THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Proceedings of the REAPS Technical Symposium

Paper No. 25: Integrating Shipyard Design and Manufacturing Functions into an Existing CAD/CAM System

U.S. DEPARTMENT OF THE NAVY CARDEROCK DIVISION, NAVAL SURFACE WARFARE CENTER
**Report Documentation Page**

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INTEGRATING SHIPYARD DESIGN AND MANUFACTURING FUNCTIONS INTO AN EXISTING CAD/CAM SYSTEM

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Manufacturing and Consulting Services Incorporated
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Dr. Hanratty is founder and President of Manufacturing and Consulting Services Inc, a firm providing consulting services, OEM interactive graphic systems, and turn-key end-user interactive graphic systems. He holds a degree in mathematics from Arizona State University, and a masters degree in systems engineering from West Coast University. He received his Doctorate in information and computer science from the University of California at Irvine.

Prior to his involvement with Manufacturing and Consulting Services Inc, Dr. Hanratty held the positions of President at Integrated Computer Systems, Manager of Automation Methods at Douglas Astronautics, Manager of Process Control at General Electric Computer Department, and Designer at General Motor Research Labs.
AD-2000 FUNCTIONS

1 MODALS AND FONTS
2 BLANK/UNBLANK
3 DELETE
4 FILE/TERM NATE
5 SPECIAL FUNCTIONS/APPLICATIONS
6 DATA BASE MANAGEMENT
7 INPUT/OUTPUT/REGENERATION
8 DISPLAY/DEPTH CONTROL
9 POI NT
10 LI NE
11 ARC/CI RCL/E FILL ET
12 OTHER CURVES
13 ENTITY MANIPULATION
14 DATA VERIFY
15 EXTENDED GEOMETRY
16 DRAFTING
17 N/C MACHINING
18 ANALYSIS
19 SI/ENGLISH/RESIZE

FUNCTION CONTROL KEYS

[ = REJECT
] = OPER ATION COMPLE TE
C = READ CROSSHAI R CURSOR
Y = YES
N = NO
M = CHANGE MENU DISPLAY
R = REPAI R THE DISPLAY
Z = WIN DOW (ZOU M)
D = CHANGE DEPTH
P = AD-2000 FUnCTI ONS
C = POI NT
P = LI NE
C = ARC/CI RCL/E
D = DELETE LAST ENTITY
P = MOMENTARY POI NT SELECT
L = MOMENTARY LI NE SELECT
C = MOMENTARY ARC SELECT
T = MOMENTARY OTHER CURVES SELECT
R = MOMENTARY SPLINE SELECT
T = MOMENTARY TEXT SELECT
? = "HELP" FUNCTION
' = DATA CAPTURE
; =

1 MODALS AND FONTS

1 MENU DISPLAY
2 CONSTRUCTI ON MODAL
3 DI SPAY TOLERANCE
4 SYSTEM DECIMAL PLACES
5 CURVE FON T
6 MODIFY ENTITY FON T
7 MODIFY ENTITY LEVEL/PEN NO.
8 SURFACE PATHS
9 CURSOR MODE
10 VIEW VECTORS
11 SEQ. NO./POINTER SELECT
12 DISPLAY MODAL STATUS
13 DISPLAY TITLE BLOCK

1-5 CURVE FON T

1 SOLID
2 DASHED
3 PHANTOM
4 CENTERLINE

1-6 MODIFY ENTITY FON T

1 SOLID
2 DASHED
3 PHANTOM
4 CENTERLINE

2 BLANK/UNBLANK

1 BLANK ALL OF A SPECIFI C TYPE
2 BLANK ALL EXCEPT A SPECIFI C TYPE
3 BLANK ALL
4 BLANK SELECT FROM SPECIFI C TYPE
5 BLANK SELECT FROM ALL
6 BLANK ALL EXCEPT N1 TO N2
7 BLANK LEVELS
8 UNBLANK ALL
9 UNBLANK ALL OF A SPECIFI C TYPE
10 UNBLANK ALL EXCEPT A SPECIFI C TYPE
11 UNBLANK N1 TO N2
12 UNBLANK LEVELS

2 & 3 ENTITY TYPES

1 POI NTS
2 LINES AND POI NT SETS
3 ARC S AND CI RCL/ES
4 OTHER CURVES
5 ARRAYS AND GROUPS
6 EXTENDED GEOMETRY
7 LABELS, DIMENSIONS AND NOTES
8 CENTERLINES
9 CROSS-HATCHING
10 POI NT-TO-POI NT PATHS
11 N/C PATHS (NON POI NT-TO- POI NT)
5 SPECIAL FUNCTIONS

1 CANON
2 GRAPL-II
3 MANAGE VARIABLES
4 USER DEFINED SYMBOLS
5 LEVEL MANAGEMENT
6 ATTRIBUTE MANAGEMENT
7 DATA GRAPHS*
8 APPLICATIONS

5-2 GRAPL-II
1 VARIABLE CALCULATION
2 INPUT/EDIT GRAPL-II PROGRAMS*
3 AUTO GRAPL-II**
4 RUN GRAPL-II PROGRAM*

5-3 MANAGE VARIABLES
1 MOVE VARIABLES FROM UTF TO RTL
2 MOVE VARIABLES FROM RTL TO UTF
3 LIST TECHNOLOGY FILE VARIABLES
4 LIST RUN TIME LIBRARY VARIABLES

5-5 LEVEL MANAGEMENT
1 CHANGE LEVEL/PEN NO.
2 DEFINE LEVELS
3 LIST LEVELS
4 DELETE LEVELS
5 INITIALIZE LEVELS

5-6 ATTRIBUTE MANAGEMENT
1 CREATE
2 INTERROGATE
3 DELETE**

5-6-2 INTERROGATE
1 RETRIEVE
2 IDENTIFY MINIMUM
3 IDENTIFY MAXIMUM
4 FIND TOTAL
5 CONSTRAINED RETRIEVE
6 DISPLAY

5-6-2-5 CONSTRAINT RELATIONALS
1 LESS THAN
2 LESS THAN OR EQUAL
3 EQUAL
4 NOT EQUAL
5 GREATER THAN OR EQUAL
6 GREATER THAN

5-7-1 DATA GRAPHS*

5-7-1 DATA GRAPH TEMPLATE MODES
1 RETRIEVE
2 SELECT FROM SCREEN
3 CREATE

5-7-1 GRAPH TYPE
1 LINEAR
2 POLAR
3 PIE

5-7-1 PLOT TYPES
1 POINT PLOT
2 LINE PLOT
3 FUNCTION
4 HISTOGRAM
5 HORIZONTAL BAR GRAPH
6 VERTICAL BAR GRAPH

6 DATA BASE MANAGEMENT

6-1 PART MANAGEMENT
1 SAVE PARTS ON TAPE
2 RESTORE PARTS FROM TAPE
3 LIST ON-LINE PART FILE
4 COPY PART UNDER NEW NAME
5 DELETE A PART
6 CHANGE PART STATUS
7 MERGE INTO CURRENT PART**

6-2 PATTERN MANAGEMENT
1 CREATE A PATTERN
2 RETRIEVE A PATTERN
3 DELETE A PATTERN
4 LIST ON-LINE PATTERN FILE
5 INITIALIZE PATTERN LIBRARY
6 SAVE PATTERNS ON TAPE**
7 RESTORE PATTERNS FROM TAPE**

6-3 TEMPLATE MANAGEMENT**
1 CREATE A TEMPLATE
2 RETRIEVE A TEMPLATE
3 DELETE A TEMPLATE
4 LIST ON-LINE TEMPLATE FILE
5 INITIALIZE TEMPLATE LIBRARY

* NOT AVAILABLE ON 16 BIT COMPUTERS
** AVAILABLE DECEMBER, 1979
9 POINT
1 SCREEN POSITION
2 KEY-IN COORDINATES
3 POLAR
4 DELTA
5 VECTORED
6 CIRCLE CENTER
7 ON A CIRCLE AT AN ANGLE
8 CURVE ENDPOINT
9 INTERSECT ON OF TVD CURVES
10 REGENERATE SPLINE POINTS
11 ON A LINE
12 CURVE NORMAL POINT
13 BEARING/DISTANCE
14 ON A CURVE AT A PARAMETER
15 SURFACE NORMAL/PERPENDICULAR POINT
16 SPHERICAL
17 FAN POINTS
18 INCREMENTAL POINTS
19 MODIFY/REPLACE

10 LINE
1 SCREEN POSITION
2 KEY-IN COORDINATES
3 JOIN OF TWO POINTS
4 TANGENT TO TWO CURVES
5 THRU POINT AND HORIZONTAL OR VERTICAL
6 THRU POINT AND TANGENT TO A CURVE
7 POLAR LINE
8 THRU POINT AND PARALLEL TO A LINE
9 THRU POINT AND PERPENDICULAR TO A LINE
10 PARALLEL TO A LINE AT A DISTANCE
11 PARALLEL TO A LINE, TANGENT TO A CURVE
12 PERPENDICULAR TO A LINE, TANGENT TO A CURVE
13 DIVIDE LINE INTO N SEGMENTS
14 JOIN TWO CURVES
15 MODIFY STATUS (INFINITY/NON-INFINITY)
16 AXES DEFINITION
17 CHAMFER
18 MODIFY/REPLACE

11 ARC/CIRCLE/FILLET
1 SCREEN POSITION AND RADIUS
2 KEY-IN CENTER AND RADIUS
3 CENTER POINT AND RADIUS
4 CENTER POINT AND TANGENT LINE
5 CENTER POINT AND TANGENT CIRCLE
6 CENTER POINT AND POINT ON EDGE
7 THROUGH THREE POINTS
8 MODIFY ANGLES
9 FILLET
10 INSCRIBE IN THREE LINES
11 NORMAL TO VIEW
12 MODIFY/REPLACE

12 OTHER CURVES
1 SPLINE
2 OFFSET CURVE
3 CONIC
4 STRING
5 MAKE STRING FROM LINES/ARCS
6 MAKE LINES/ARCS FROM STRING
7 N-GON
8 TRIM CURVES
9 CONVERT STRING TO POINT SET CURVE

12-3 CONIC
1 ELLIPSE
2 HYPERBOLA
3 PARABOLA
4 GENERAL CONIC
5 LOFT CONIC
6 RHO CONIC
7 CYLINDER SLICE

12-4 STRING
1 SCREEN POSITION
2 KEY-IN COORDINATES
3 EXISTING POINTS
4 DELTA
5 POLAR
6 BEARING
7 CW ARCS
8 CCW ARCS
9 CONNECT TO CURVE
10 INDICATE ARC
11 CLOSE OPTIONS

12-7 N-GON
1 TRIANGLE
2 RECTANGLE
3 HEXAGON

12-8 TRIM MODE
1 ONE END
2 BOTH ENDS
3 MIRROR
4 TVD CURVES AT INTERSECTION
13 ENTITY MANIPULATION
1 RECTANGULAR ARRAY
2 CIRCULAR ARRAY
3 GROUP
4 MIRROR
5 TRANSLATE
6 ROTATE
7 DUPLICATE AND TRANSLATE
8 DUPLICATE AND ROTATE
9 ARRAY EXPLODE
10 STRETCH

14 DATA VERIFY
1 POINTS
2 LINES
3 ARCS AND CIRCLES
4 SPLINES
5 ELLIPSES
6 HYPERBOLAS
7 PARABOLAS
8 ARRAYS
9 GROUPS
10 GENERAL MEASUREMENTS
11 DRAFTING ENTITIES
12 TRIANGLES, RECTANGLES, HEXAGONS

15 EXTENDED GEOMETRY
1 3-D CURVES
2 SURFACES
3 SOLIDS
4 CROSS SECTION SLICE
5 DEVELOPABLE SURFACE LAYOUT

15-1 3-D CURVES
1 3-D SPLINE
2 SURFACE EDGE CURVE
3 SURFACE INTERSECTION CURVE
4 DRAFT OR MACHINE CURVE
5 COMPOSITE CURVE
6 VECTOR

15-2 SURFACES
1 PLANE
2 SURFACE OF REVOLUTION
3 3-D TABULATED CYLINDER
4 RULED SURFACE
5 DEVELOPABLE SURFACE
6 CURVE MESH SURFACE
7 FILLET SURFACE*
8 OFFSET SURFACE
9 SPHERE
10 CYLINDER
11 TORUS
12 CONE
13 COMPOSITE SURFACE
14 CHANGE PARAMS FOR NEW SURFACE
15 PROJECTED SURFACES
16 CURVE DRIVEN SURFACE

15-1-6 VECTOR
1 SCREEN POSITION
2 KEY-IN
3 TWO POINTS
4 PLANE UNIT NORMAL
5 SCALAR TIMES VECTOR
6 CROSS TWO VECTORS
7 NORMALIZED VECTOR
8 THRU PT AT GIVEN LENGTH & ANG
9 INTERSECTION OF TWO PLANES
10 SUM OR DIFFERENCE OF TWO VECTORS
11 THRU A PT AT ANG WITH LINE/VECTOR

* NOT AVAILABLE ON 16 BIT COMPUTERS
15-2-1 PLANE
1 COEFFICIENTS
2 THRU THREE NON-COLLINEAR POINTS
3 THRU A POINT AND PARALLELS TO A PLANE
4 PARALLEL TO A PLANE AT A DISTANCE
5 THRU A POINT AND PERP TO A VECTOR
6 THRU TWO PT AND PERP TO A PLANE
7 THRU A PT AND PERP TO TVD PLANES
8 TVD Li NES

15-3 SOLIDS
1 HEXAHEDRON
2 SPHEROID
3 CIRCULAR ROD
4 TOROID
5 ELLIPTIC
6 PROJECTED***
7 ROTATED***
8 FROM ORTHOGONAL VI EW***
9 SI MULTANEOUS MULTI- VIEW CONSTRUCT***
10 COMPOSITION***

16 DRAFTING FUNCTIONS
1 DRAFTING MODALS
2 PROJECTED ENTITIES
3 CROSS-HATCHING
4 HORIZONTAL DIMENSIONS
5 VERTICAL DIMENSIONS
6 PARALLEL DIMENSIONS
7 ANGULAR DIMENSIONS
8 CIRCULAR DIMENSIONS
9 DIAMETER DIMENSIONS
10 GENERAL NOTE
11 GENERAL LABEL
12 CENTERLINE
13 MODIFY DRAFTING ENTITIES
14 DETAIL LINES CAT ON
15 BALLOON
16 TRUE POSITI ON SYMBOLS
17 ARROWHEAD AT END OF LINE
18 THICKNESS DEMENTS

16-1 DRAFTING MODALS
1 CHARACTER SIZE
2 VITNESS LINE CONTROL
3 TEXT/ARROW CONTROL
4 AUTOMATIC DIMENSIONS
5 KEY-IN DIMENSIONS
6 CROSS-HATCHING MATERI AL
7 DECIMAL PLACES
8 FRACTION DIMENSIONS
9 LABEL AND DIMENSION ORIGIN
10 ARROWHEAD ALIGMENT
11 DRAFTING SCALE FACTOR
12 CHARACTER SET CONTO
13 SLANT STATUS (ON/OFF)
14 CHARACTER, D SPLAY RATIO
15 ARROWHEAD LENGTH
16 DI MENSIONS OFFSET DISTANCES
17 TEXT ANGLE CONTROL
18 DUAL DIMENSIONS
19 D SPLAY DRAFTING MODALS

16-1-2 VITNESS LINE CONTROL
1 NO SUPPRESSION
2 SUPPRESS FIRST
3 SUPPRESS SECOND
4 SUPPRESS BOTH
5 LABEL LEADER TO FIRST TEXT LINE
6 LABEL LEADER TO MIDDLE TEXT LINE

16-1-3 TEXT/ARROW CONTROL
1 TEXT IN, ARROWS IN
2 TEXT IN, ARROWS OUT
3 TEXT OUT, ARROWS IN
4 TEXT OUT, ARROWS OUT

*** AVAILABLE 1ST QUARTER, 1980
16-13 MODIFICATION TYPE
1 NEW ORIGIN
2 BASIC
3 REFERENCE
4 ADD TOLERANCE OR LIMITS
5 NEW CHARACTER SIZE
6 MODIFY TEXT
7 MODIFY SLANT STATUS
8 MODIFY ANGLE
9 CHANGE TOLERANCE

16-13-6 MODIFY TEXT
1 DELETE LINE
2 INSERT LINE
3 REPLACE STRING

16-16 TRUE POSITION SYMBOL ORIGIN
1 SCREEN POSITION
2 KEY-IN
3 EXISTING POINT
4 BELOW FEATURE CONTROL BOX
5 ABOVE FEATURE CONTROL BOX

16-16 GEOMETRIC CHARACTERISTIC
1 STRAIGHTNESS
2 FLATNESS
3 ROUNDNESS (CIRCULARITY)
4 CYLINDRICITY
5 PROFILE TO A LINE
6 PROFILE TO A SURFACE
7 ANGULARITY
8 PERPENDICULARITY (SQUARINGNESS)
9 PARALLELISM
10 POSITION
11 CONCENTRICITY
12 SYMMETRY
13 CIRCULAR RUNOUT
14 TOTAL RUNOUT

16-16 OTHER T.P. SYMBOLS
1 MAXIMUM MATERIAL CONDITION
2 REGARDLESS OF FEATURE SIZE
3 DIAMETER
4 PROJECTED TOLERANCE ZONE

16-1 - 6 CROSS-HATCHING MATERIAL
1 IRON
2 STEEL
3 BRONZE, BRASS, COPPER
4 RUBBER, PLASTIC
5 REFRACTORY MATERIAL
6 MARBLE, SLATE, GLASS
7 ZINC, LEAD, BABBITT
8 MAGNESIUM, ALUMINUM
9 ALUMINUM ALLOYS

16-1-9 LABEL AND DIMENSION ORIGIN
1 INDICATE POSITION
2 KEY-IN
3 DELTA
4 AUTOMATIC

16-1-12 CHARACTER SET CONTROL
1 FAST
2 STANDARD
3 USER GENERATED

16-1-17 TEXT ANGLE CONTROL
1 NONE
2 ACCEPT ANGLE INPUT
3 ASK FOR PARALLEL LINE/ARC IN NOTE
4 TOTAL ANGLE CONTROL

16.12 CENTERLINE
1 POINTS
2 CIRCLE(S)
3 BOLT CIRCLE
17 N/C MACHINING

1 N/C MODALS
2 POI NT TO POI NT
3 PROFILE (PLANAR/3-AXIS/5-AXIS)
4 POCKET (PLANAR/3-AXIS/5-AXIS)
5 3-AXIS MILLING
6 5-AXIS END CUTTING
7 5-AXIS SWARF CUTTING
8 ABSOLUTE TOOL MOTION
9 LATHE
10 DEFINE CYCLE
11 DISPLAY AND EDIT
12 3 SURFACE PROFILE*
13 3-AXIS FLANGE*
14 COMPOSITE TOOL PATHS*
15 POST PROCESSORS****

17-1 N/C MODALS

1 SFM
2 TOOL PATH DISPLAY MODE
3 COOLANT
4 SPINDLE DIRECTION
5 FEED RATES
6 SPINDLE SPEED
7 CLEARANCE/RETRACT PLANES
8 TOLERANCES
9 DEEP HOLE PARAMETERS
10 RAPID FEED MODE
11 TOOL DISPLAY FOR DISPLAY & EDIT
12 DISPLAY N/C MODALS

17-1-15 TOOL DISPLAY FOR DISPLAY & EDIT

1 NONE
2 NORMAL TO VIEW
3 PARALLEL TO VIEW

17-2 POI NT TO POI NT TOOLS

1 SPOT DRILL
2 TAP
3 DRILL
4 BORE
5 FINISH BORE
6 SPOT FACE
7 COUNTER SINK
8 REAM
9 MILL

17-10 CYCLE COMMANDS

1 CLW
2 CCLW
3 SPINDLE SPEED
4 COOLANT ON
5 COOLANT OFF
6 FLOOD COOLANT ON
7 MIST COOLANT ON
8 TAP COOLANT ON
9 PLUNGE (RAPID)
10 RETRACT (RAPID)
11 FEED TO FIXED ZT FROM CURRENT DEPTH
12 FEED TO DELTA ZT FROM CURRENT DEPTH
13 FEED TO POI NT + DELTA DISTANCE
14 DWELL
15 STOP
16 DEEP HOLE

* NOT AVAILABLE ON 16 BIT COMPUTERS
**** AVAILABLE AS SPECIAL ORDER ONLY
## 18 ANALYSIS

1 SPLINE ANALYSIS
2 ANALYTIC AREA/PERIMETER
3 2-D SECTION ANALYSIS
4 3-D ANALYSIS
5 WEIGHTS & VOLUMES
6 CURVE ANALYSIS

### 18-1 SPLINE ANALYSIS

1 SLOPE
2 CURVATURE
3 RADIUS OF CURVATURE
4 X vs. PARAMETER PLOT
5 Y vs. PARAMETER PLOT
6 EXTENDED ANALYSIS

### 18-2 2-D SECTION ANALYSIS

1 LENGTH OF PERIMETER
2 AREA
3 CENTER OF GRAVITY
4 FIRST MOMENT
5 MOMENT OF INERTIA
6 RADIUS OF GYRATION
7 POLAR MOMENT OF INERTIA
8 POLAR RADIUS OF GYRATION
9 MIN/MAX X, Y

### 18-4 3-D ANALYSIS

1 SURFACE AREA
2 VOLUME
3 WEIGHT
4 WEIGHT/UNIT LENGTH
5 FIRST MOMENT OF MASS
6 CENTER OF MASS
7 MOMENT OF INERTIA
8 RADIUS OF GYRATION
9 SPHERICAL MOMENT OF INERTIA
10 SPHERICAL RADIUS OF GYRATION

### 18-5 WEIGHTS & VOLUMES

1 SOLIDS
2 SURFACES TO A DEPTH

### 18-6 CURVE ANALYSIS

1 CURVE LENGTH
2 DERIVATIVES
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