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Methodology for CFD Design Analysis of National Launch System Nozzle Manifold

Scot L. Haire
Pratt & Whitney, West Palm Beach, FL

ABSTRACT

The current design environment dictates that high technology CFD (Computational Fluid Dynamics) analysis produce quality results in a timely manner if it is to be integrated into the design process. The design methodology outlined describes the CFD analysis of an NLS (National Launch System) nozzle film cooling manifold. The objective of the analysis was to obtain a qualitative estimate for the flow distribution within the manifold. A complex, 3D, multiple zone, structured grid was generated from a 3D CAD file of the geometry. An Euler solution was computed with a fully implicit compressible flow solver. Post processing consisted of full 3D color graphics and mass averaged performance. The result was a qualitative CFD solution that provided the design team with relevant information concerning the flow distribution in and performance characteristics of the film cooling manifold within an effective time frame. Also, this design methodology was the foundation for a quick turnaround CFD analysis of the next iteration in the manifold design.

METHODOLOGY FOR CFD ANALYSIS OF A NATIONAL LAUNCH SYSTEM FILM COOLING NOZZLE MANIFOLD

PRATT & WHITNEY
DEPENDABLE ENGINES

Scot Haire

Pratt & Whitney, GESP

West Palm Beach, Florida

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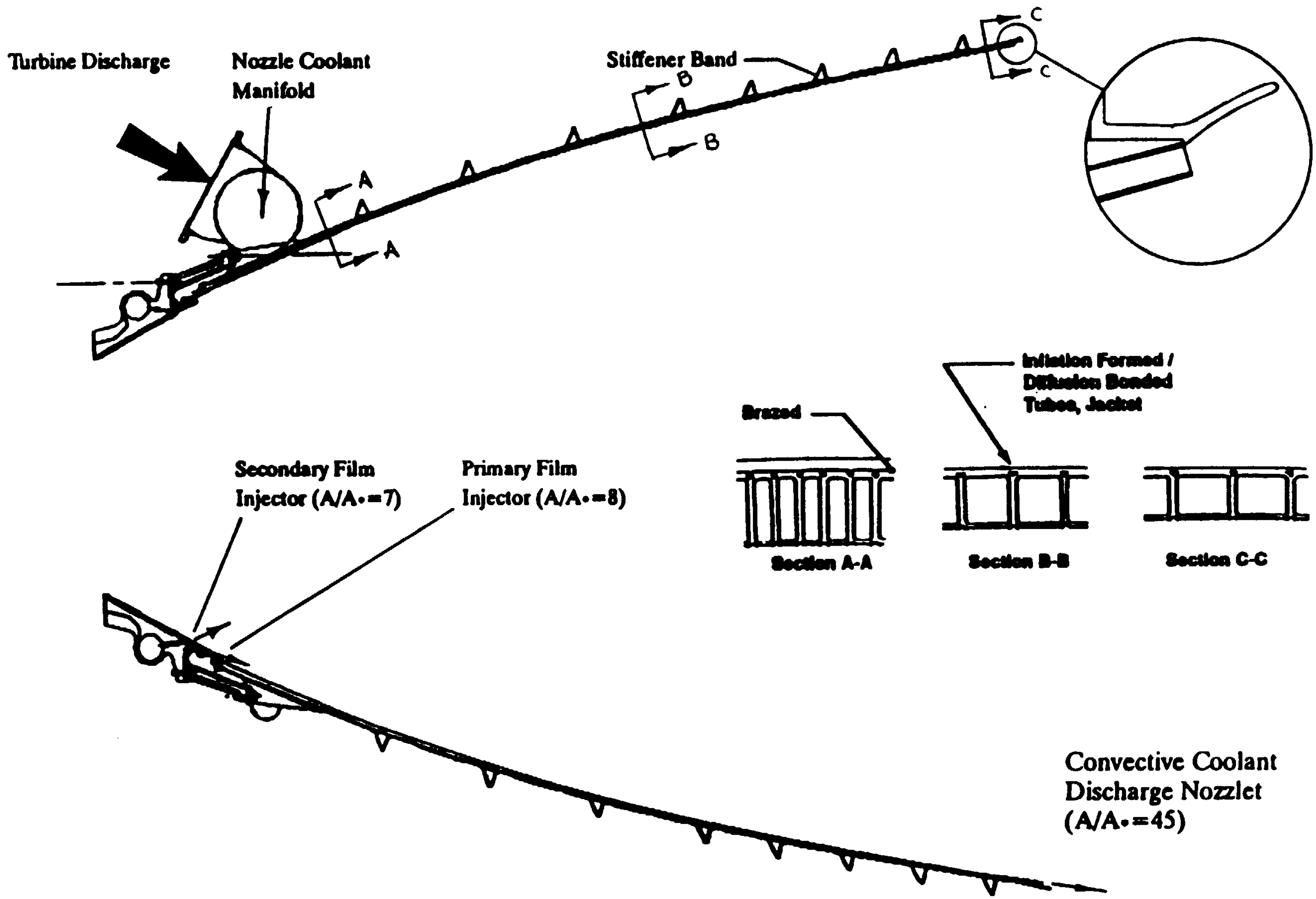
NLS MANIFOLD ANALYSIS

- Purpose of the analysis
- Manifold geometry
- Schedule limitations
- Pre–processing
  - Geometry modification
  - Grid generation
- Solution
- Post–processing
  - Color graphics
  - Performance
- Summary

ANALYSIS OBJECTIVE

To determine the flow distribution at the exit of the manifold without the effects of a choked orifice. This will identify the flow uniformity as a function of the volute manifold geometry alone.

STME FILM/CONVECTIVE COOLED NOZZLE



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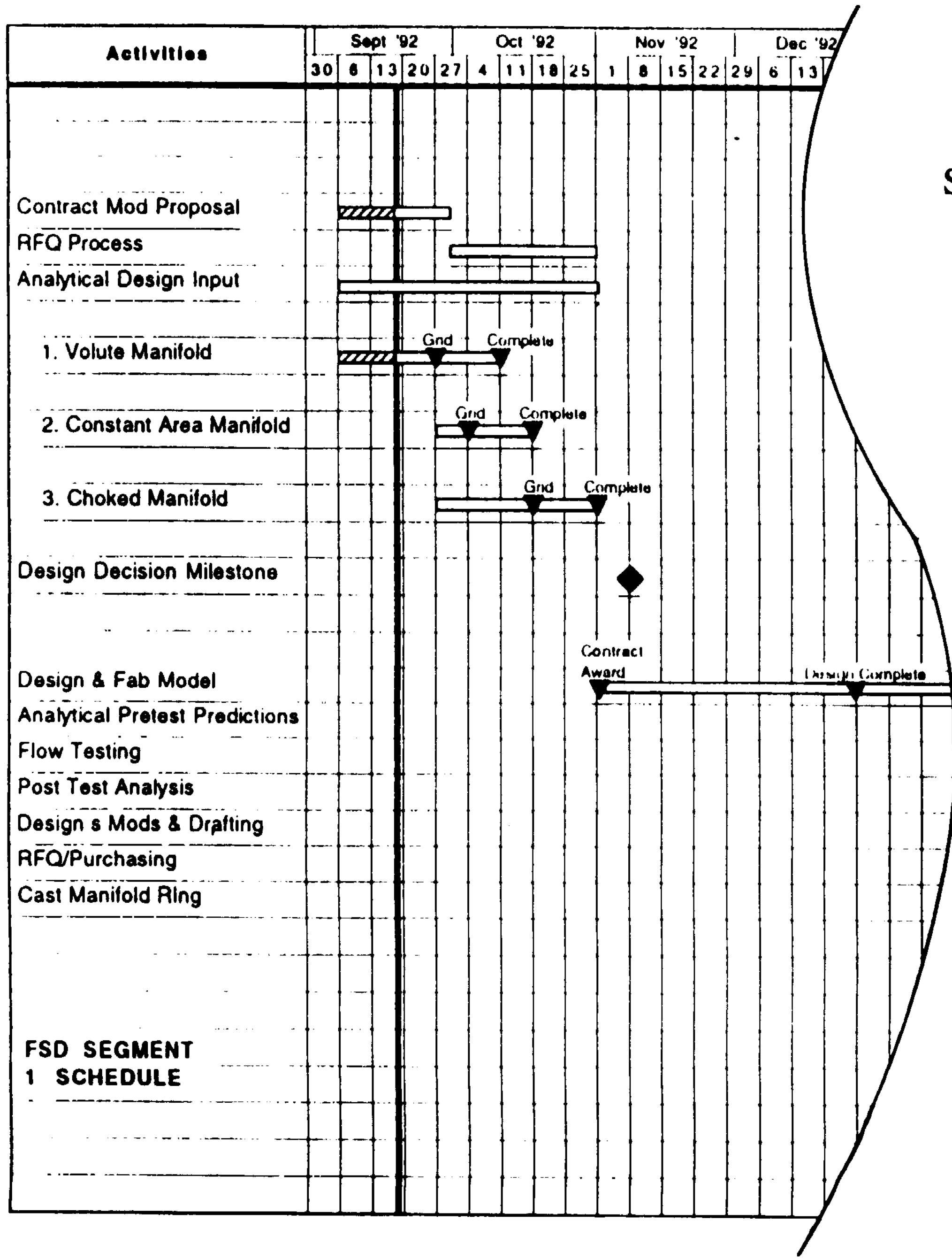
SCHEDULE REQUIREMENT



STME Nozzle Manifold Development

PRELIMINARY

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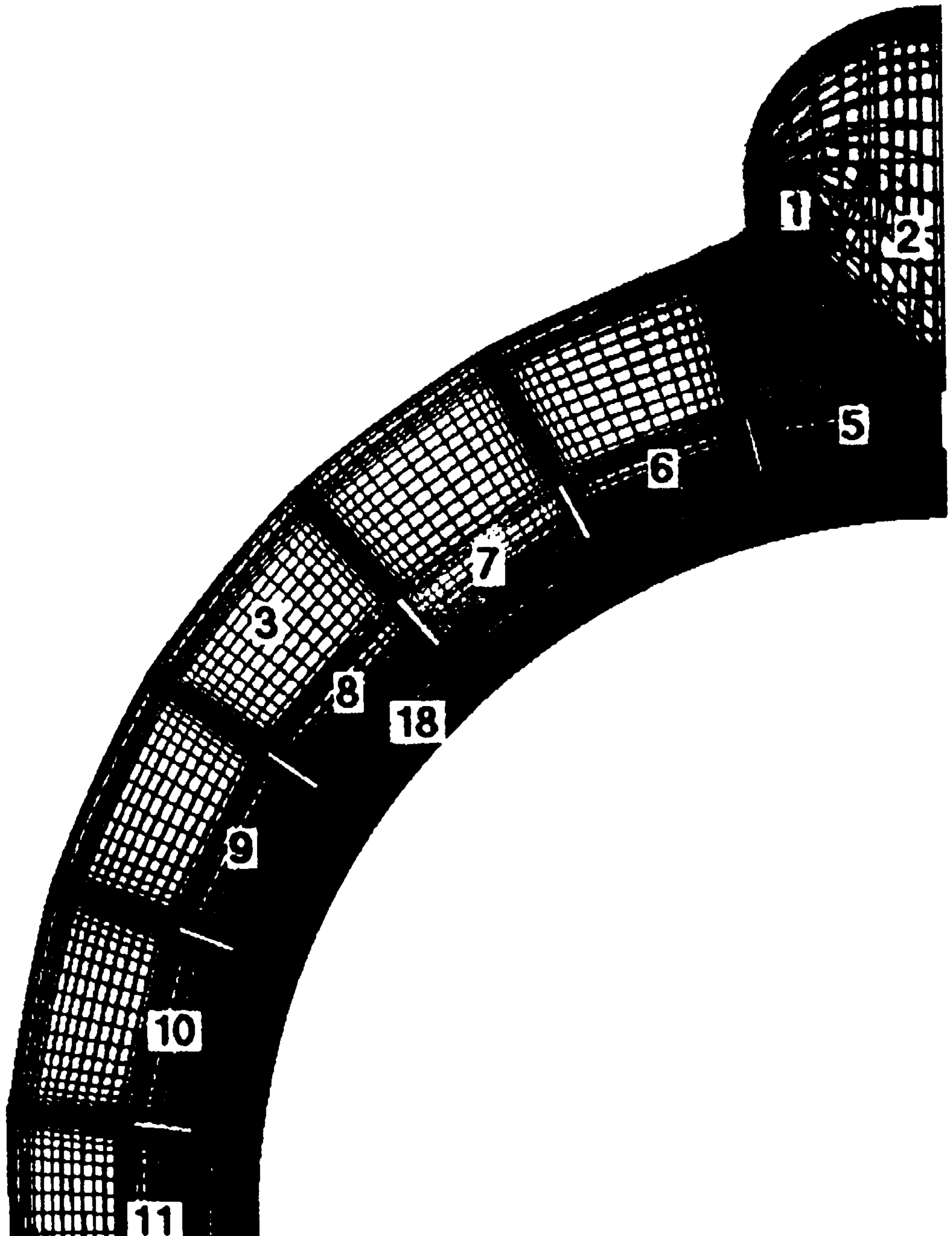
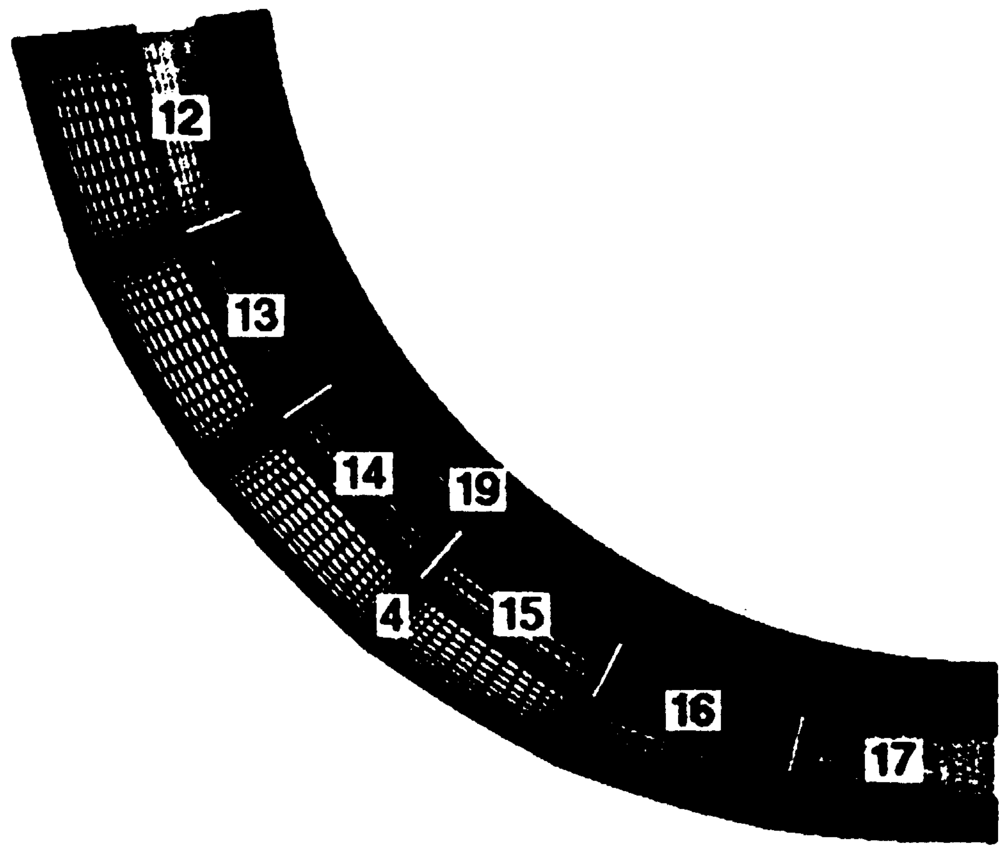
PRE–PROCESSING

- Geometry modification
  - Splitter vane
  - ICEM DDN (CDC)
- Grid generation
  - ICEM DDN, PADDAM, MULCAD (CDC)
  - $\sim$ 130,000 points
  - 19 zones
- Time to complete $\sim$ 7 days

Computational Grid Zones



Computational Grid Zones



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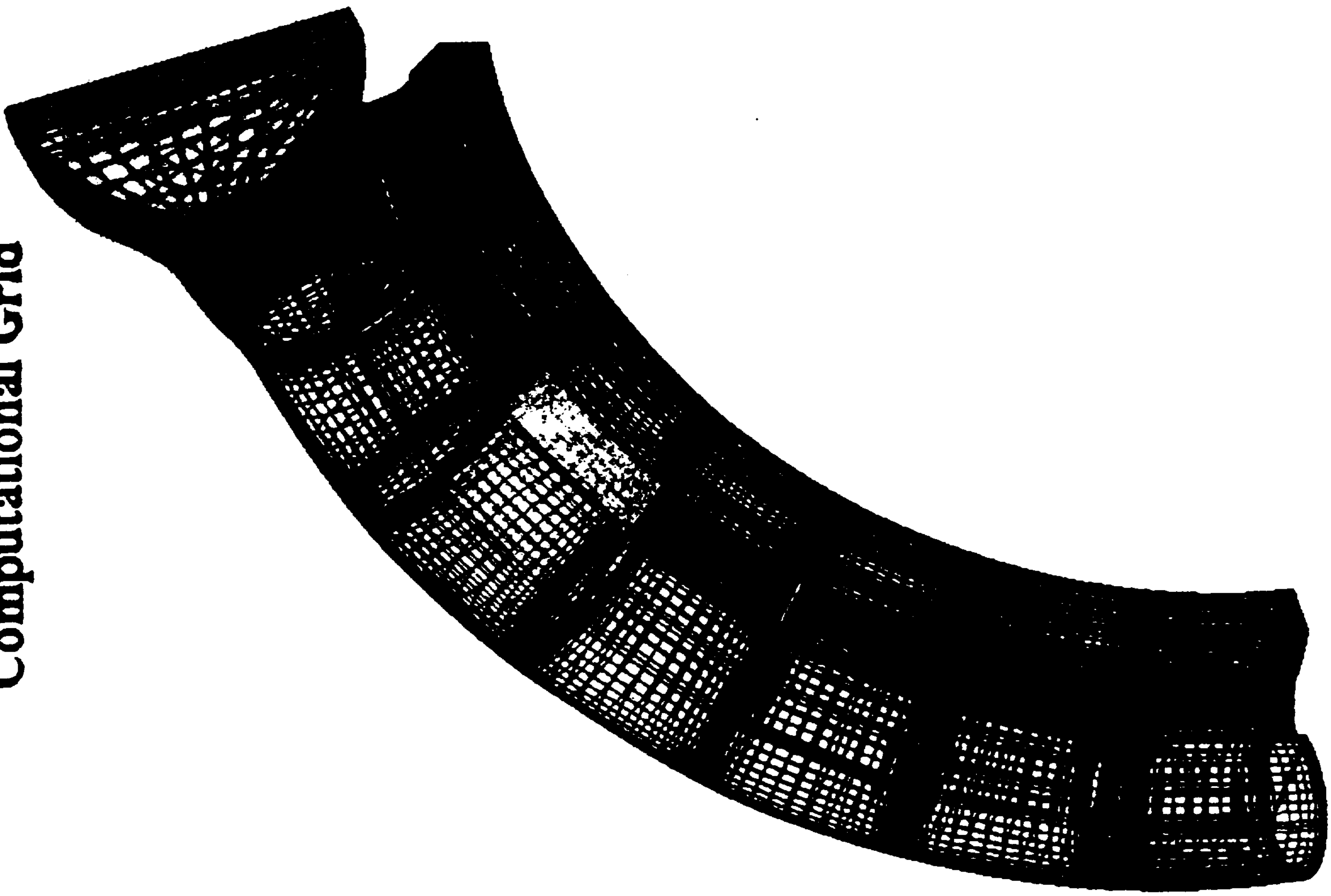
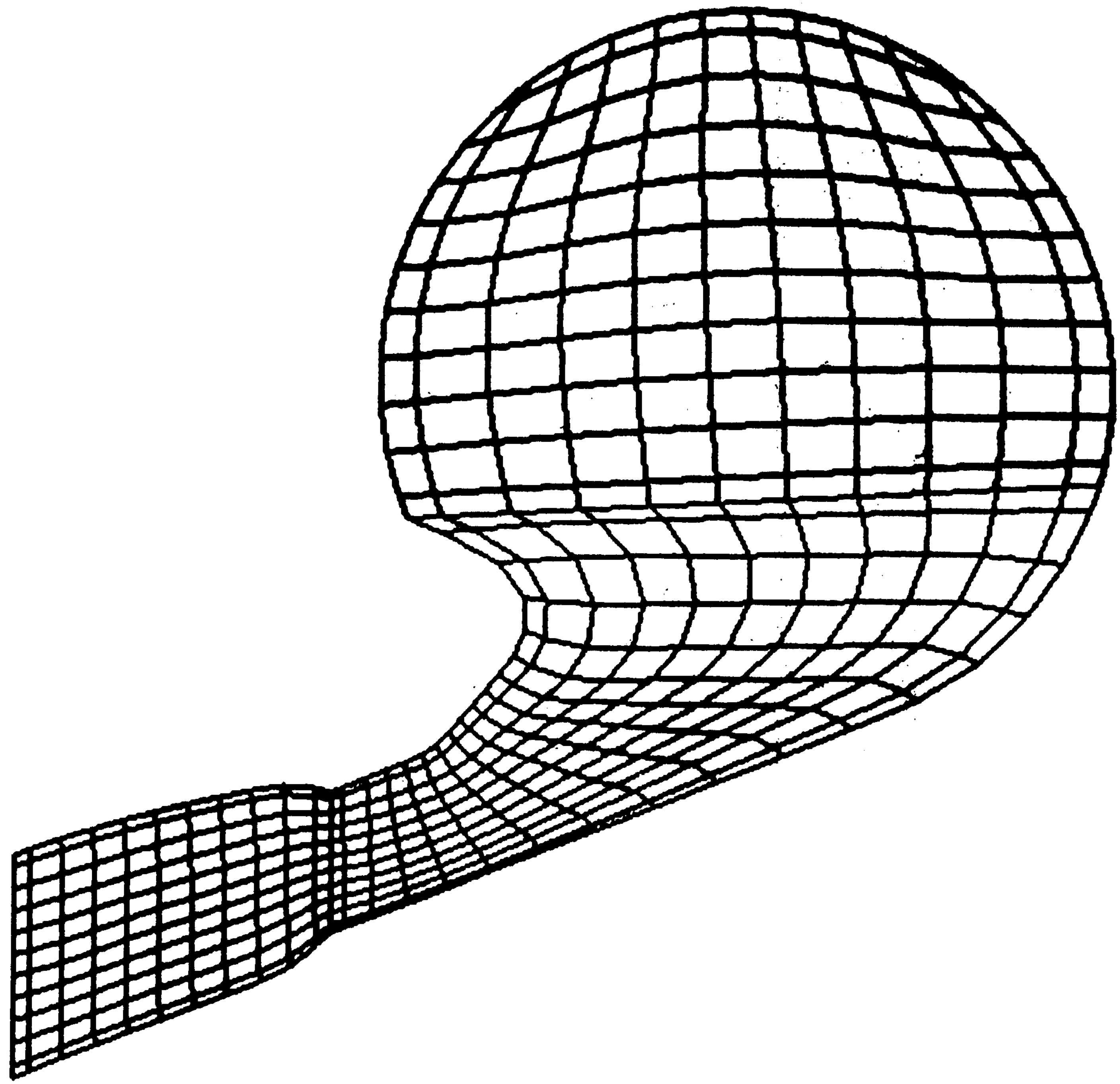
Computational Grid



Computational Grid Cross Section

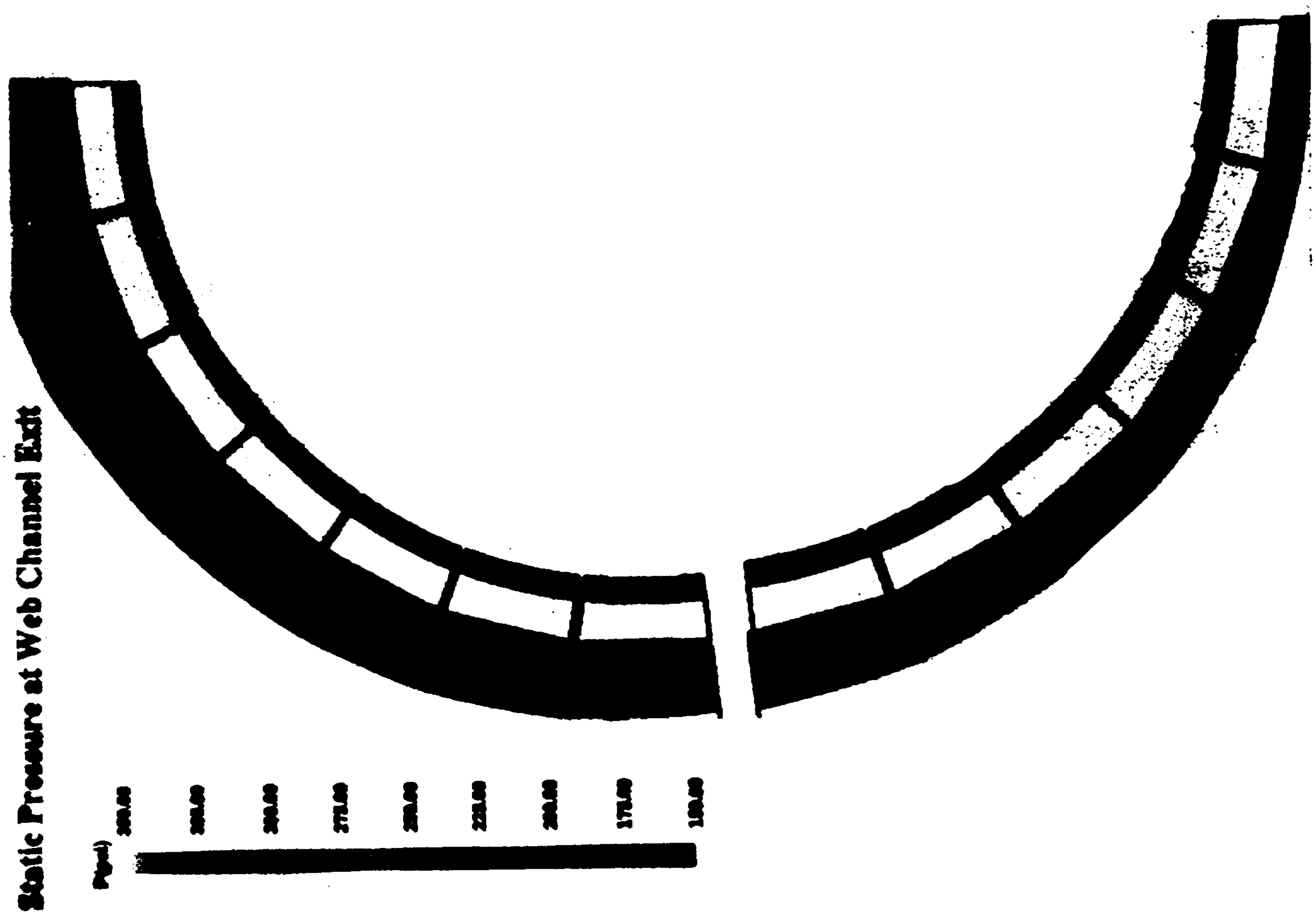


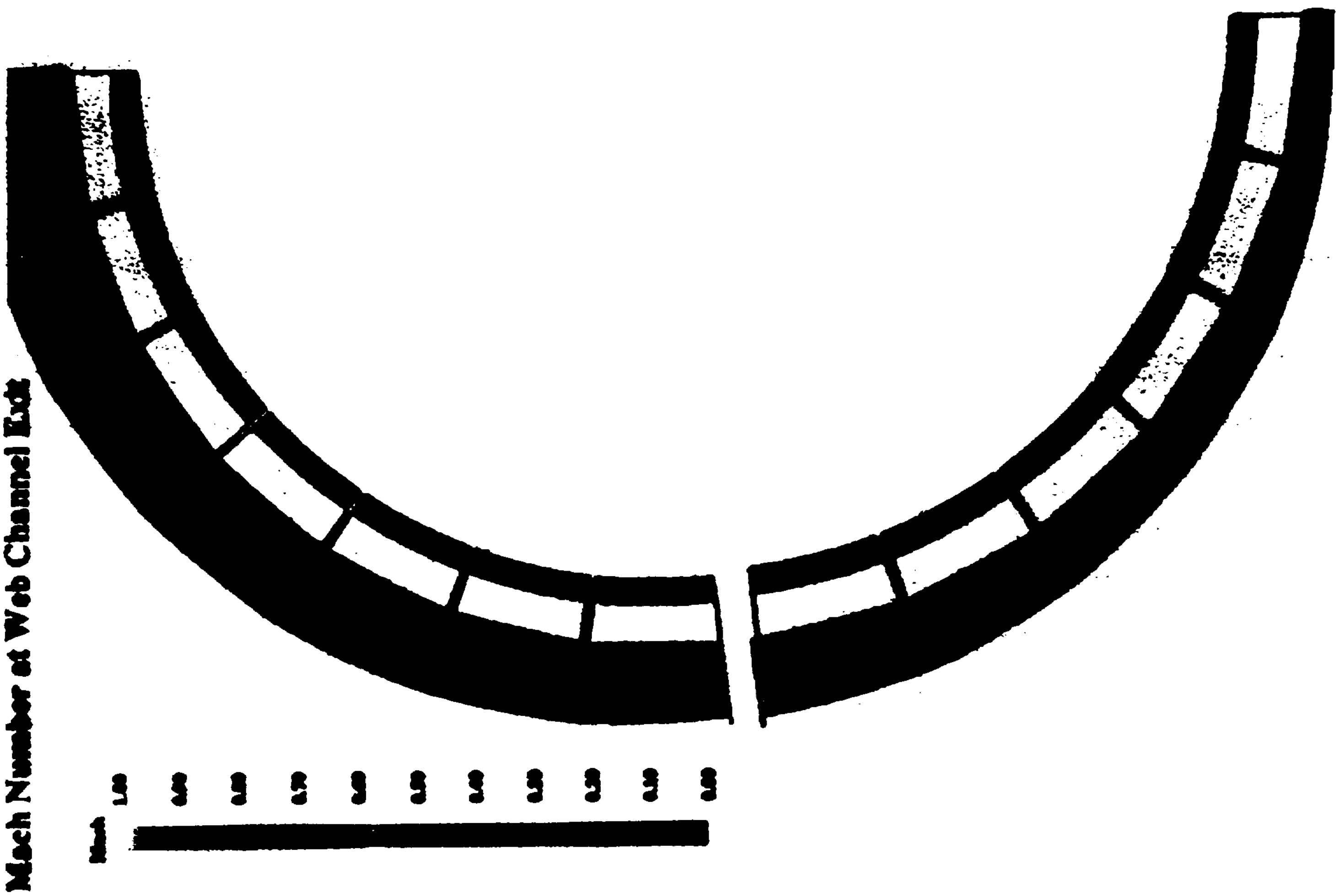
SOLUTION

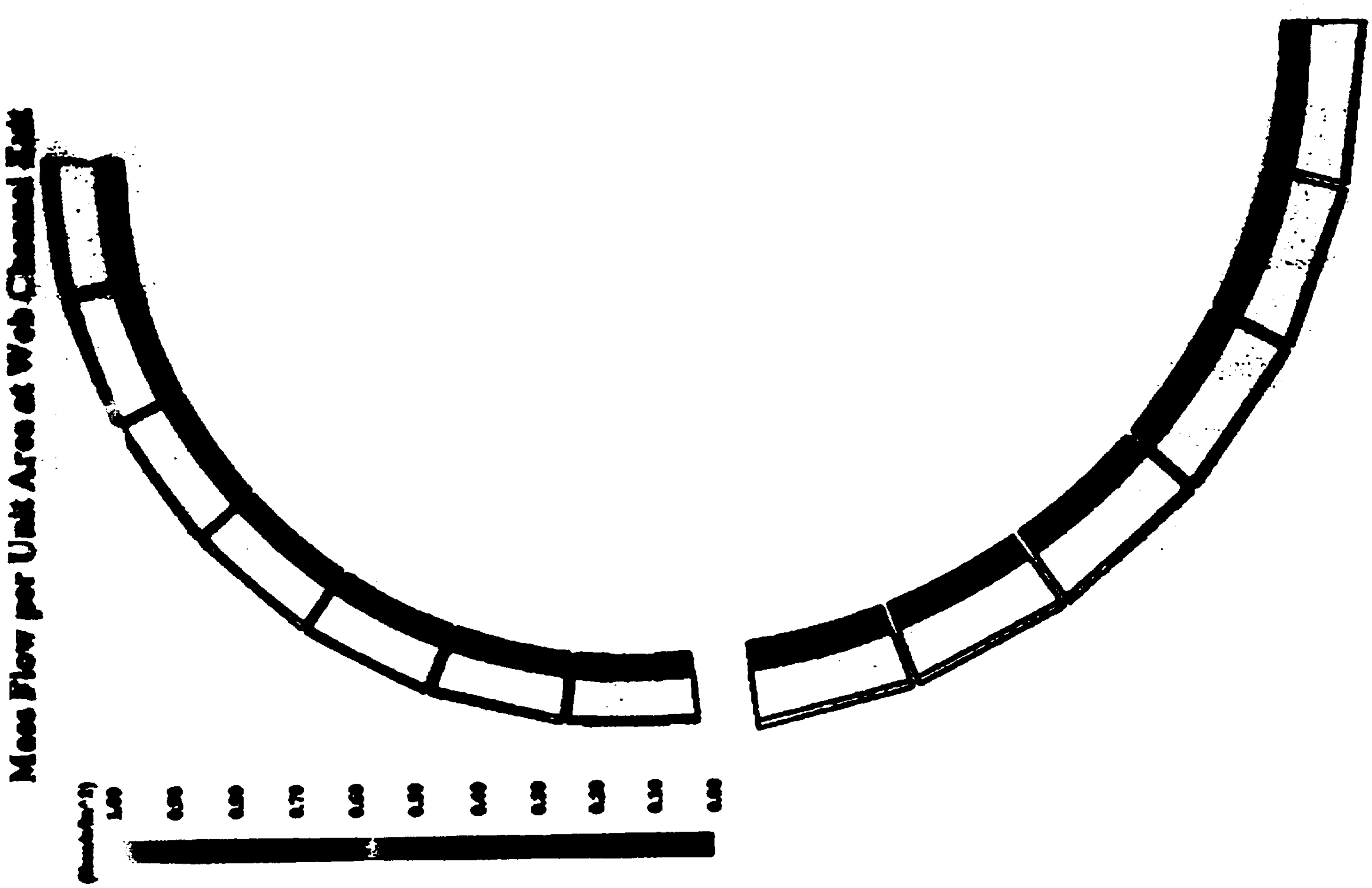
- GASP 2.0 (AeroSoft)
  - Fully Implicit
  - Finite volume
- 64 MW SGI Machine
- Flow solution
  - 3–D inviscid (viscous)
  - 108 CPU hours ($\sim$ 5 days)
- Time to complete $\sim$ 7 days

POST PROCESSING

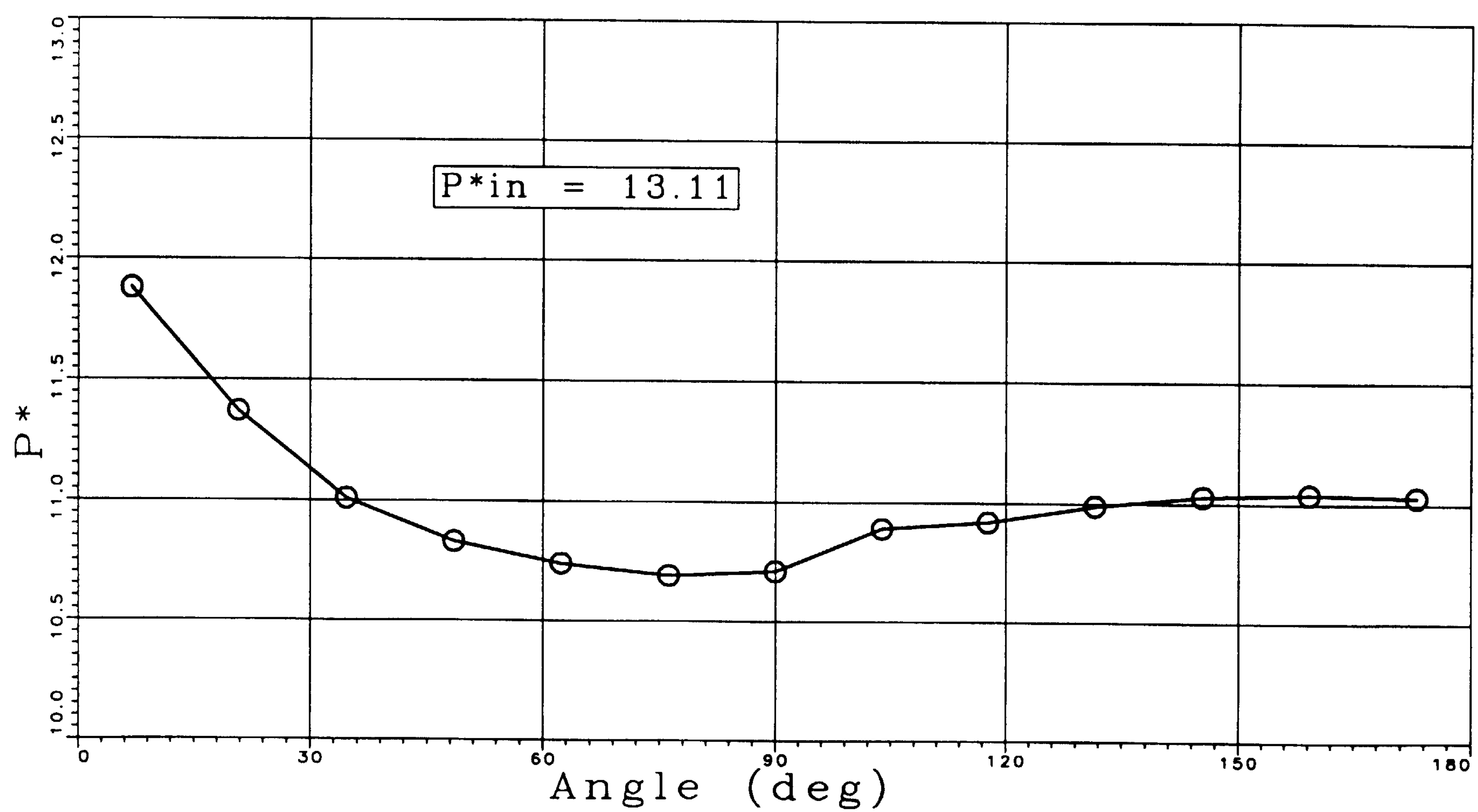
- Color graphics
  - FAST (NASA Ames)
  - Visualization of flow distribution
- Mass averaged performance
  - Pratt & Whitney utilities
  - Static pressure
  - Mach number
  - Mass flow rate

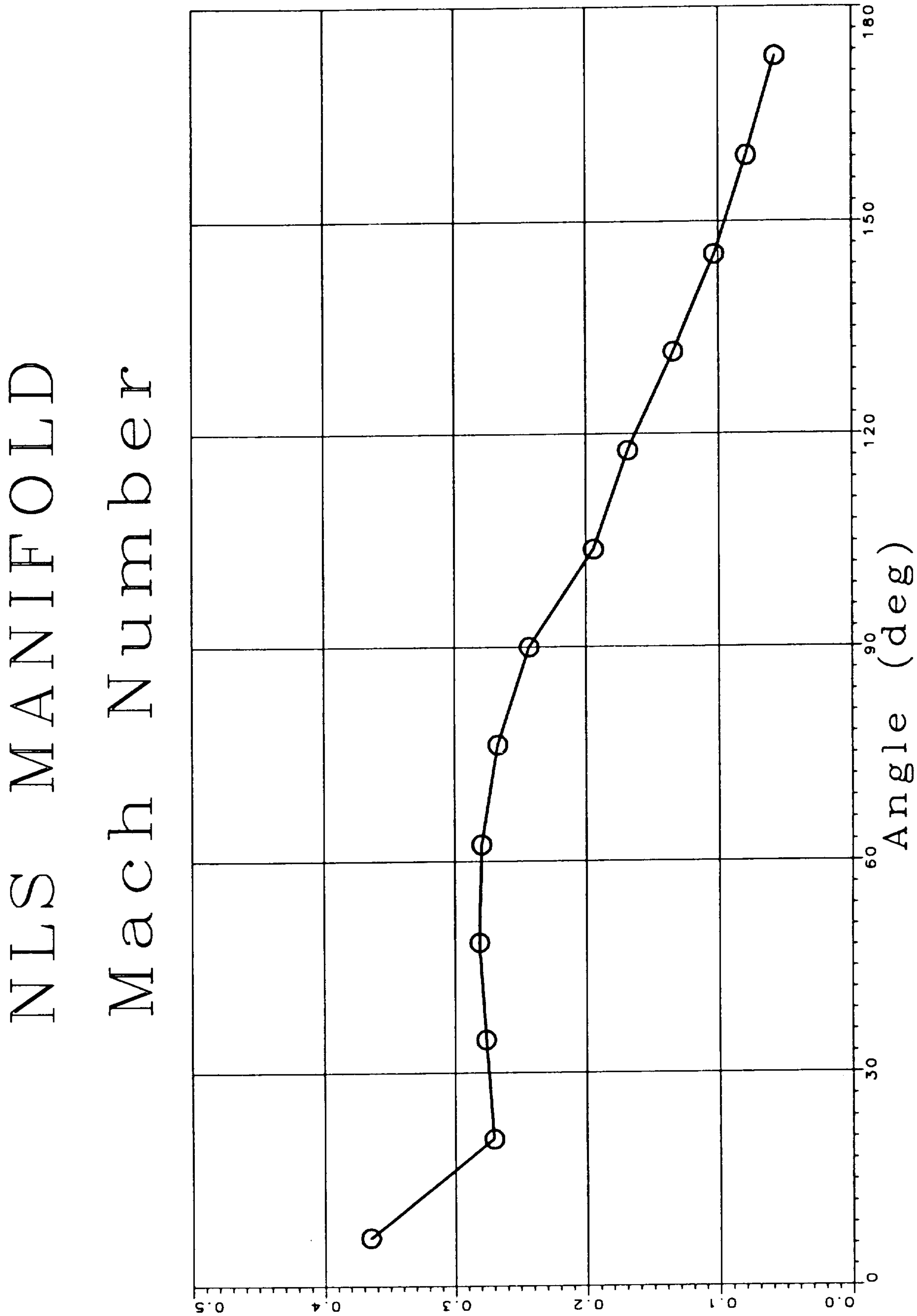

Static Pressure at Web Channel Exit

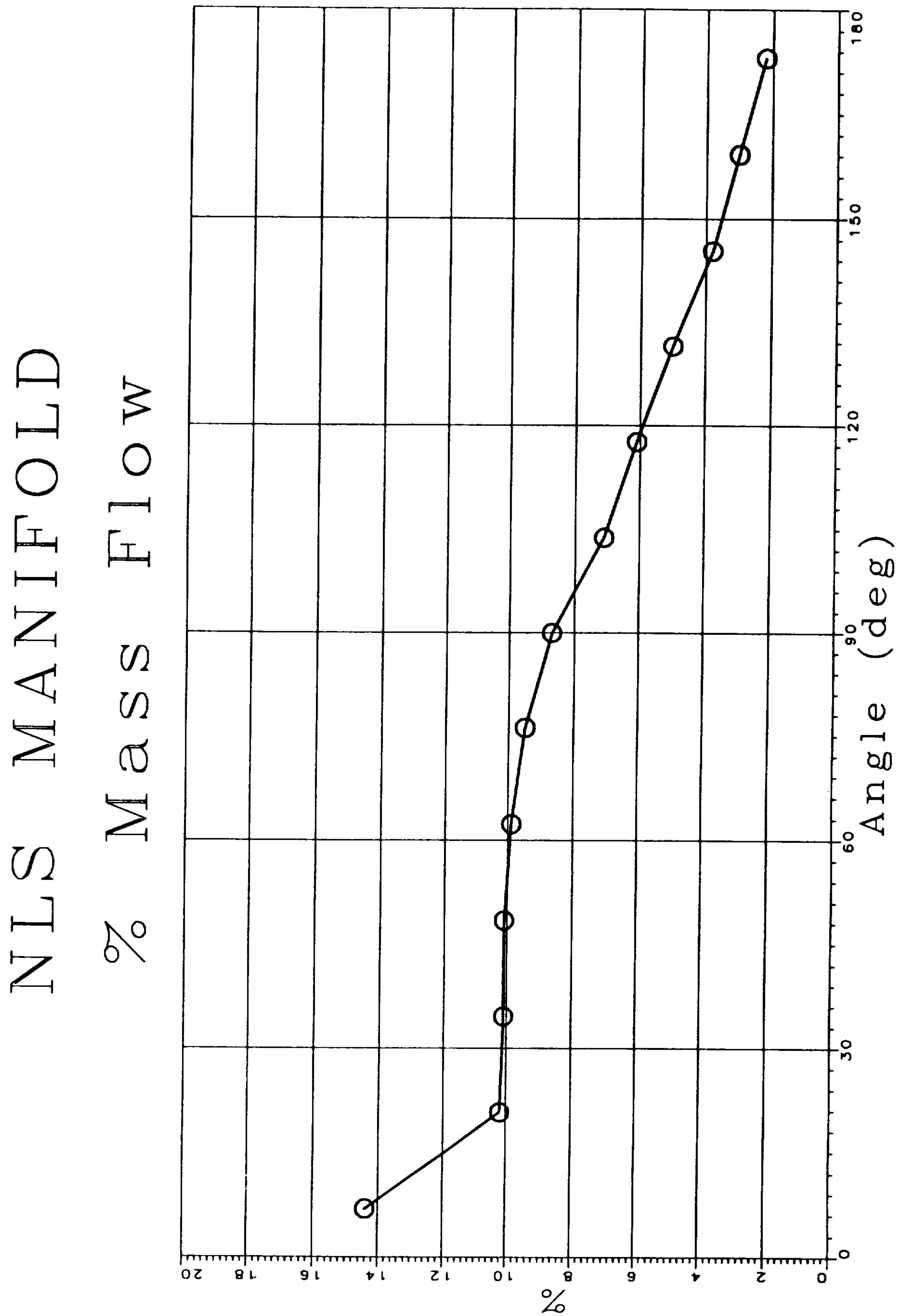

Mach Number at Web Channel Exit


Mass Flow per Unit Area at Web Channel Exit

NLS MANIFOLD
Normalized Static Pressure




NLS MANIFOLD
Mach Number
Angle (deg)
0
30
60
90
120
150
180
0.0
0.1
0.2
0.3
0.4
0.5



NLS MANIFOLD
% Mass Flow
Angle (deg)
%
0
30
60
90
120
150
180
0
2
4
6
8
10
12
14
16
18
20

SUMMARY

- Working parameters
  - Limited time
  - Complex geometry
- Qualitative results
  - Mass averaged circumferential variations
- Timely response –
  - $\sim$ 14 days for first analysis