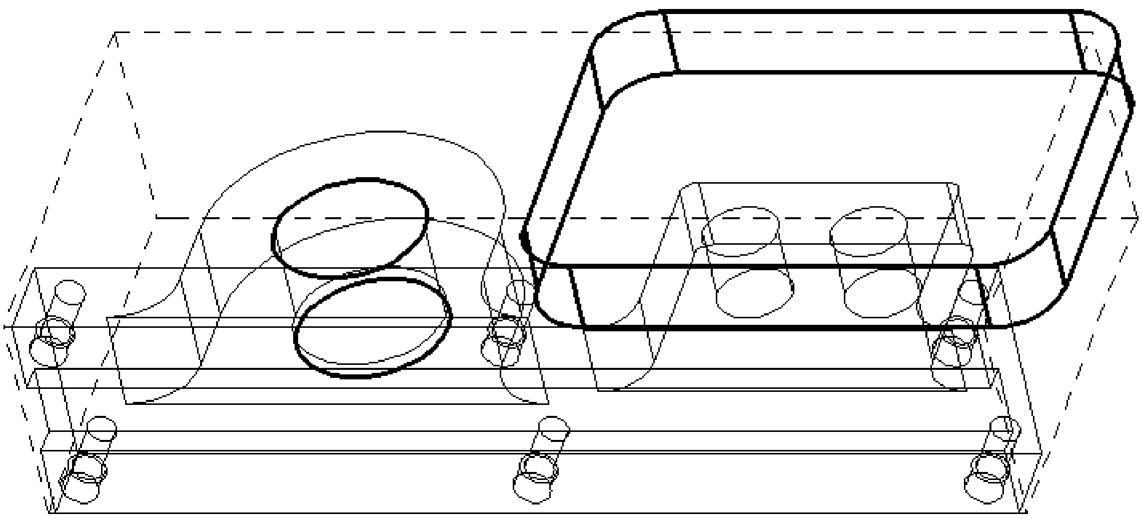
WHAT DOES A MRSEV LOOK LIKE?

Hole and Rectangular Pocket MRSEV's



In this figure, the MRSEV's "rectangular_pocket23" and "hole30" are shown with a heavy outline, superimposed on a picture of the design (light solid outline) and the workpiece (light dashed lines).

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WHAT HAPPENS WHEN ONE MACHINING PROCESS PLAN STEP IS EXECUTED?

1. THE STEP IS DISPLAYED

2. THE MRSEV OF THE STEP IS DRAWN

3. A TOOL OF THE GIVEN TYPE IS SELECTED

4. A SEGMENT OF MODELER CODE (not displayed) IS WRITTEN TO SUBTRACT THE MRSEV FROM THE WORKPIECE

5. A BLOCK OF NC-PSEUDOCODE IS WRITTEN AND DISPLAYED

6. THE PSEUDOCODE IS CONVERTED TO B-REP FORM AND DISPLAYED

7. THE LISTS OF DONE, READY, AND WAITING STEPS ARE READJUSTED

8. THE NEXT STEP TO EXECUTE IS SELECTED

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WHAT MODELING IS DONE?

1. WHEN IT RUNS, OLPS WRITES A COMMAND FILE FOR THE "KID" INTERFACE TO PARASOLID

2. WHEN THE COMMAND FILE IS LOADED INTO KID, PARASOLID BUILDS A MODEL OF THE SOLID RESULTING FROM SUBTRACTING ALL THE MRSEV's FROM THE WORKPIECE

3. MODELS OF EACH INTERMEDIATE SHAPE OF THE WORKPIECE AND THE INTERSECTION OF EACH MRSEV WITH THE WORKPIECE (what actually gets cut away) CAN ALSO BE SAVED

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WHAT DOES KID CODE LOOK LIKE?

HERE ARE THE FIRST 10 LINES OF A KID MODELING PROGRAM WRITTEN BY OLPS

```
(modeller start)
(load “plisp/load_functions.l”)
(define workpiece body)
(workpiece receive “olps_workpiece_in.xmt_txt”)
(translate_body -0.1 0.0 0.0)
(init_graphics)
(make_pocket ‘rectangular_pocket1
        1.75 1.91 1.11 4.4 2.6 0.39 0.4)
(workpiece subtract ‘rectangular_pocket1)
(graphics clear)
(graphics sketch ‘workpiece)
```

WHAT ARE OLPS GRAPHICS CAPABILITIES?

1. OLPS USES SUNCORE GRAPHICS

2. BLACK AND WHITE

3. USER INTERFACE USES 2-DIMENSIONAL DRAWING WITH BITMAP ICONS

4. MILLING AREA DISPLAY USES 3-DIMENSIONAL WIRE-FRAME DRAWING WITH VIEW CONTROL INCLUDING SCALING, ROTATION, AND TRANSLATION

5. MILLING AREA DISPLAY HAS INDEPENDENT VISIBILITY CONTROL OF:
   - WORKPIECE
   - DESIGN
   - FIXTURE
   - MRSEV's
   - TOOL PATH

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WHAT ARE OLPS USER INTERFACE PRINCIPLES?

1. THE USER SHOULD HAVE A CHOICE OF MOUSE OR KEYBOARD CONTROL

2. USER OPTIONS SHOULD BE BROADLY AVAILABLE

3. ON-LINE HELP SHOULD BE EASILY AVAILABLE

4. THE SYSTEM SHOULD RUN EITHER AUTOMATICALLY OR INTERACTIVELY, WITH GRACEFUL TRANSITIONS

5. GRAPHICS SHOULD BE USED EXTENSIVELY FOR BOTH INPUT FROM THE USER AND FEEDBACK TO THE USER

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HOW DOES THE USER INTERACT WITH THE USER INTERFACE SYSTEM?

1. COMMANDS ARE GIVEN BY PICKING ICONS WITH A MOUSE OR BY KEYBOARD INPUT

2. OPTIONS ARE ENTERED ON CONTROL PANELS BY PICKING RADIO BUTTONS WITH THE MOUSE OR BY ENTERING TEXT IN TEXT BOXES WITH THE KEYBOARD

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WHAT ARE THE INTERNALS OF THE USER INTERFACE SYSTEM?

1. SCREEN LAYOUT IS DATA DRIVEN
   - LOCATION, HIGHLIGHTING, VISIBILITY, AND DETECTABILITY OF ICONS
   - CONTENT AND LAYOUT OF CONTROL PANELS

2. THE TOP LAYERS OF CONTROL ARE DATA DRIVEN

3. ABOUT 370 LINES OF DATA ARE REQUIRED

WHAT DOES PSEUDOCODE LOOK LIKE?

HERE ARE 10 LINES FROM A PSEUDOCODE PROGRAM WRITTEN BY OLPS

```
(use-program-xy-zero)
(set-spindle-speed 3500)
(set-feed-rate 17.0)
(start-spindle-clockwise)
(comment milling a rectangular pocket)
(rapid x 0.8999999999999999 y 1.91)
(rapid z 1.6)
(flood-on)
(set-feed-rate 8.5)
(cut-straight x 0.8999999999999999 y 1.91 z 1.5)
```

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WHAT DOES GE2000 CODE LOOK LIKE?

HERE ARE THE 6 LINES OF GE2000 CODE PRODUCED BY OLPS FROM 10 LINES OF PSEUDOCODE

```
n0260 g56 g90 x(p66) y(p67)
n0270 f17.0 s3500 m3
n0280 ! milling a rectangular pocket
n0290 g0 x+0.9 y+1.91
n0300 g0 z+1.6
n0310 g1 y+1.91 z+1.5 f8.5 m8
```

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HOW WAS OLPS DEVELOPED?

1. OLPS IS A SUCCESSOR TO THE DATA EXECUTION MODULE OF THE VWS2 SYSTEM OF THE NIST AMRF

2. OLPS DEVELOPMENT BEGAN IN LATE 1987 AND HAS CONSUMED ONE MAN-YEAR SINCE THEN

3. OLPS DEVELOPMENT WAS UNDERTAKEN ORIGINALLY IN CONNECTION WITH THE "MANUFACTURING DATA PREPARATION PROJECT"

4. OLPS DEVELOPMENT CONTINUED AT A REDUCED LEVEL IN CONNECTION WITH THE "MANUFACTURING SYSTEMS INTEGRATION PROJECT"

5. QUICK CHANGES TO OLPS HAVE BEEN UNDERTAKEN AS PART OF NIST WORK ON PDES/STEP

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WHAT ARE OTHER OLPS SPECIAL FEATURES?

1. GENERAL STEP FILE READER AND LISP WORKING FORM

2. STEP FEATURES (MRSEV's) TO B-REP CONVERTER

3. NC-CODE GENERATOR FOR ROUGH CUTTING GENERALIZED POCKETS WITH ISLANDS INCLUDES MINIMAL ENGAGEMENT DETECTION

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