Surface and Volume grid generation in parametric form

by

Tzuyi Yu, Bharat K. Soni

NSF/ERC For Computational Field Simulation

Mississippi State University, MS39762

Ted Benjamin, Robert Williams

Marshall Space Flight Center, AL 35812

/32115

ABSTRACT

The algorithms for surface modeling and volume grid generation using parametric NURBS geometric representation are presented. The enhanced re–parameterization algorithm which can yield a desired physical distribution on the curve, surface and volume is also presented. This approach bridges the gap between CAD surface / volume definition and surface / volume grid generation.

INTRODUCTION

Surface grid generation is the most labor intensive part of the overall complex three dimensional grid generation process. Also, a significant amount of effort is required in changing the resolutions (grid sizes) and / or the distribution of the grid while maintaining geometry fidelity. In the last few years, various researchers have concentrated on utilizing the Computer Aided Geometry Design (CAGD) techniques to expedite the overall surface generation process. In this presentation, a parametric formula which has been used in CAD system is extended with re–parameterization approach to numerical grid generation for modeling the surface as well as the volume grid.

There are many parametric approaches for representing sculptured geometry, such as rational or non–rational Bezier, cubic splines, rational or non–rational B–spines, ... ,etc. Among these representation, the Non–Uniform Rational B–Splines (NURBS) has been widely accepted among these researchers. NURBS has been widely utilized to represent and design geometry in the CAD/CAM and the graphics community due to its powerful features, such as the local control property, variation diminishing, convex hull and affine invariance [Ref 1,2]. Also the geometry tool kits, such as curve/surface interpolation, data reduction, degree elevation, knot insertion and splitting, are well–developed [Ref 1,2,]. These properties have made NURBS representation very popular in recent developments in CAD/CAM. However, the distribution requirements in CFD application are much complicated than those in CAD system. Hence, the NURBS must be cooperated with re–parameterization algorithm so that it can be more useful in grid generation. Computational examples associated with practical configurations are shown in Figure 1 and 2. The re–parameterization approach described in many research [Ref 2,3] is implemented by iteration process, which needs a lot of computation time. The more efficient and robust approach presented here needs only one interpolation process.

The development of the software based on NURBS representation package: CAGI (Computer Aided Grid Interface) was initiated by authors under the sponsorship of NASA Marshall Space Flight Center. The purpose of this presentation is to present the progress realized in enhancing the NURBS based curve / surface grid generation techniques into a 3D volume grid generation technique. To this end, various options for generating 3D volume geometry–grid are discussed. A reparameterization scheme has been developed to achieve desired distribution in physical space. Computational examples for modeling practical configurations have been exercised using the volume options and the reparameterization scheme.

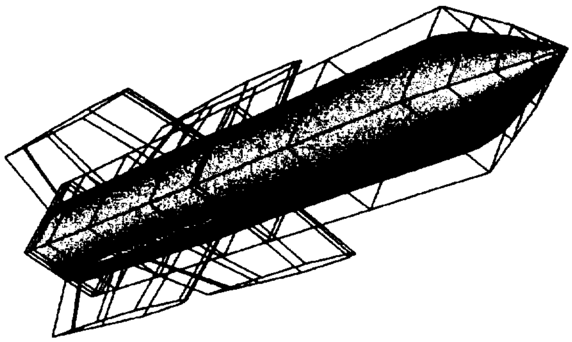


Figure 1: Propulsional example.
3D NURBS control patches model
the missile (with fins) geometry.

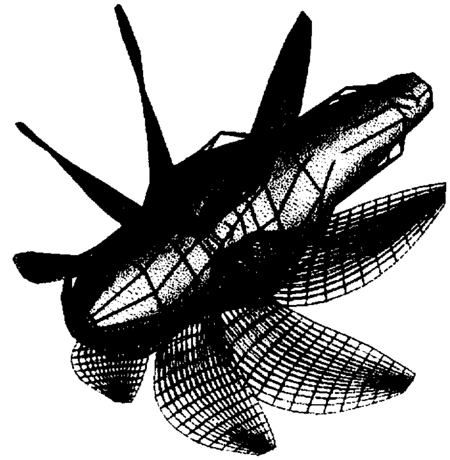


Figure 2:
3D NURBS control patches model
the single rotation propfan.

References

[1] Piegl, L., – *'On NURBS: A survey' IEEE Computer Graphics & Applications,* Vol 11, No 1, pp 57 – 71, January, 1991.

[2] FARIN, G. "NURB curves and surfaces: from projective geometry to practical use," First Edition, A K Peters, Ltd., 1995.

[3] Yu, T.Y. and Soni, B.K.,"Geometry Transformer and NURBS in grid Generation," 4th International Conference on Numerical Grid Generation in CFD and Related Fields, Swansea, UK., April 6–8, 1994.

[4] Yu, T.Y., Soni, B.K., and Shih M. H. "CAGI: Computer Aided Grid Interface," AIAA–95–0243, 33nd Aerospace Sciences Meeting & Exhibit., Reno, Nevada January 09~12,1995.

Title: Surface and Volume grid generation in parametric form

Authors: Tzu–Yi Yu, Bharat K. Soni

Missisippi State University /Engineering Research Center
2 Research Blvd., Starkville, MS 39759, USA

Ted Benjamin, Robert Williams

NASA/Marshall Space Flight Center

Sponsor: NASA/Marshall Space Flight Center

Geometry generated in parametric space:

Advantages:

1> Natural for grid generation algorithm.

2> Easy manipulation. ◄««« Designer's Dream.

3> Less storage & standard data structure.

4> Way of future.

Disadvantage:

0> Distribution differs in parametric space and physical space.

NURBS: Non–Uniform Rational BSpline is selected.

1> Stable and robust geometric properties.

Degree raising, spliting/join algorithm, convex hull, shape preserving, local support, ... etc.

2> IGES (Initial Graphics Exchange Specification) ,NASA IGES, NINO.

3> Way of Future :

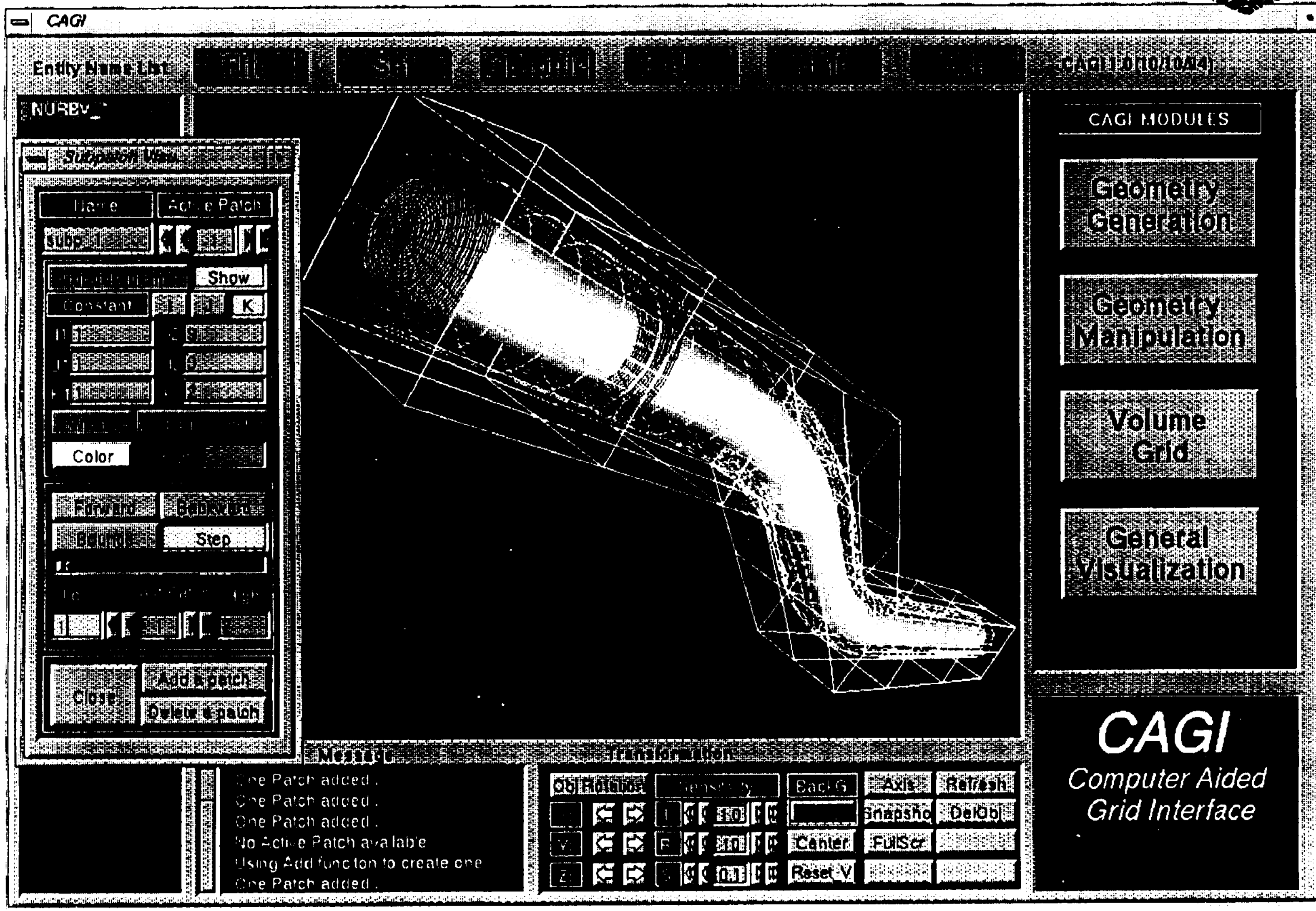
Solid Geometry Modeling.

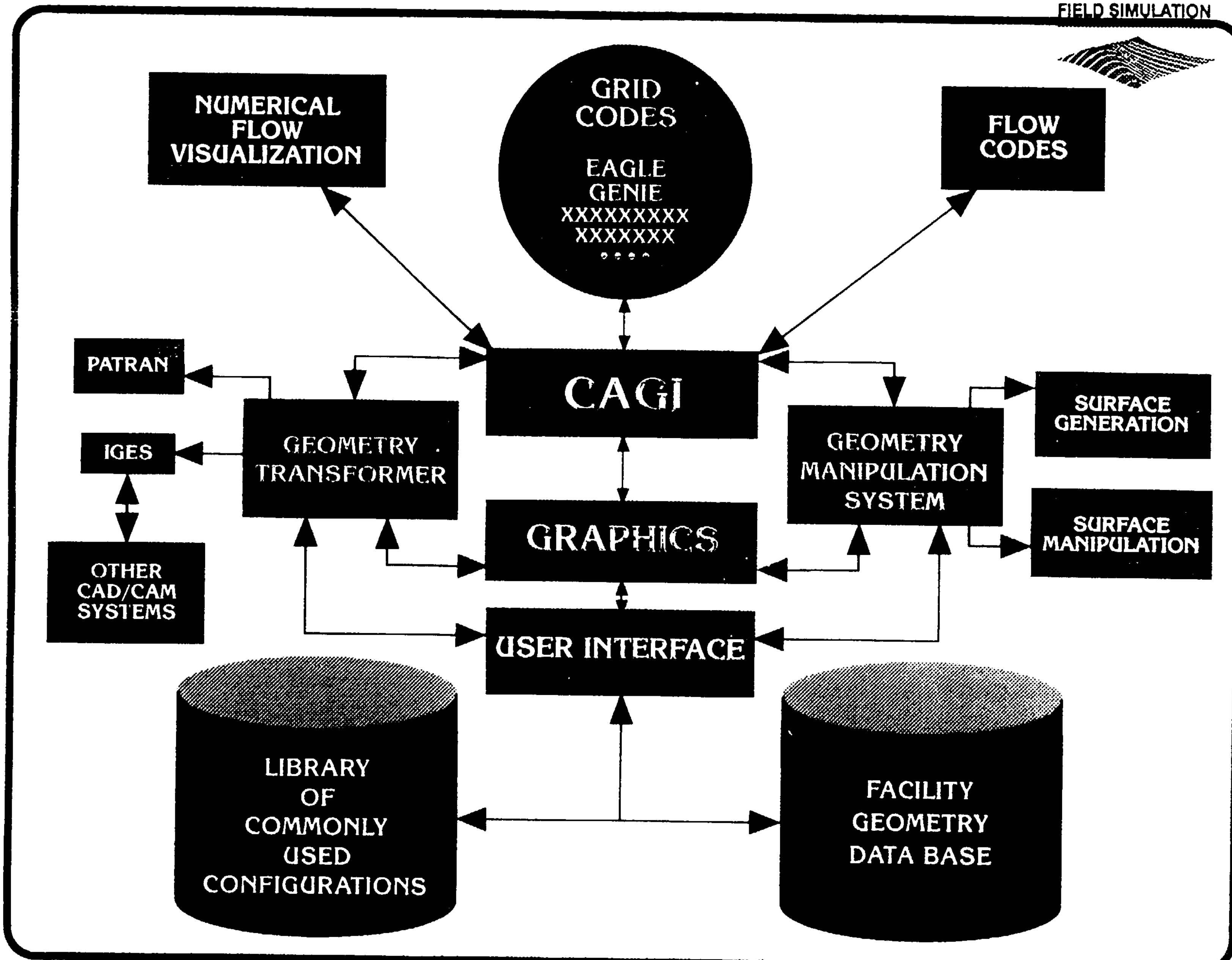
STEP.

***CAGI*: A NURBS database package.**

MISSISSIPPI STATE UNIVERSITY / National Science Foundation

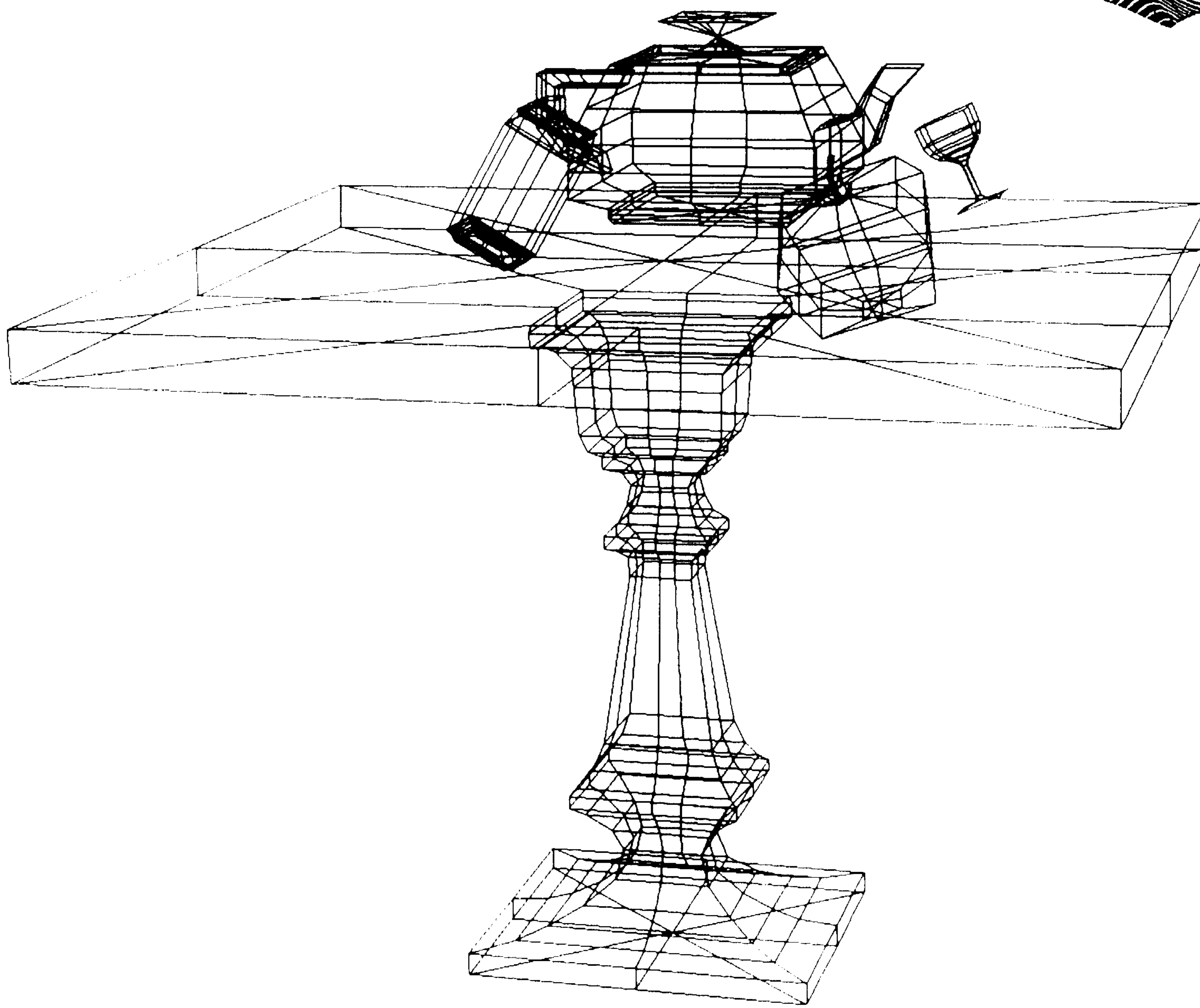
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION



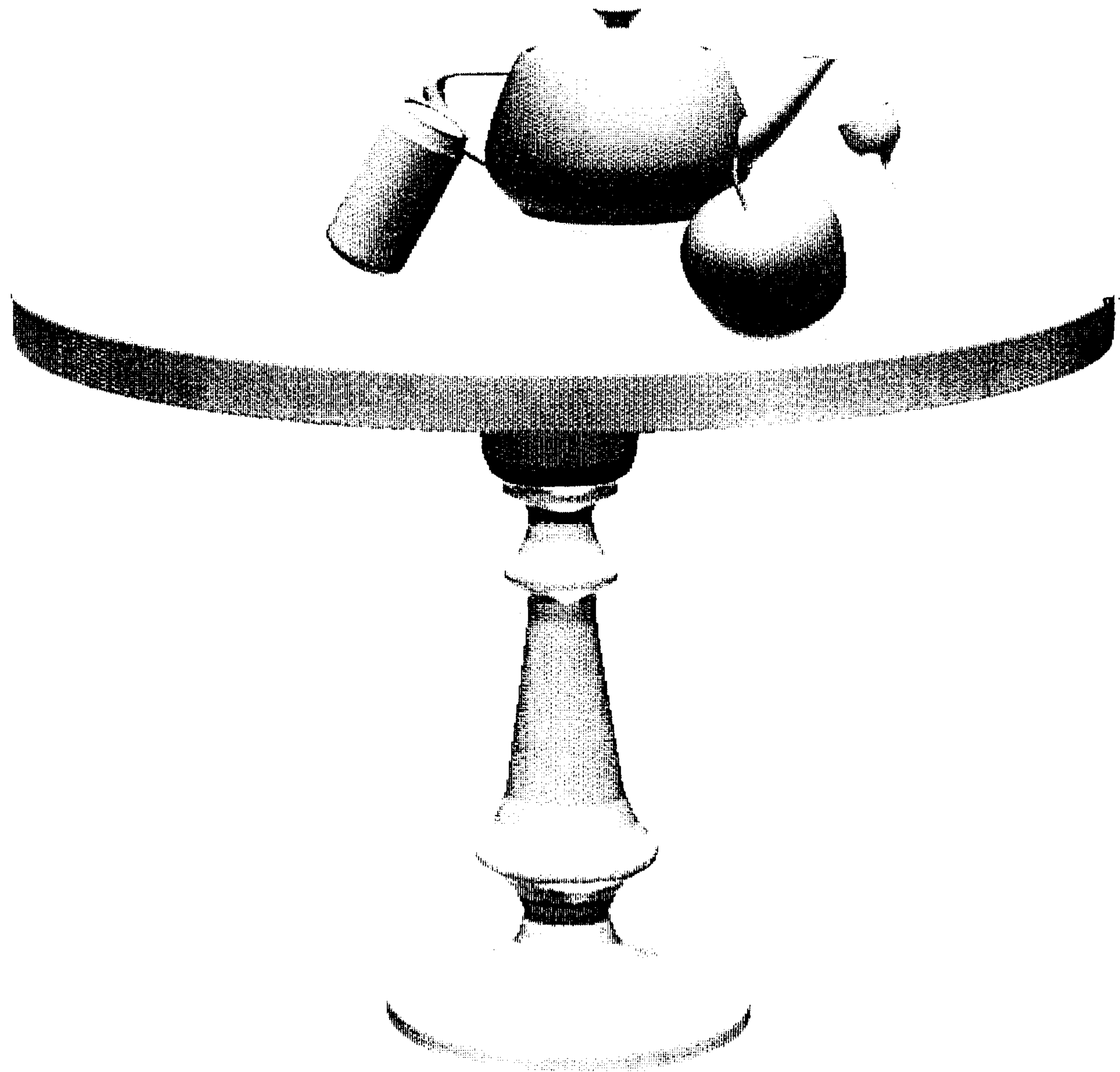

NUMERICAL FLOW VISUALIZATION
GRID CODES
EAGLE
GENIE
XXXXXXXXX
XXXXXXX
FLOW CODES
PATRAN
IGES
OTHER CAD/CAM SYSTEMS
GEOMETRY TRANSFORMER
CAGI
GRAPHICS
USER INTERFACE
GEOMETRY MANIPULATION SYSTEM
SURFACE GENERATION
SURFACE MANIPULATION
LIBRARY OF COMMONLY USED CONFIGURATIONS
FACILITY GEOMETRY DATA BASE

MISSISSIPPI STATE UNIVERSITY / National Science Foundation

ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

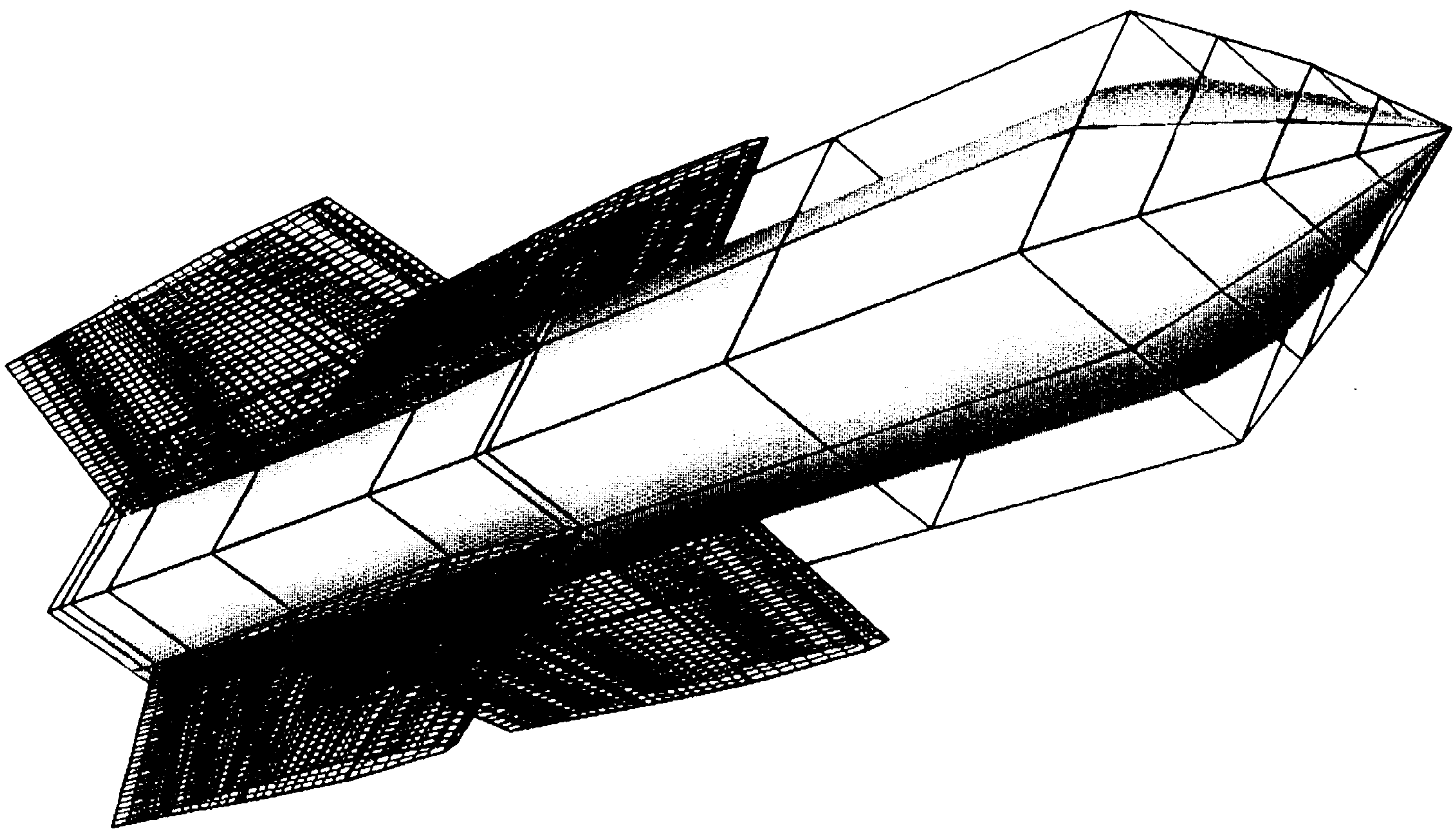


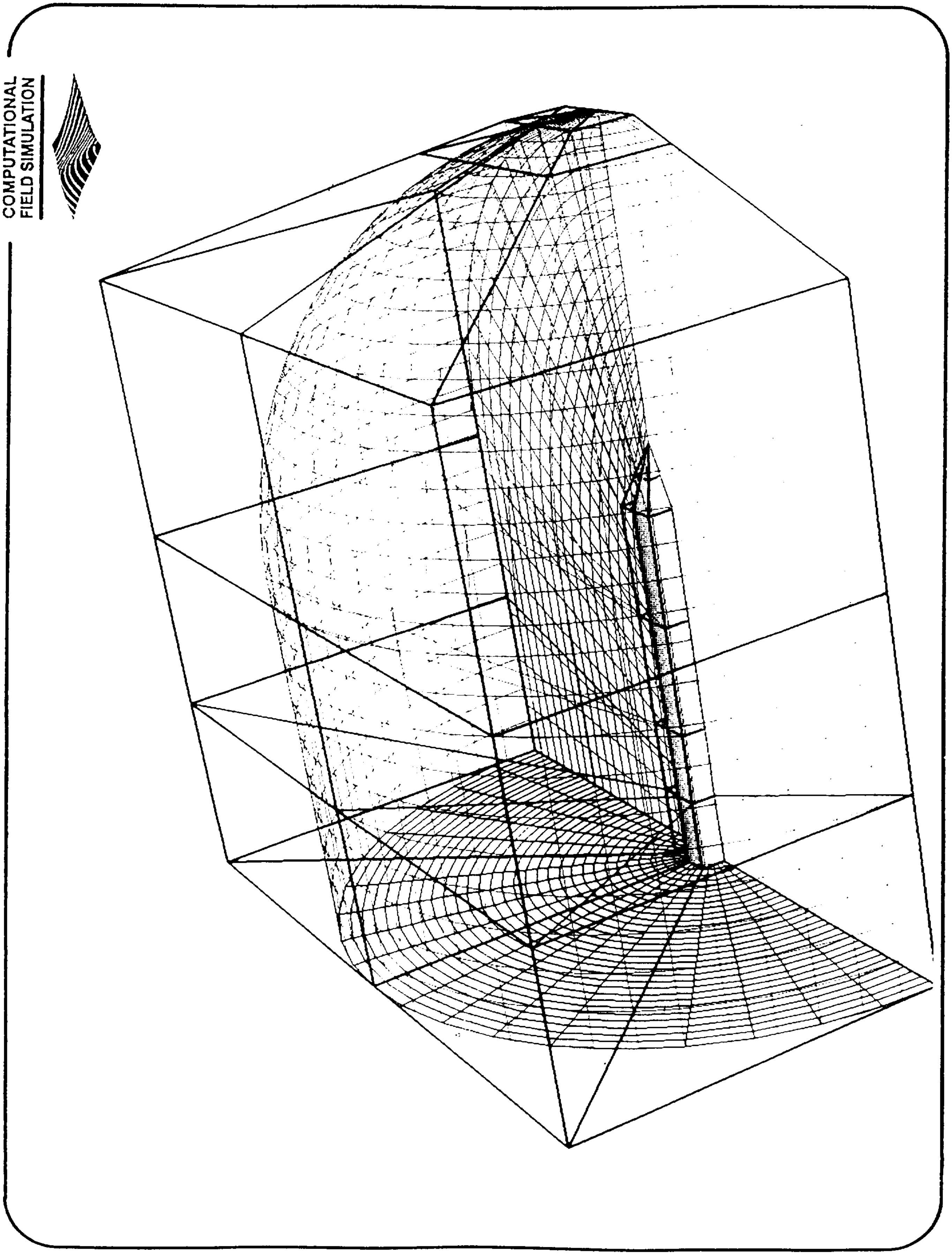
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION



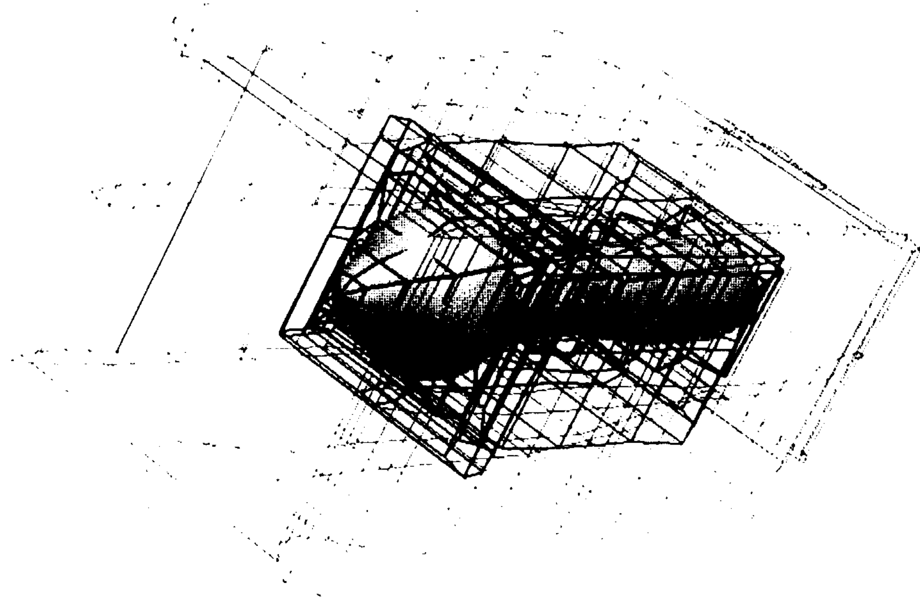
MISSISSIPPI STATE UNIVERSITY / National Science Foundation

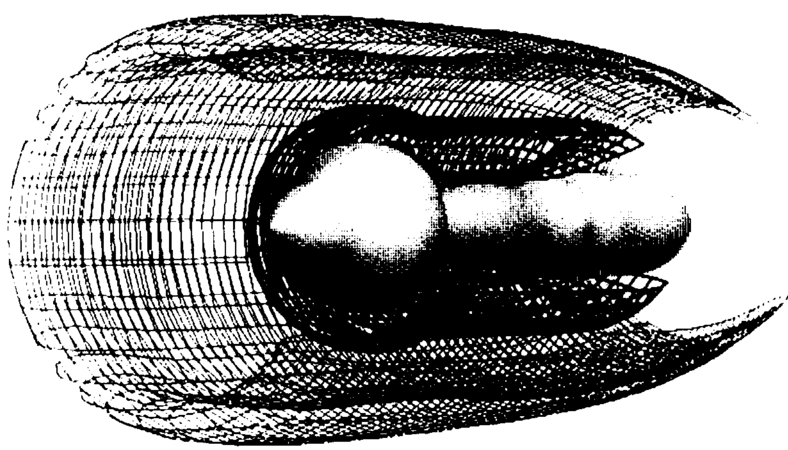
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

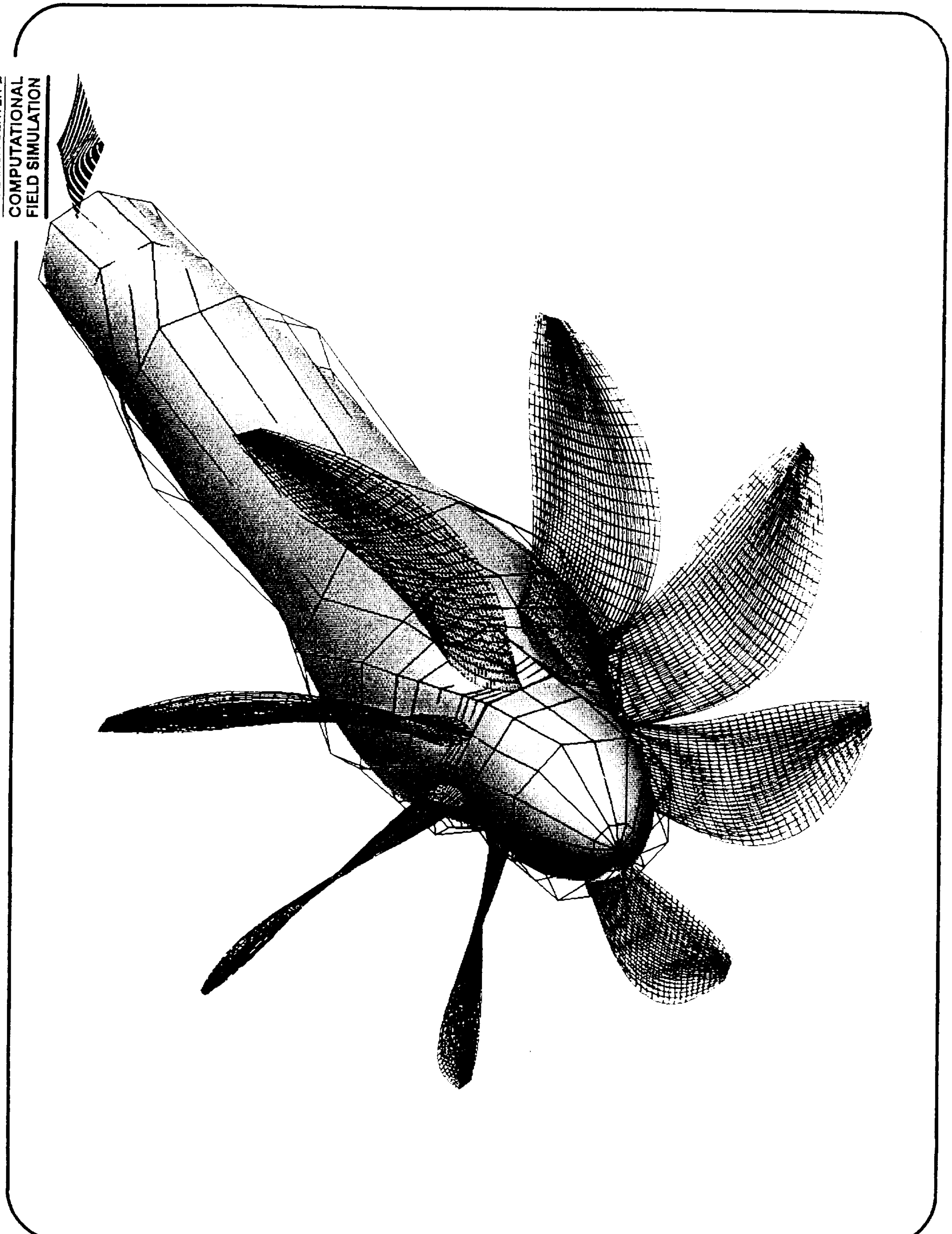



MISSISSIPPI STATE UNIVERSITY / National Science Foundation
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

NURBS CONTROL NET WITH MOCKED ENGINE

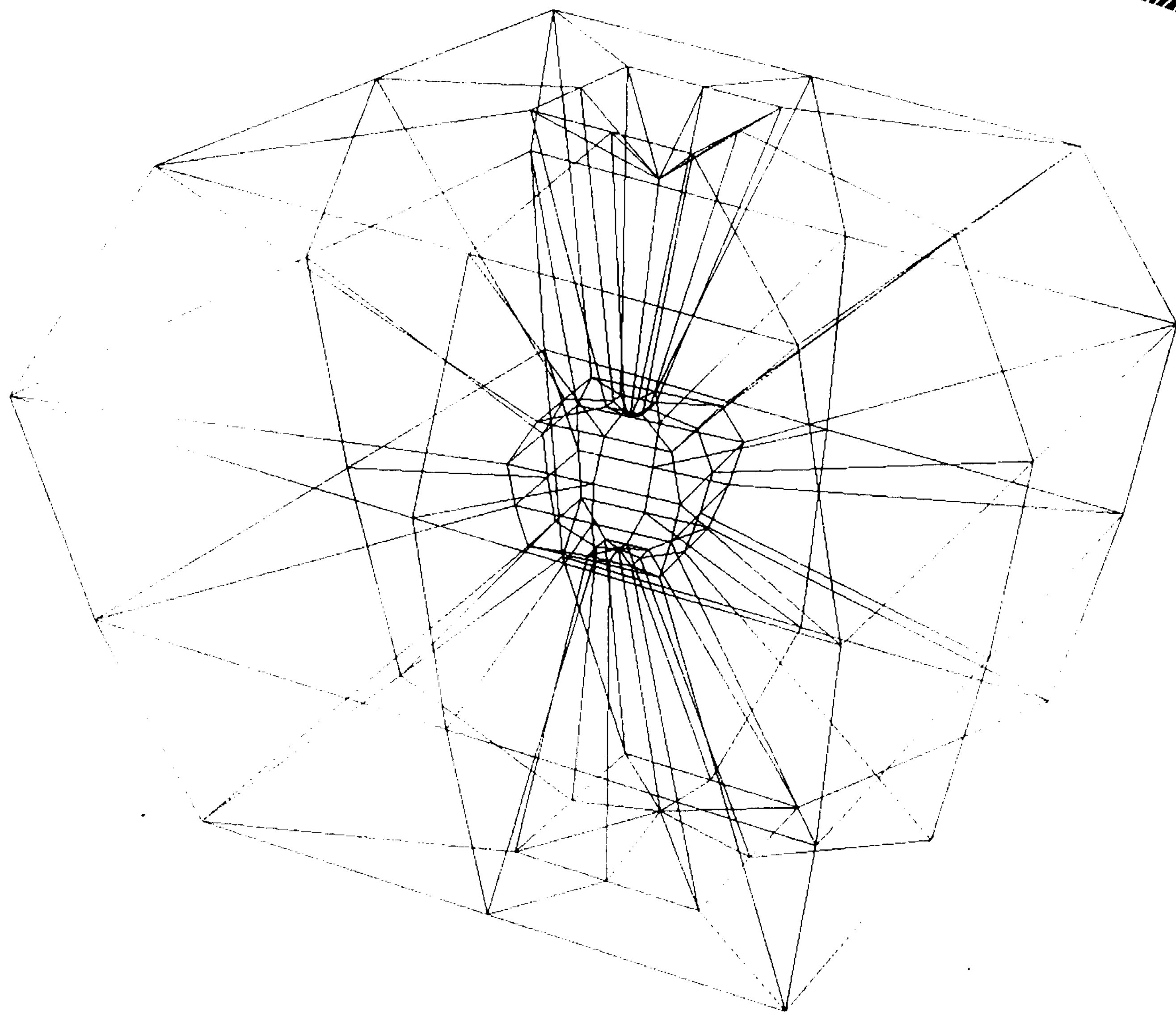


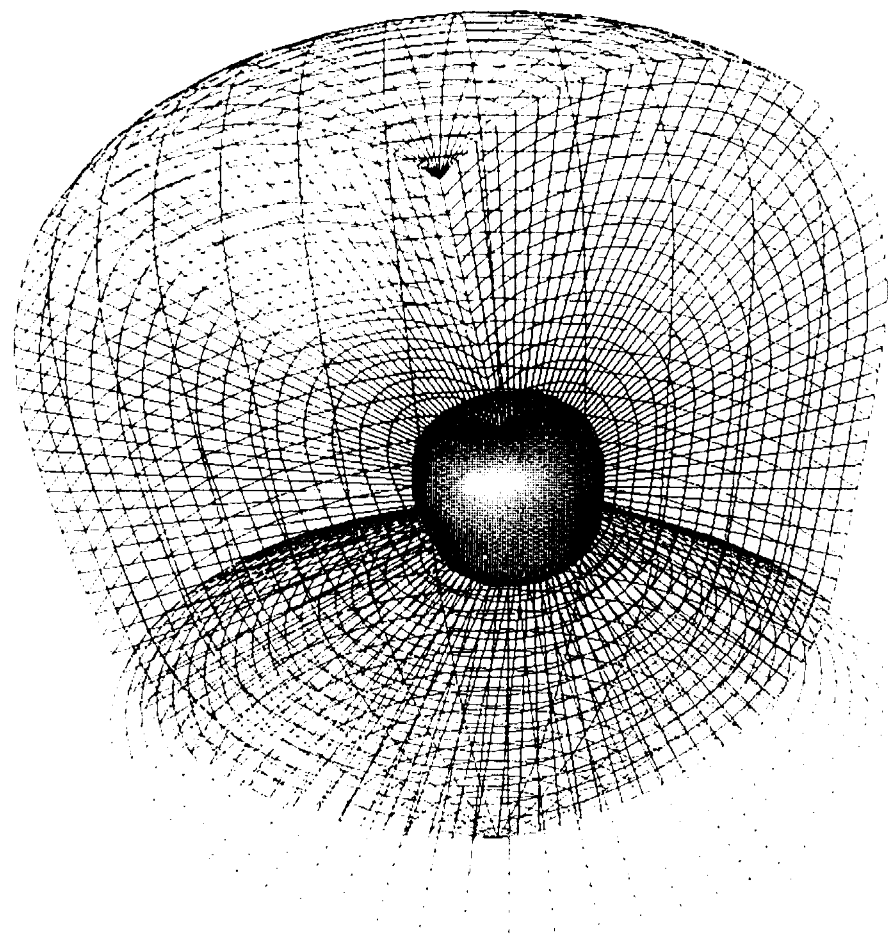



ENGINEERING RESEARCH CENTER FOR
COMPUTATIONAL FIELD SIMULATION
MISSISSIPPI STATE UNIVERSITY / National Science Foundation

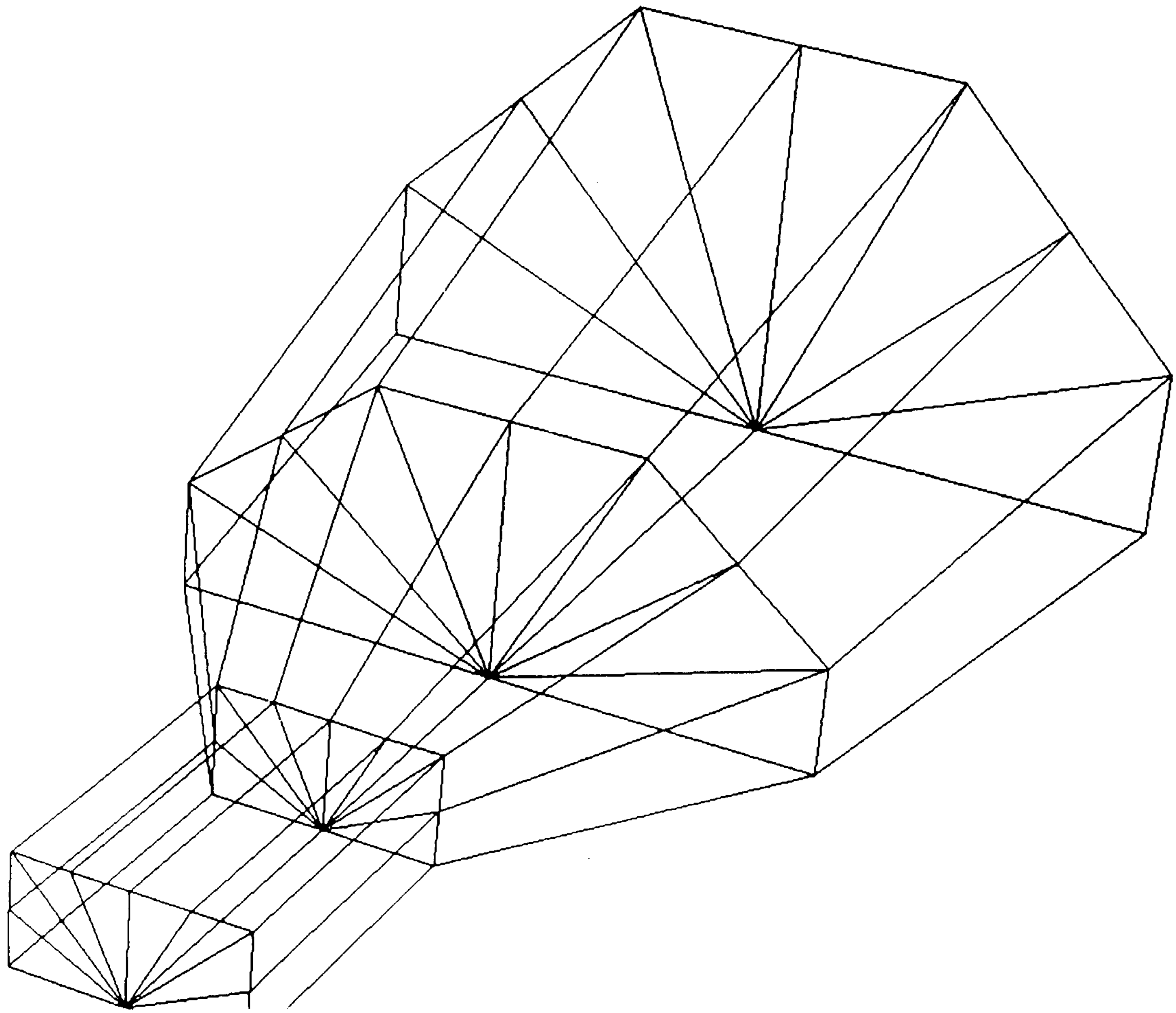
MISSISSIPPI STATE UNIVERSITY / National Science Foundation

ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION



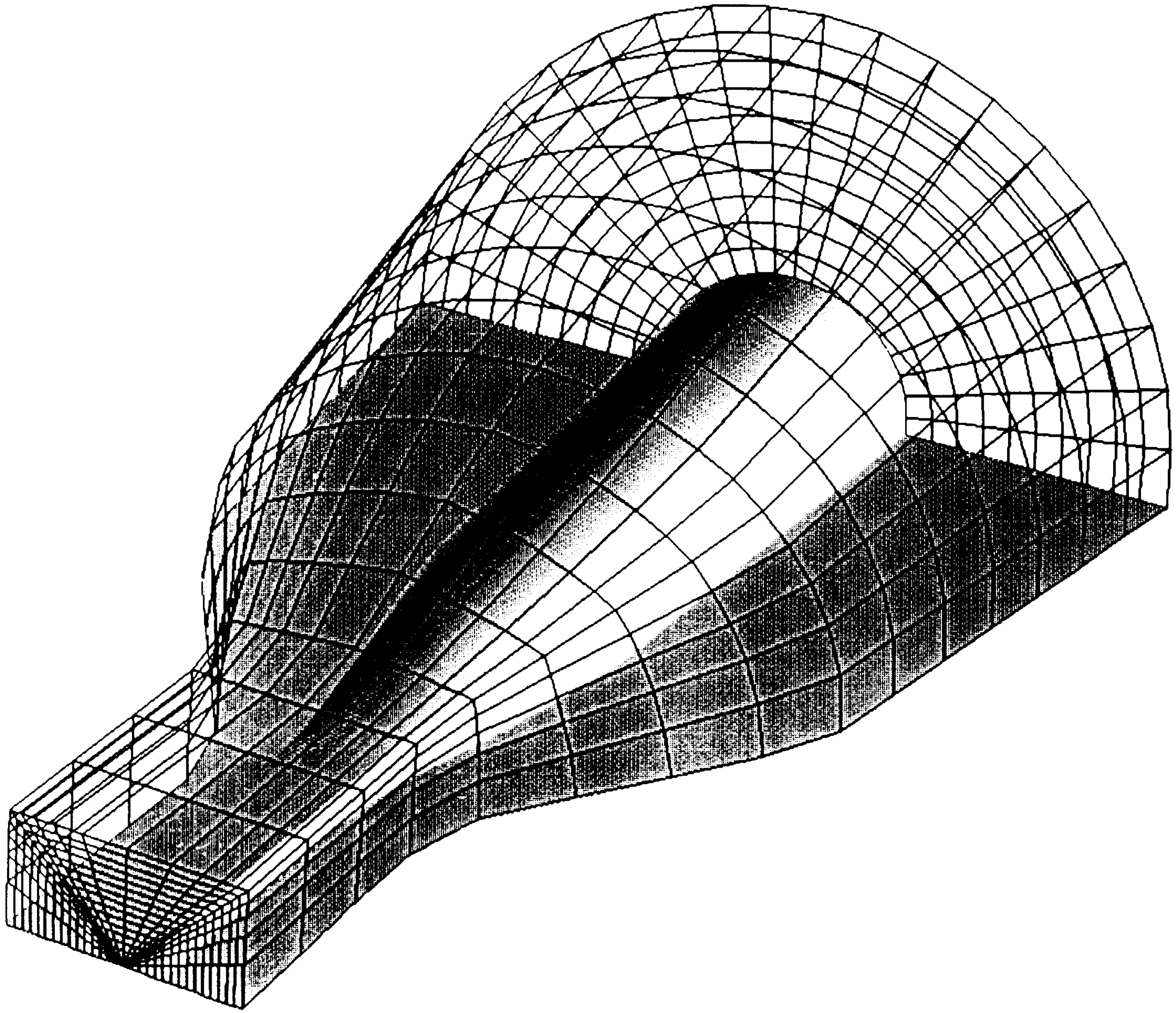


NURBS control volume for a nozzle with square-ellipse-circle sections
(O Type Control Volume)



Nozzle with square-ellipse-circle section

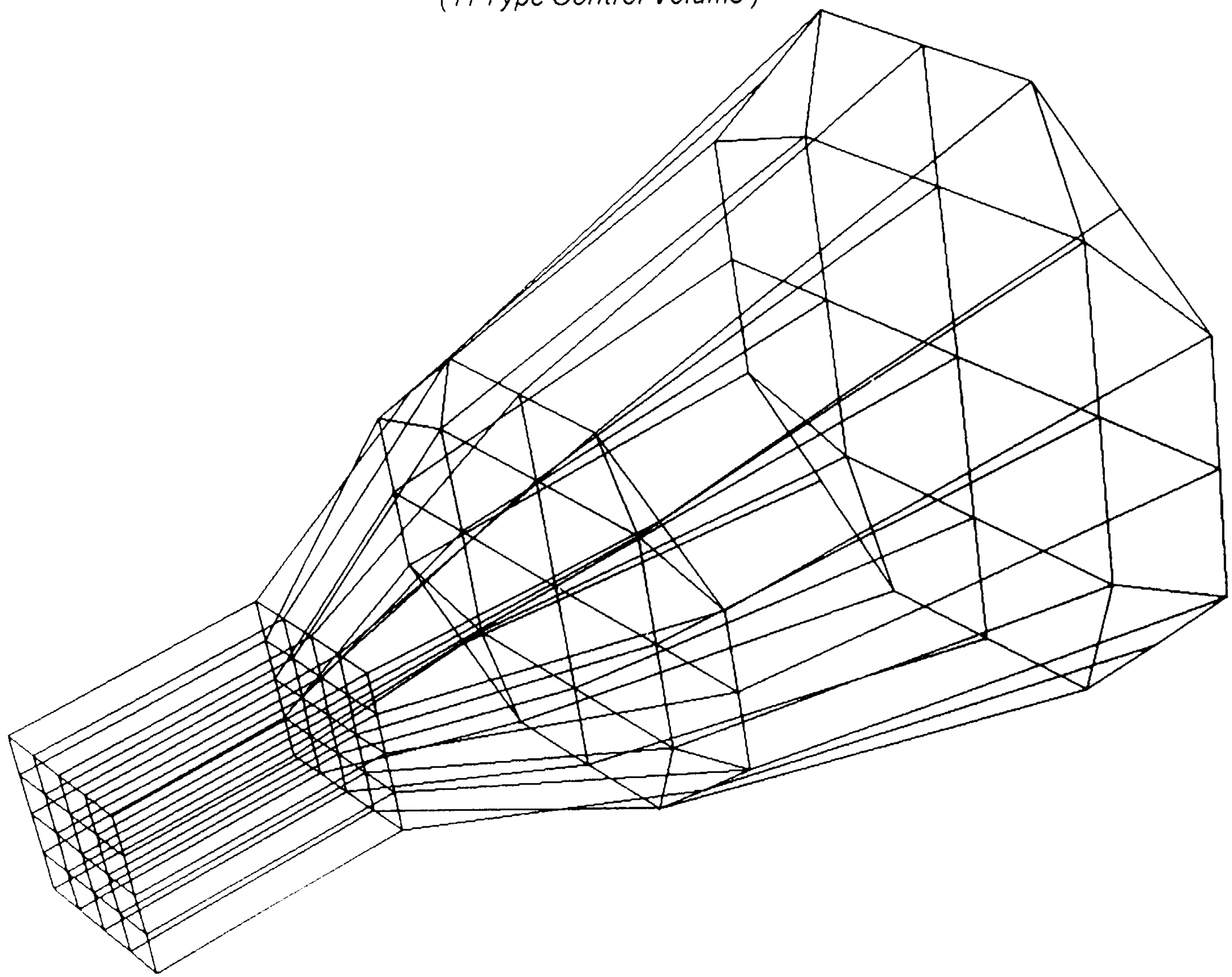
(O Type Volume Grid)



MISSISSIPPI STATE UNIVERSITY / National Science Foundation

ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

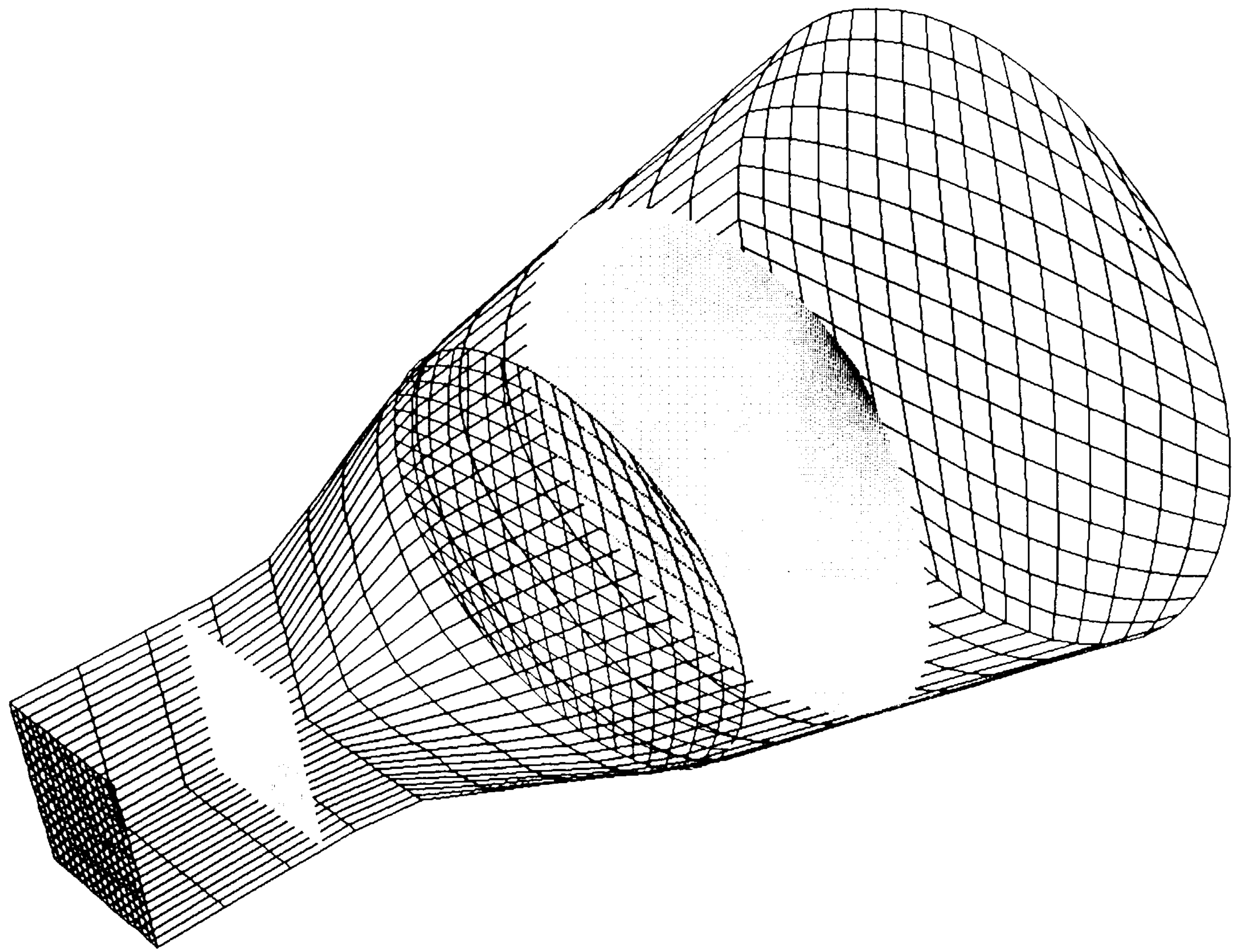
NURBS control volume for a nozzle with square-elliptic-circular sections
(H Type Control Volume)

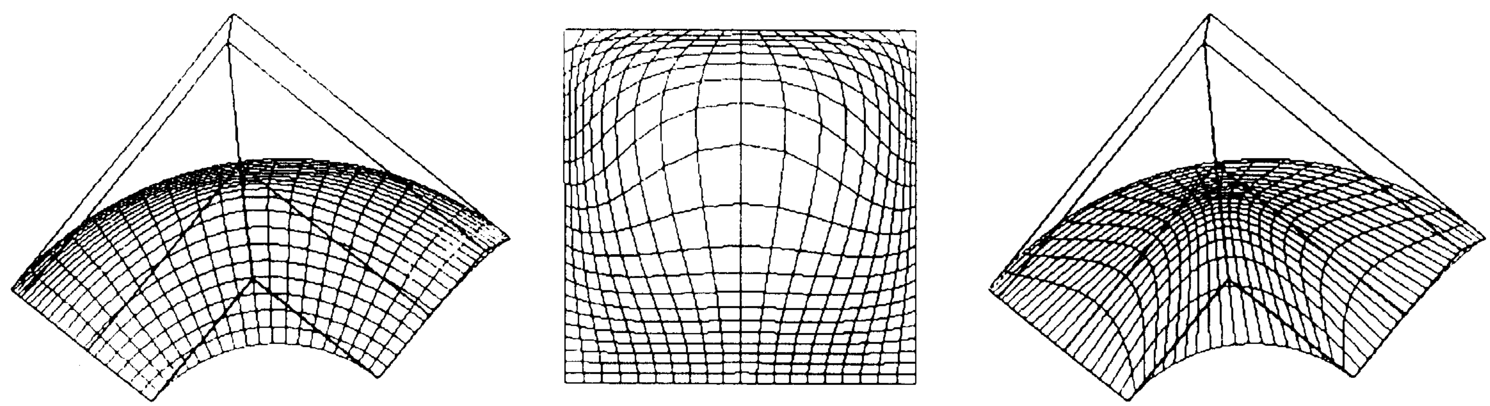


MISSISSIPPI STATE UNIVERSITY / National Science Foundation

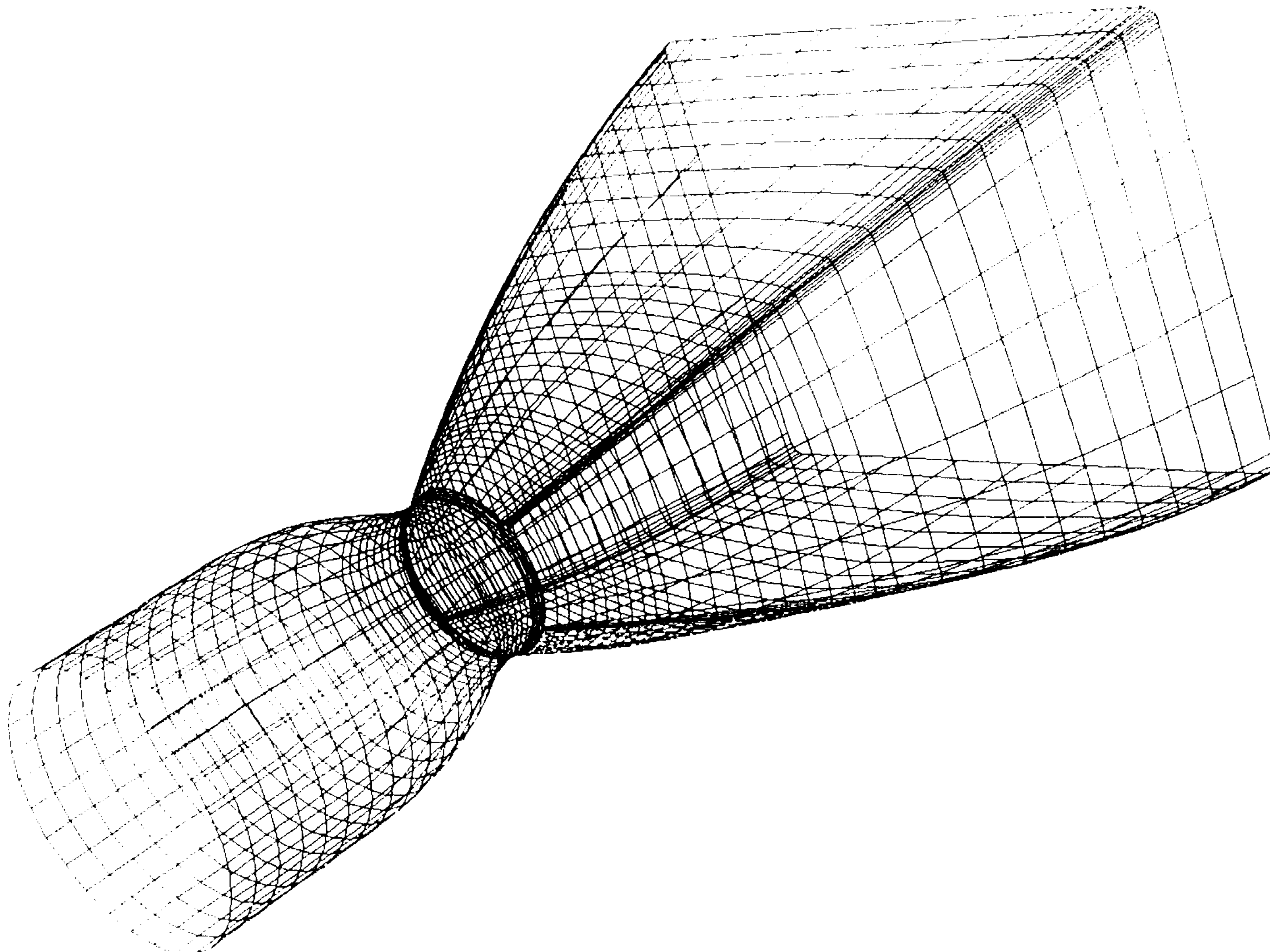
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

A Nozzle with square-ellipse-circular sections
(H Type Volume Grid)





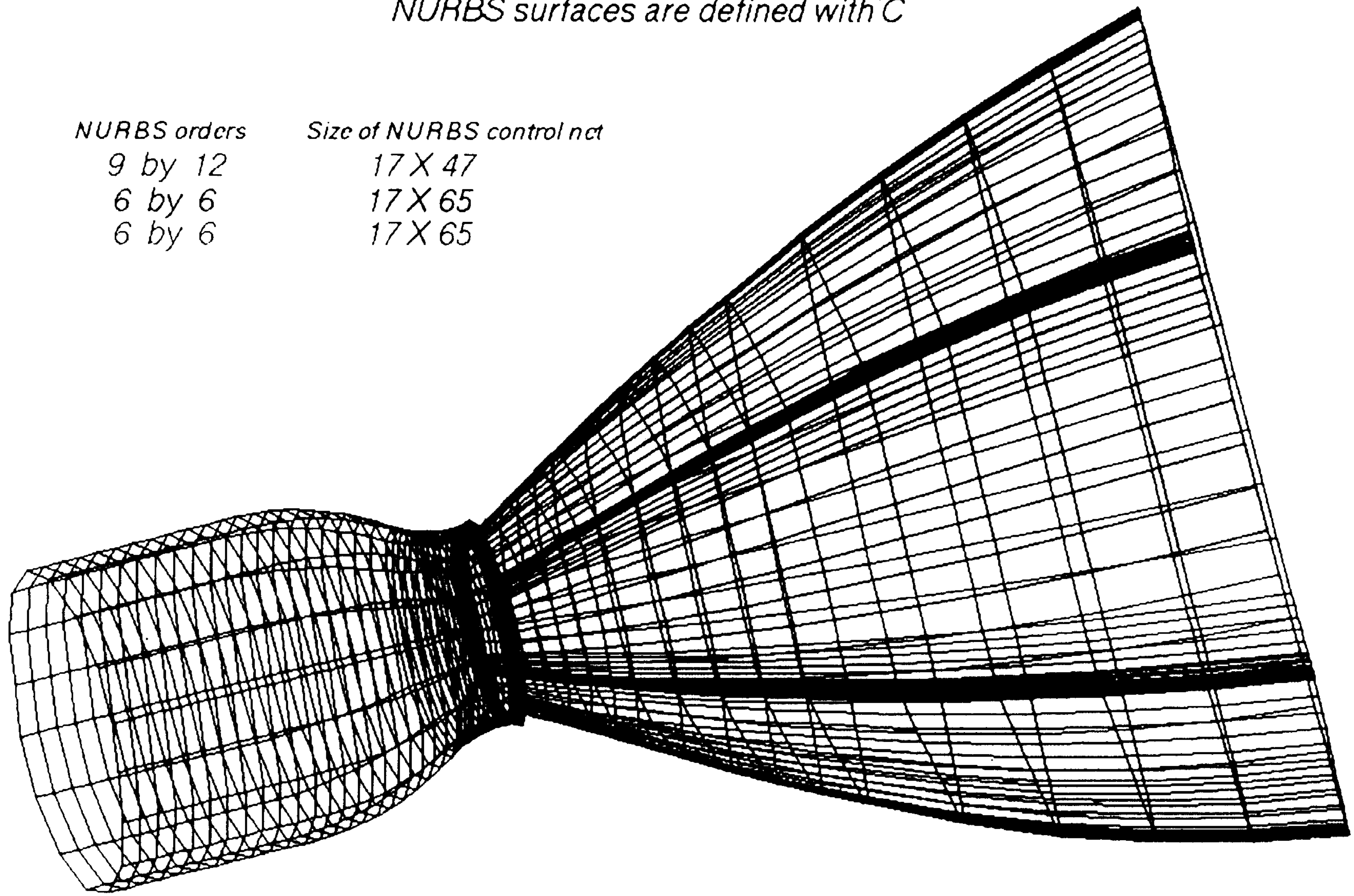
Original Geometry (from CAD/CAM System)



Original NURBS control net from CAD/CAM

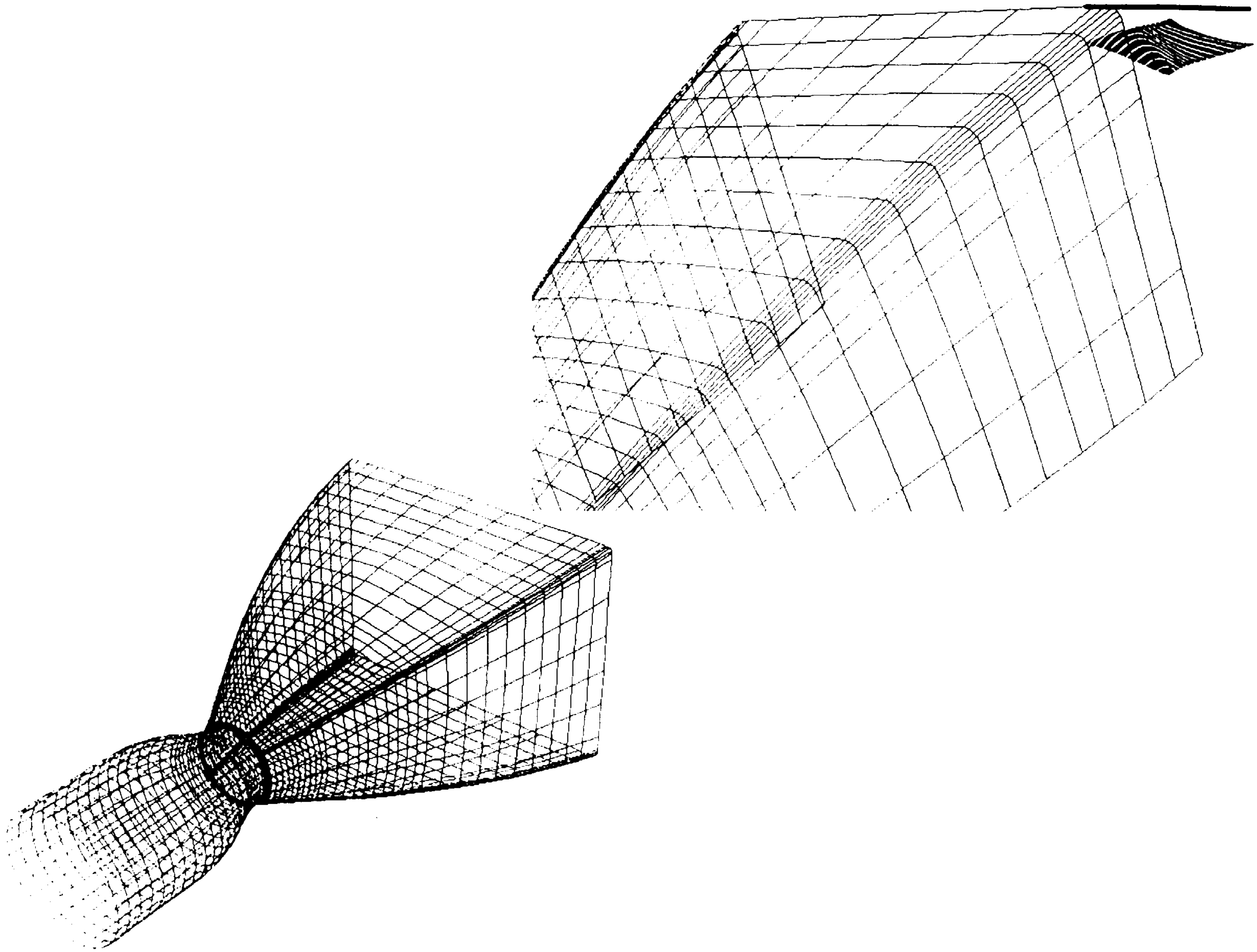
NURBS surfaces are defined with C^{-1}

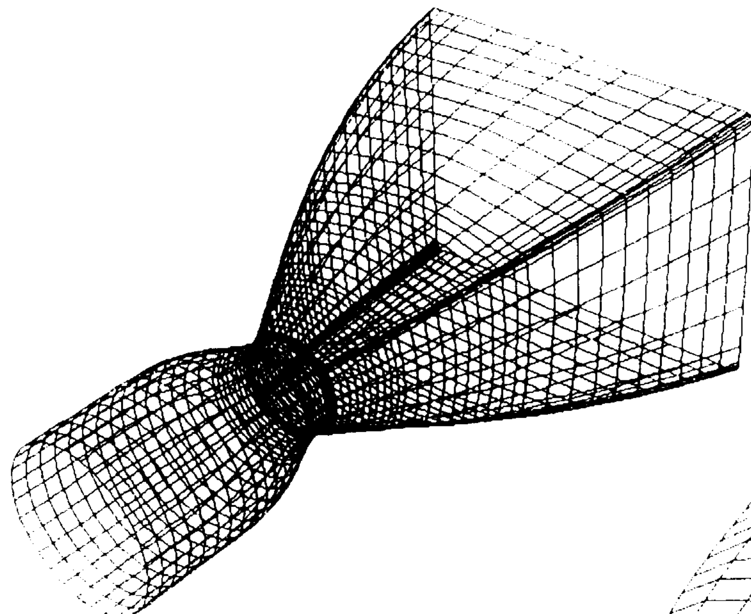
NURBS orders	Size of NURBS control net
9 by 12	17 X 47
6 by 6	17 X 65
6 by 6	17 X 65

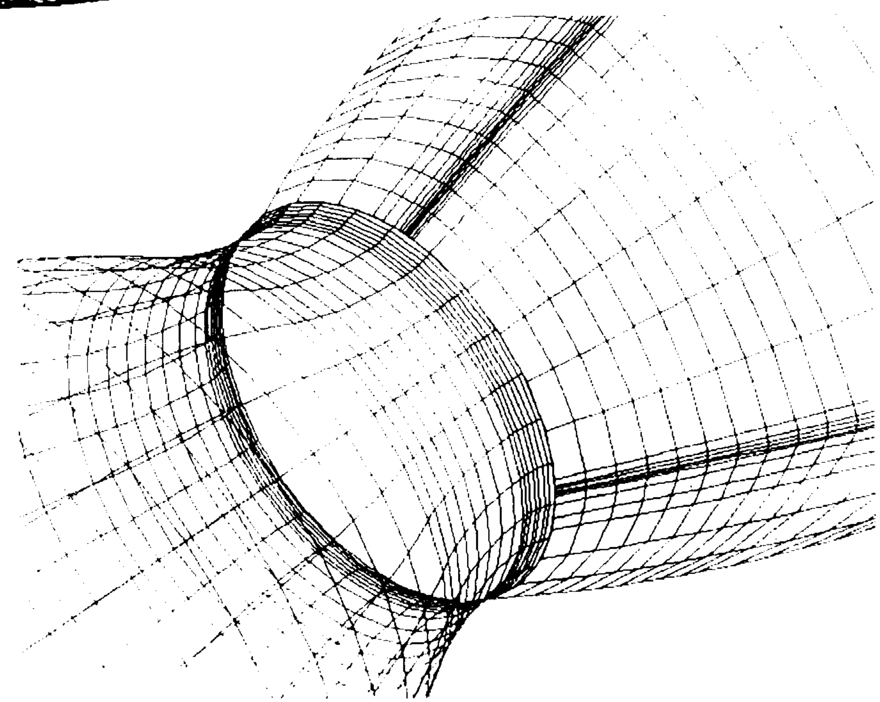


MISSISSIPPI STATE UNIVERSITY / National Science Foundation

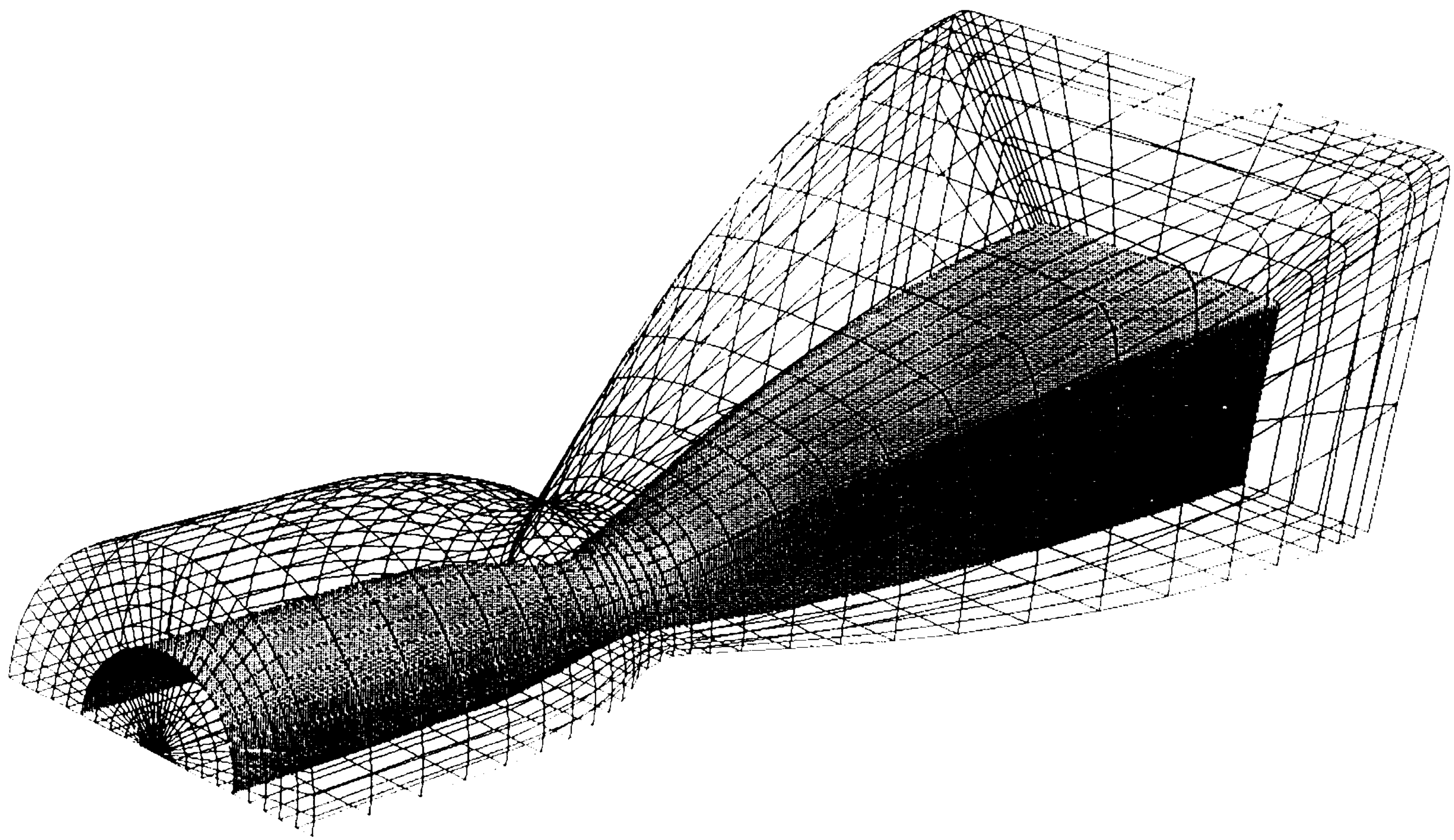
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION



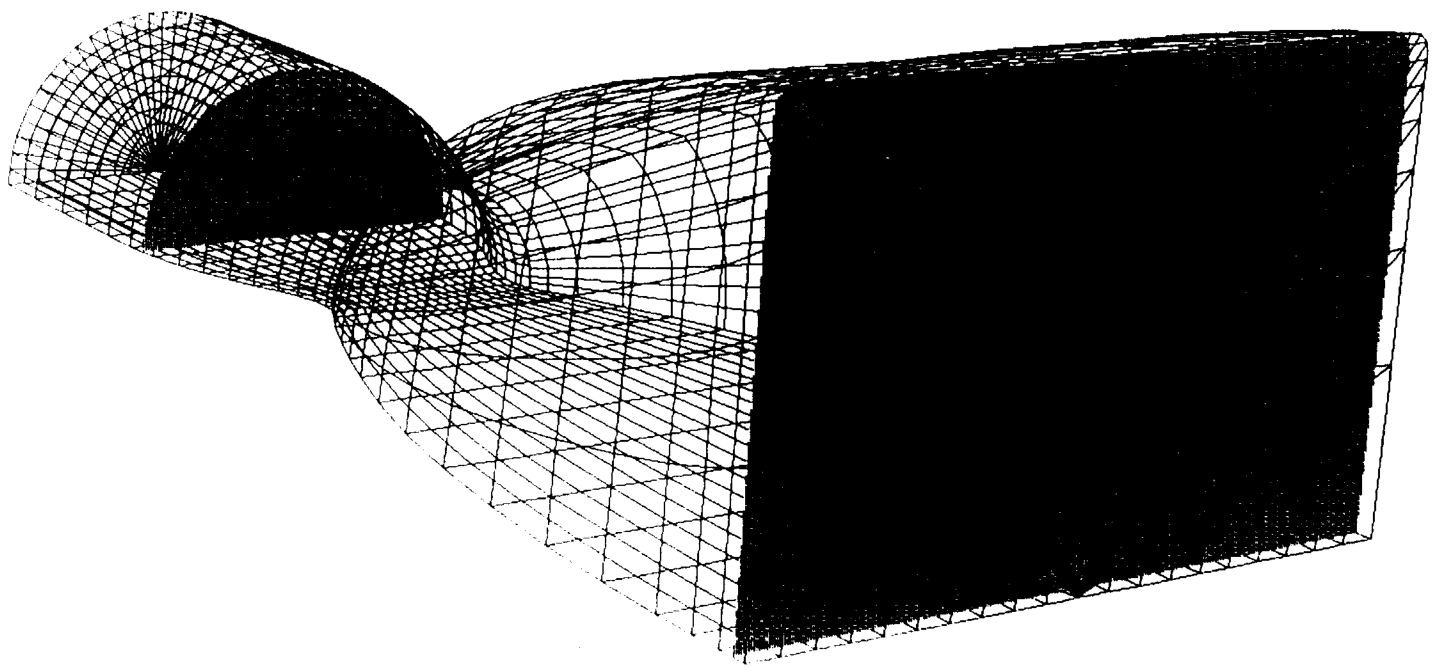




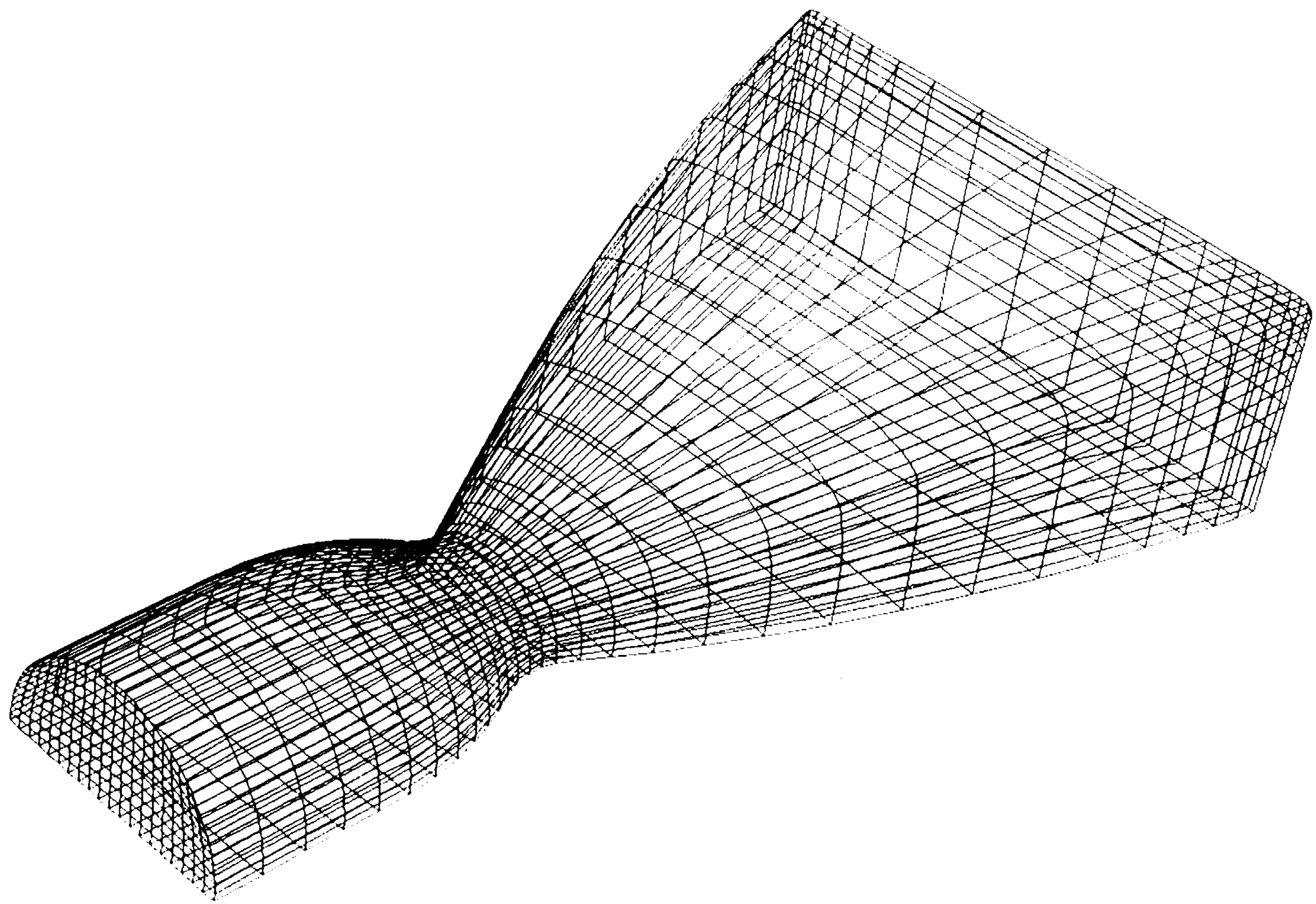
Manipulating CAD geometry and generating the volume grid
(O Type Grid)



Manipulating CAD geometry and generating the volume grid
(O Type Grid)

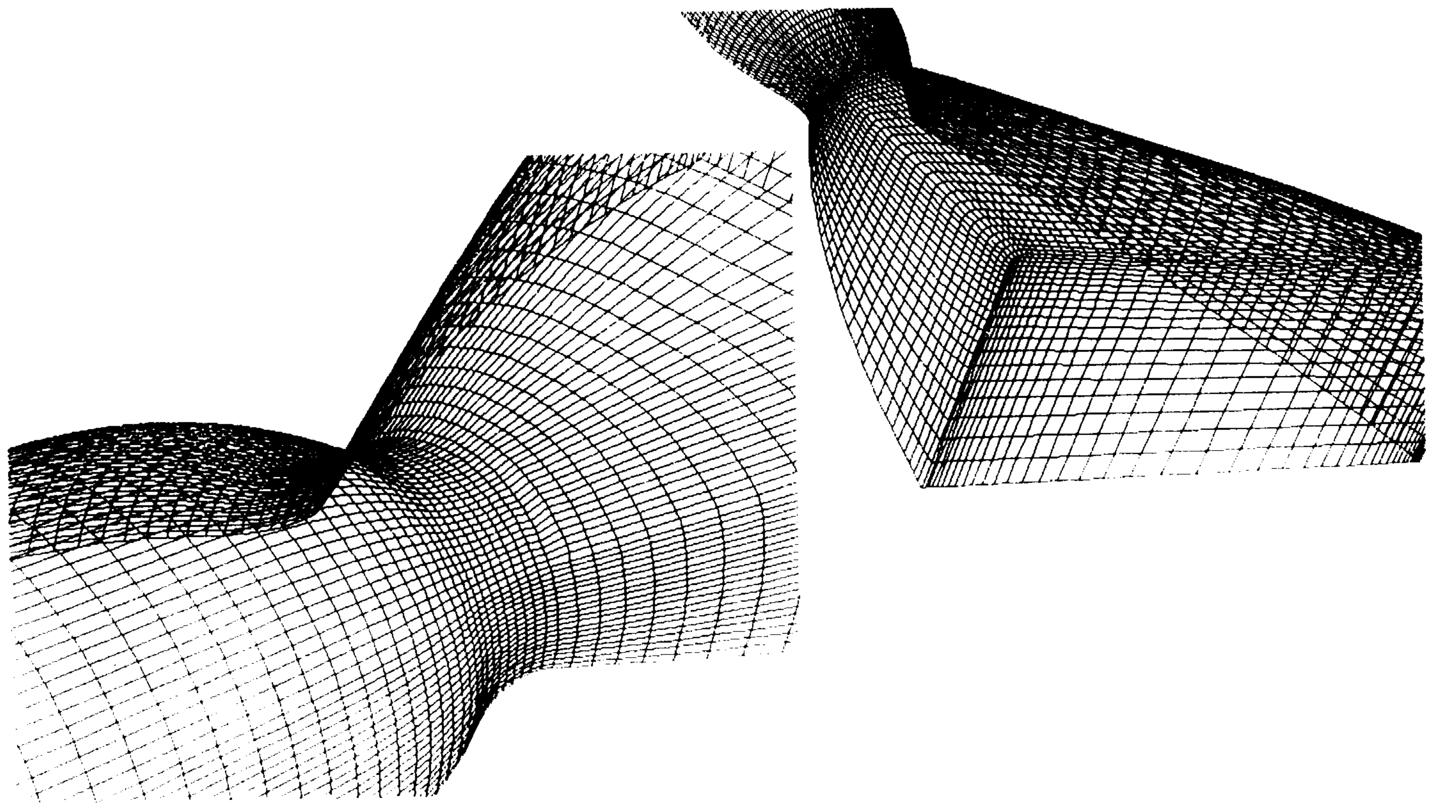


Manipulating CAD geometry and generating the volume grid

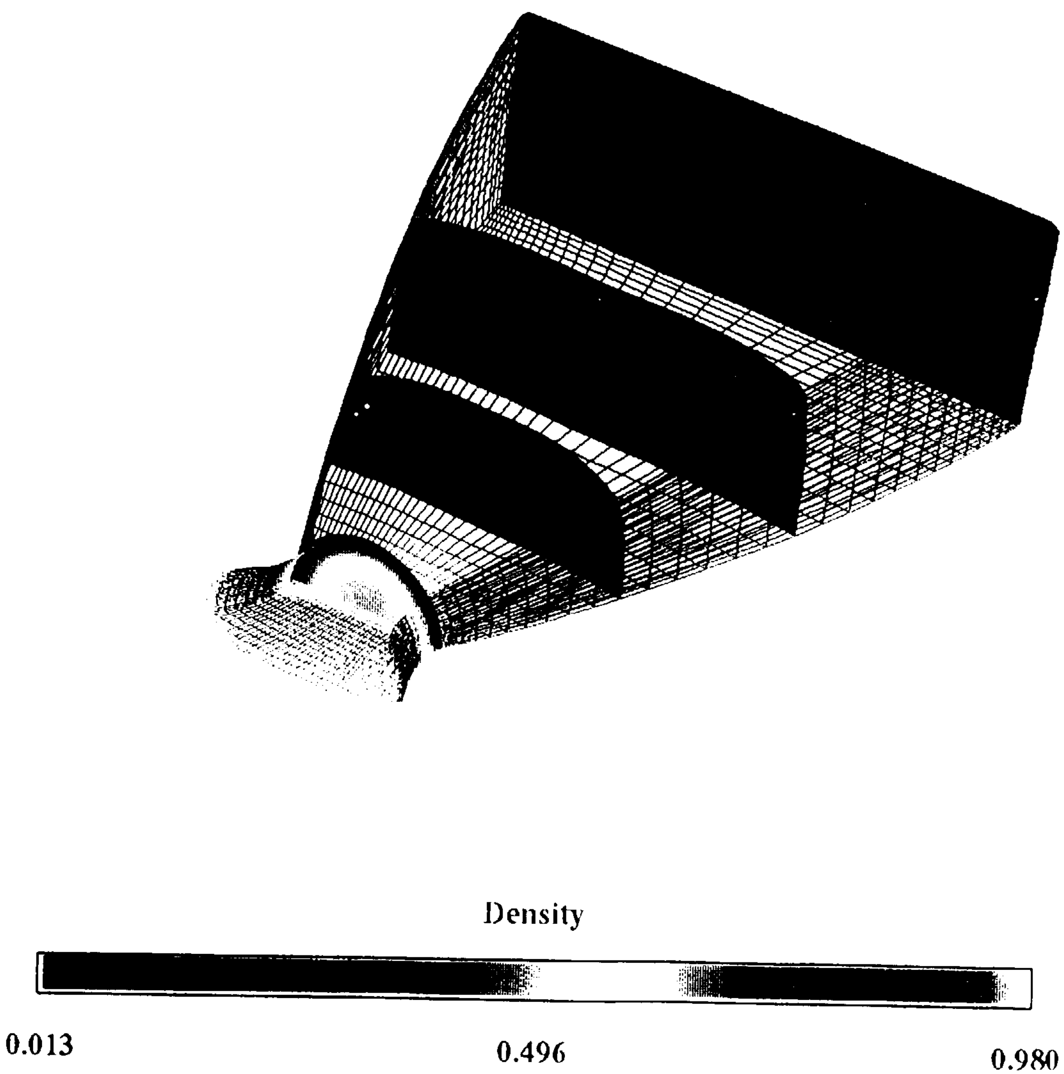


MISSISSIPPI STATE UNIVERSITY / National Science Foundation

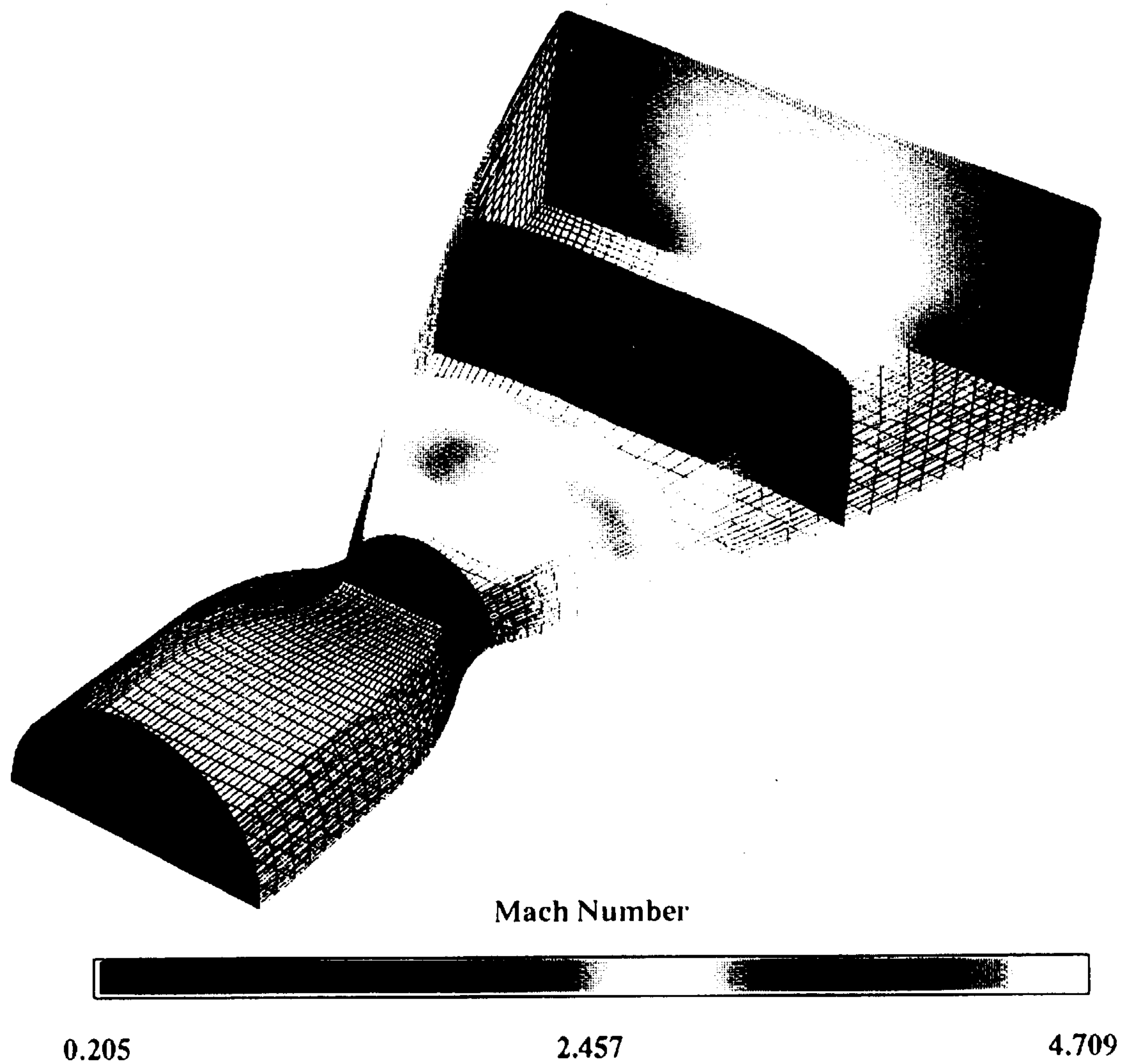
ENGINEERING RESEARCH CENTER FOR COMPUTATIONAL FIELD SIMULATION

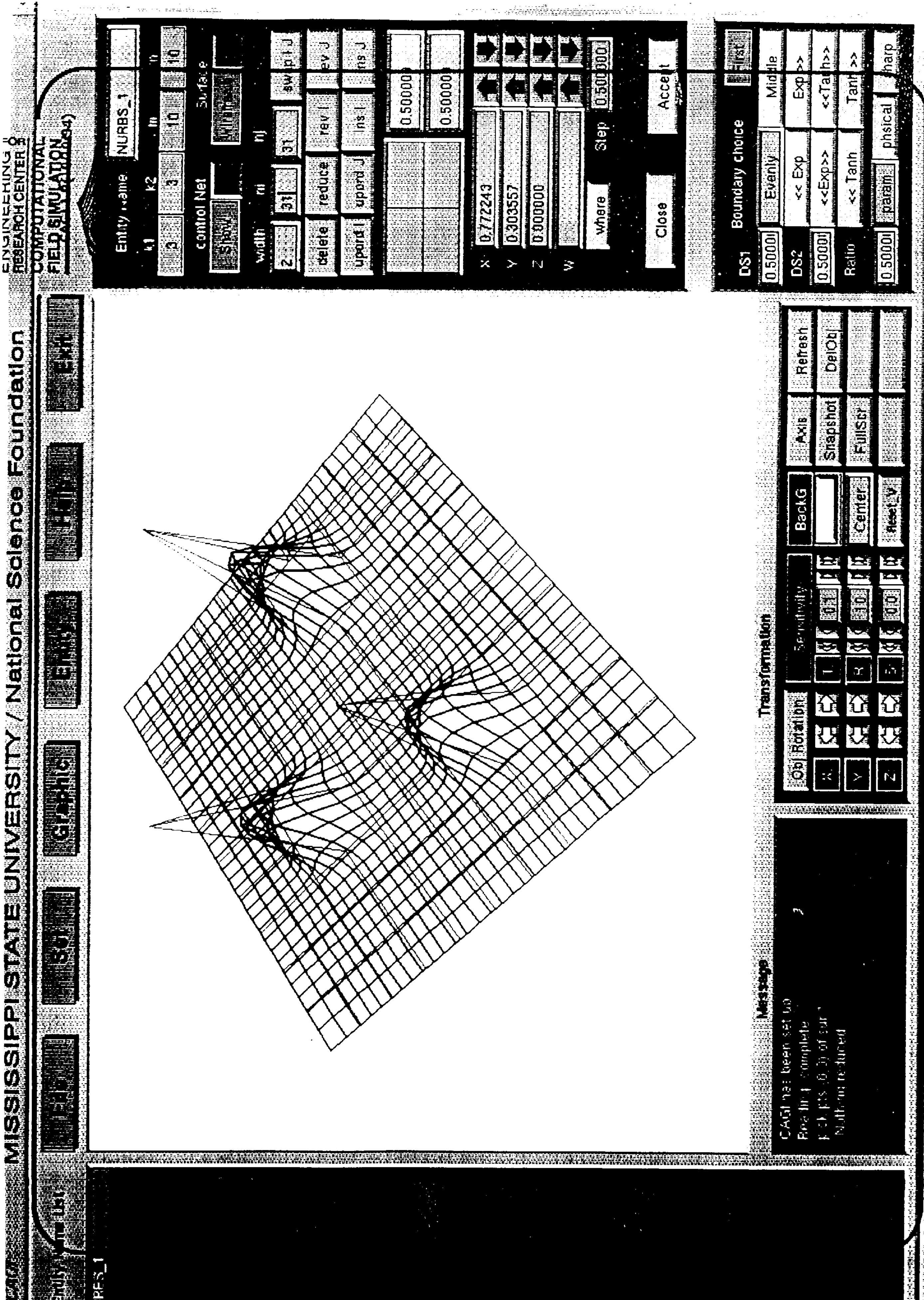


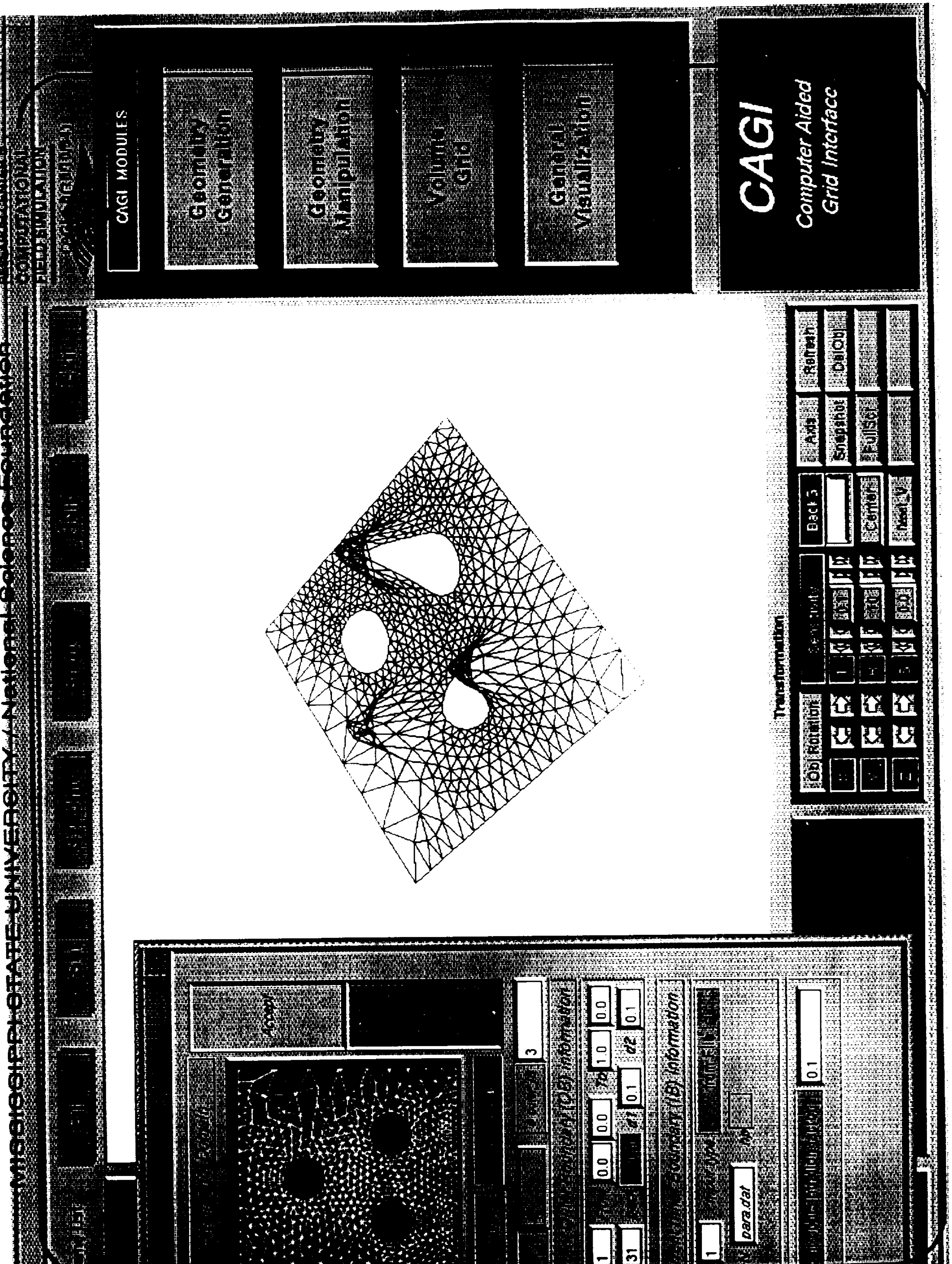
Converge/Diverge nozzle with circular-rectangular section



Converge/Diverge nozzle with circular-rectangular section




MISSISSIPPI STATE UNIVERSITY / National Science Foundation
ENGINEERING RESEARCH CENTER
COMPUTATIONAL FIELD SIMULATION
Exit
Entity name
NURBS_1
Control Net
Surface
width
delete
reduce
Close
Accept
Step
where
Boundary choice
DS1
DS2
Ratio
Evenly
Middle
<< Exp
Exp>>
<<Exp>>
<< Tanh
Tanh
<<Tanh>>
param
phsical
0.772243
0.303557
0.000000
0.50000
Transformation
Obj Rotation
Sensitivity
BackG
Axis
Refresh
Snapshot
DelObj
Center
FullScr
Reset_V
Message
NURBS_1


MISSISSIPPI STATE UNIVERSITY / National Science Foundation
ENGINEERING RESEARCH CENTER
COMPUTATIONAL FIELD SIMULATION
CAGI MODULES
Geometry Generation
Geometry Manipulation
Volume Grid
General Visualization
CAGI
Computer Aided Grid Interface
Accept
Transformation
Ob Rotation
Back 5
Axis
Refresh
Snapshot
DelObj
Center
FullScr
para.dat
Boundary (IB) Information
Boundary (OB) Information

On Going Activities:

- Surface/Volume grid characteristic improvement.
  (Distribution control, Orthogonality, smoothness ...)
- General algorithm allowing trim surface for structured grid.
- Enhance geometric generation/manipulation functions.
- Reparametration algorithm for unstructured grid.
- Unstructured/Hybrid grid generation.