

## Ascent Aerodynamic Pressure Distributions on WB001

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To support the reusable launch vehicle concept study, the aerodynamic data and surface pressure for WB001 were predicted using three CFD codes at several flow conditions during the ascent phase. The results have been compared between code to code and code to aerodynamic database as well as available experimental data. A set of particular solutions have been selected and recommended for use in preliminary conceptual designs. These CFD results have also been provided to the structure group for wing loading analyses.



National Aeronautics and  
Space Administration

## **RLV Concept Study Review**

Computational Fluid Dynamics Branch  
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George C. Marshall Space Flight Center

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# **Ascent Aerodynamics Analysis of WB001 Configuration**

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# RLV Concept Study Review

## OUTLINE

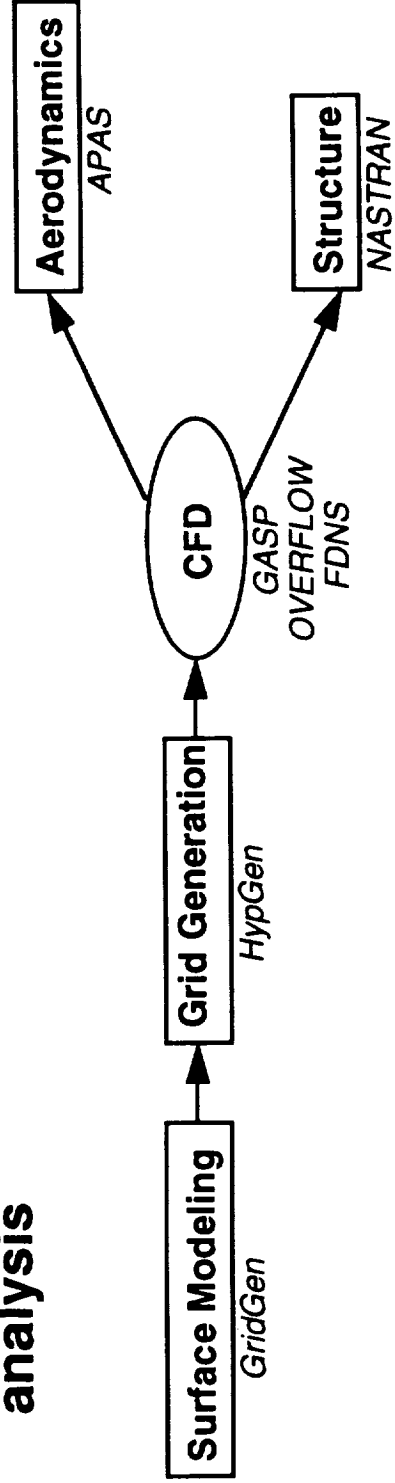
- Objectives
- Codes employed
- Cases considered
- Results and discussions
- Structural analyses
- Conclusions



# RLV Concept Study Review

## OBJECTIVES

- Predict the flow field environment during ascent
- Compute the aerodynamic coefficients
- Provide three-dimensional surface pressure for structure analysis





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## CODES EMPLOYED

- **OVERFLOW**
  - capable of solving overset grids
  - used at ARC and JSC for orbiter analyses
  
- **GASP**
  - finite-volume, density-based
  - used at LaRC and Wright Patterson for NASP vehicle design
  
- **FDNS**
  - finite-difference, pressure-based
  - used at MSFC for reacting flow analyses



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## CASES CONSIDERED

Transonic (M=1.1)      Supersonic (M=5.72)

<u>AOA</u> 6°	0°	<u>AOA</u> 6°	8°
<i>GASP inv./vis</i>		<i>GASP vis</i>	
<i>OVERFLOW inv./vis</i>	<i>OVERFLOW vis</i>	<i>OVERFLOW vis</i>	<i>OVERFLOW vis</i>
<i>FDNS vis.</i>			



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## RESULTS & DISCUSSIONS

- Computational domain for both cases properly generated to capture physics associated flow conditions
- Surface pressure and symmetry Mach contours
  - good agreement for surface pressure
  - good agreement centerline Mach contours
- Pressure coefficients for vehicle nose
  - predicted stagnation  $C_p$  agrees with isentropic theory
  - $M = 1.1$   $C_p = 1.36$  (CFD / GASP)
  - $M = 1.1$   $C_p = 1.34$  (Theory)



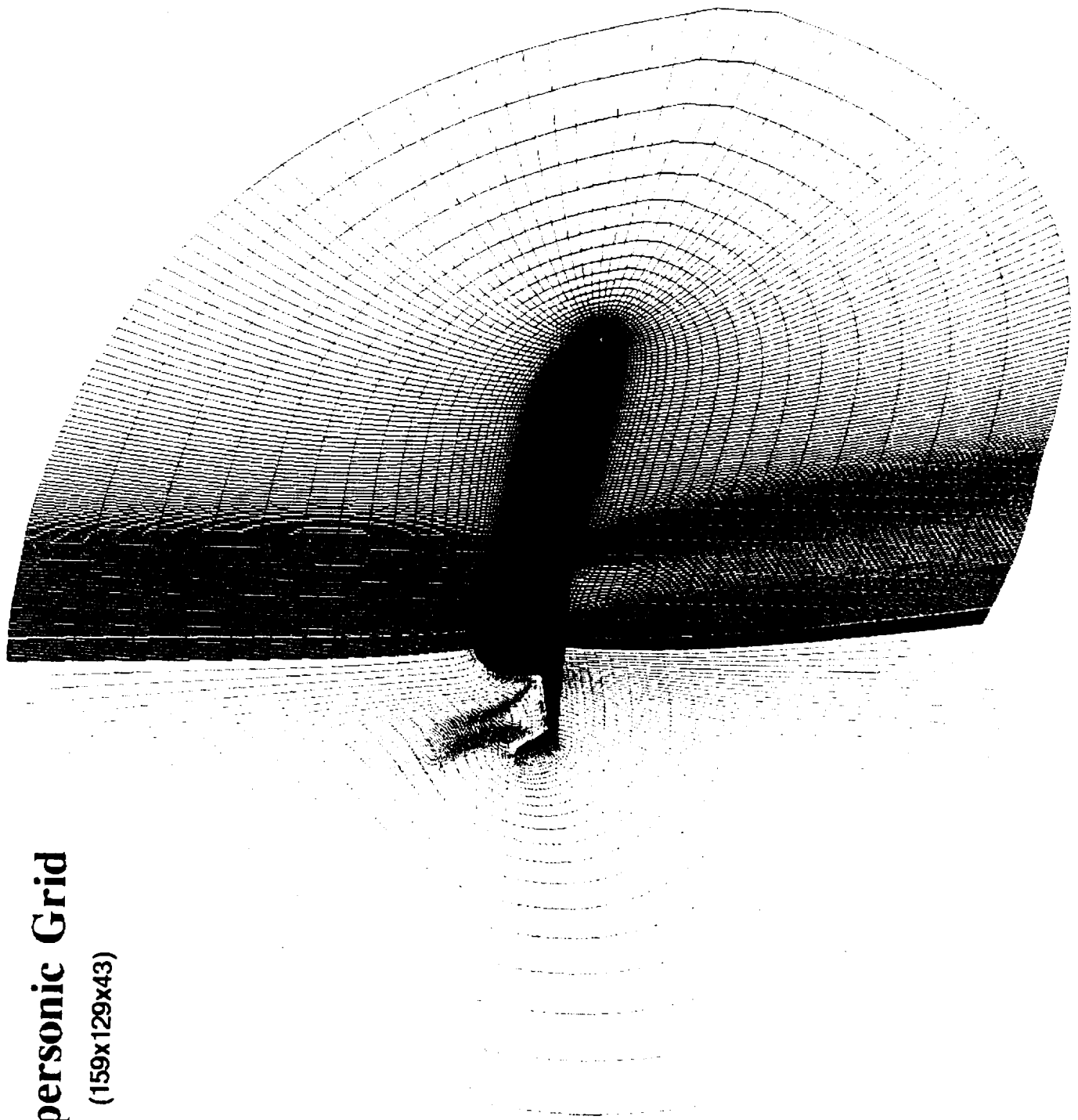
# Transonic Grid

(159x129x65)



# Supersonic Grid

(159x129x43)





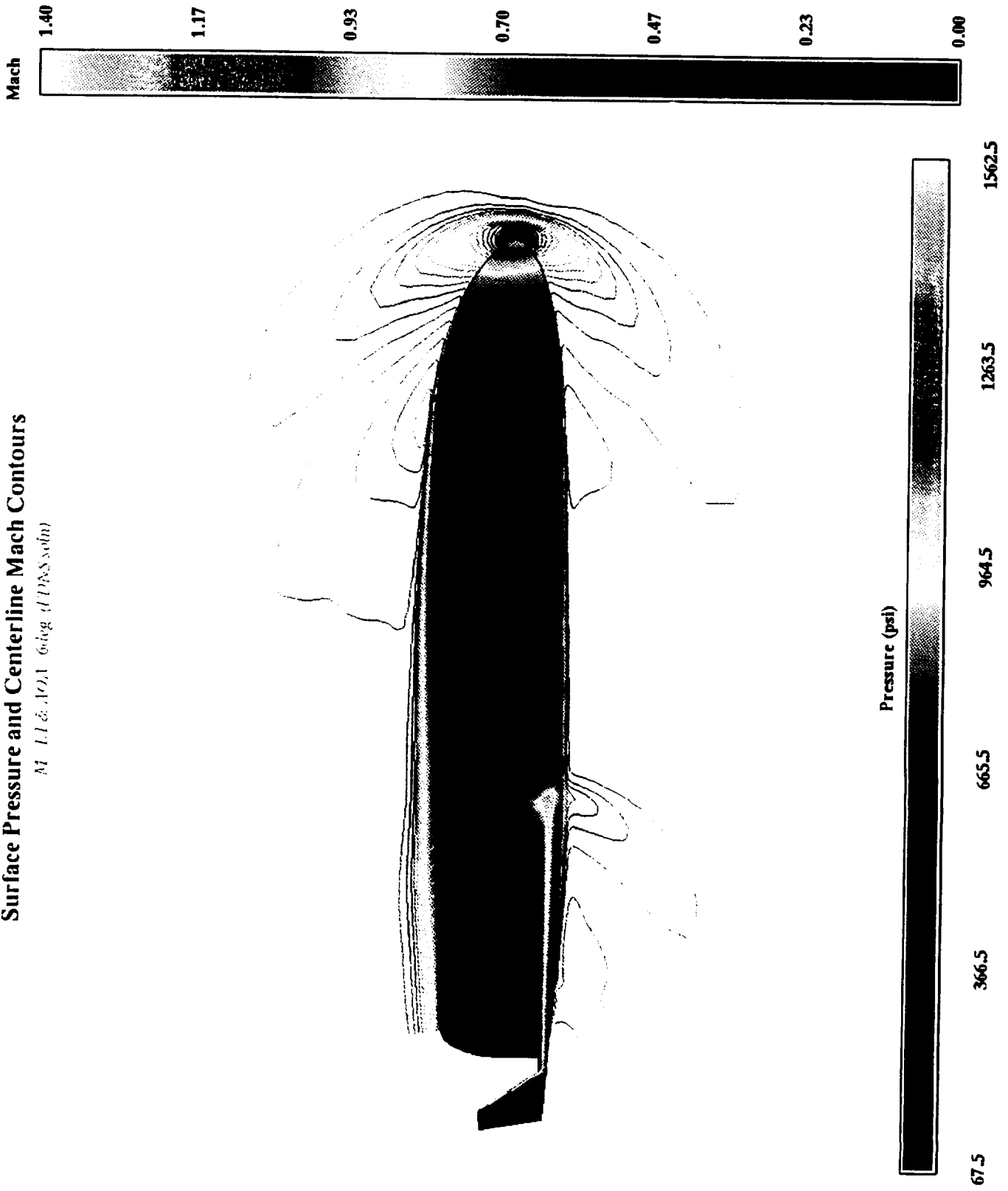
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## COMPARISONS

- **Code-to-code comparison**
  - good agreement for surface pressure and centerline Mach contours
- **3 aerodynamic coefficients are compared between codes and with APAS database**
  - excellent agreement in high supersonic case
  - good agreement in transonic case

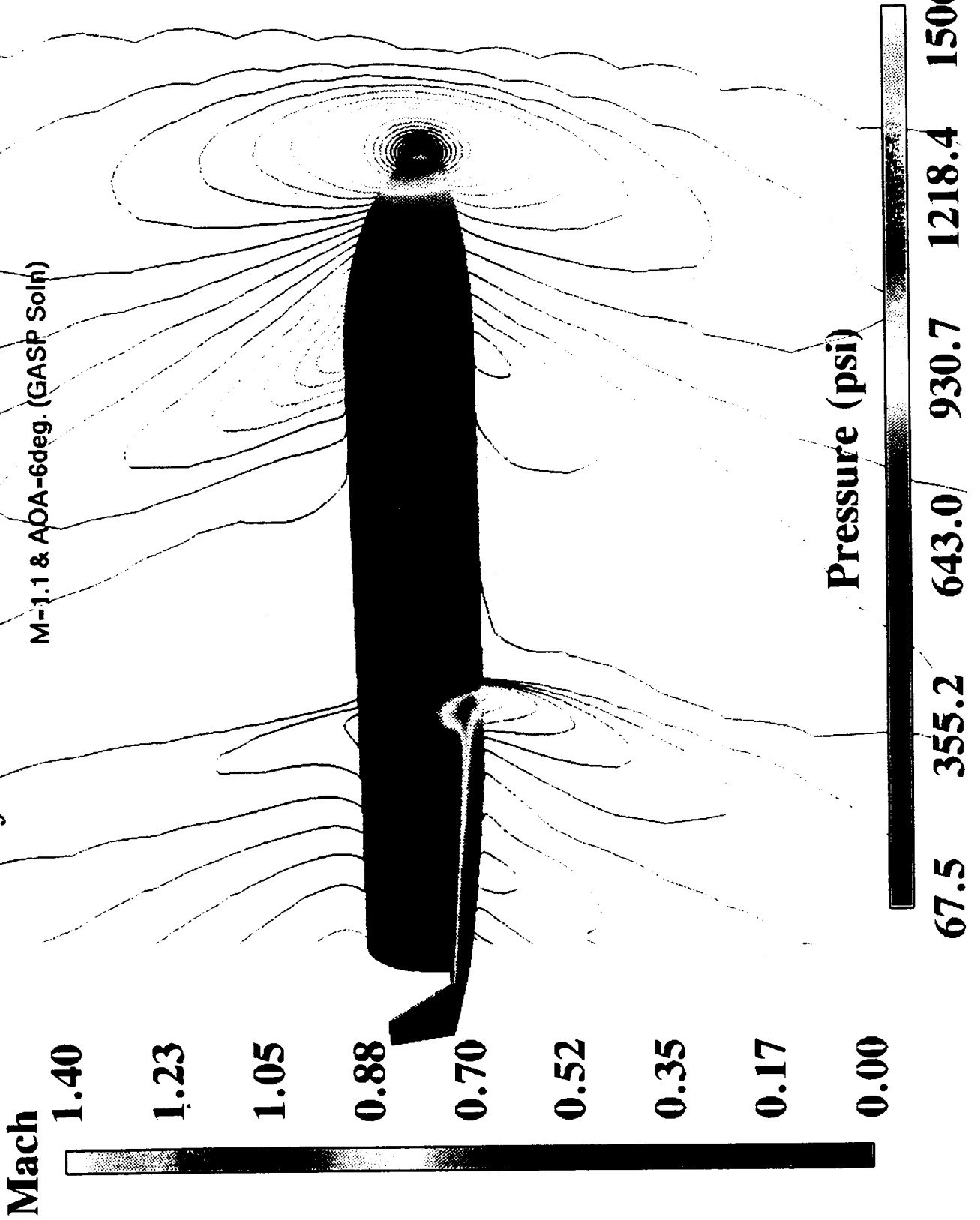
# Surface Pressure and Centerline Mach Contours

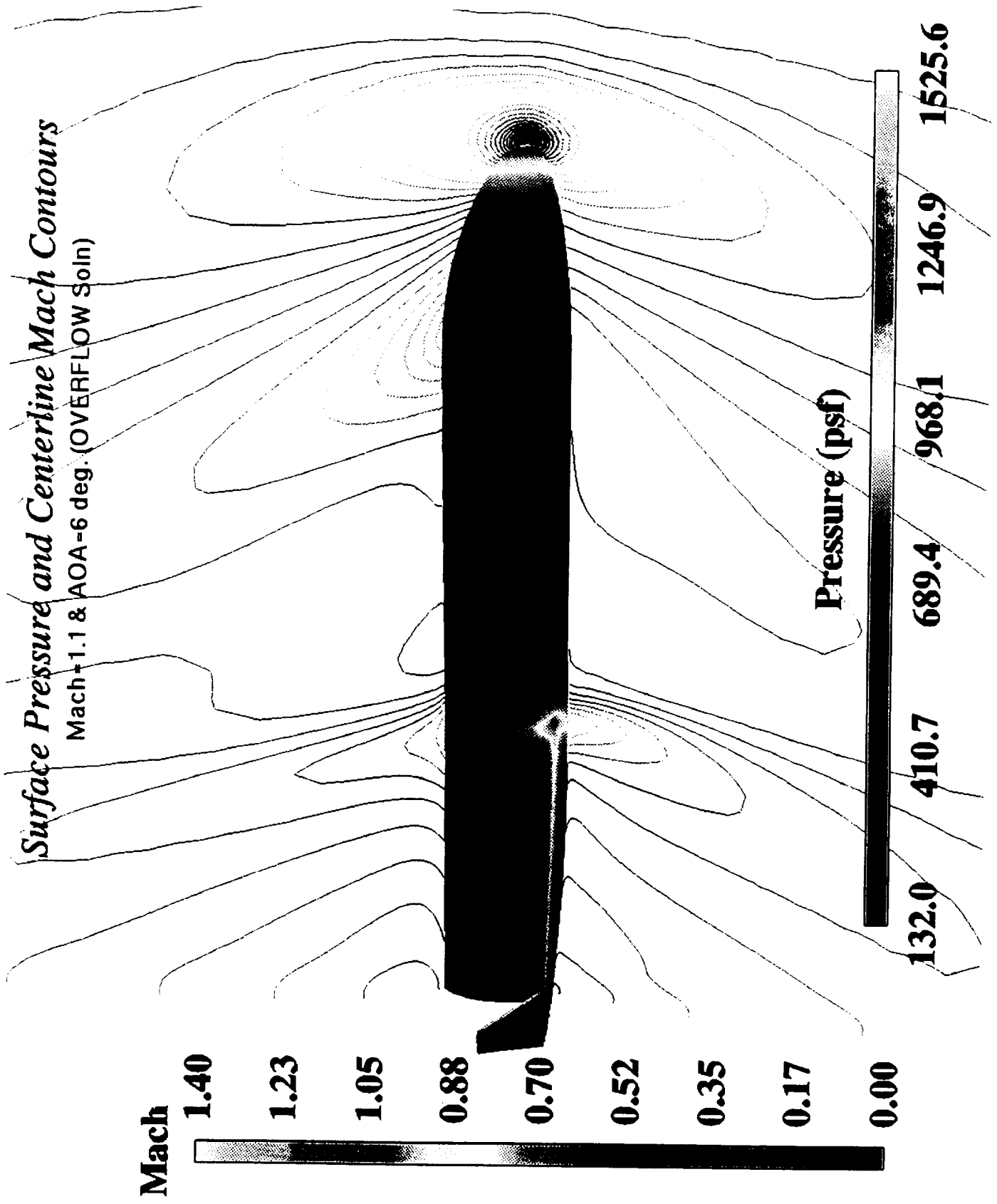
*M 1.16, 10/1 6deg (DNS soln)*



# Surface Pressure and Centerline Mach Contours

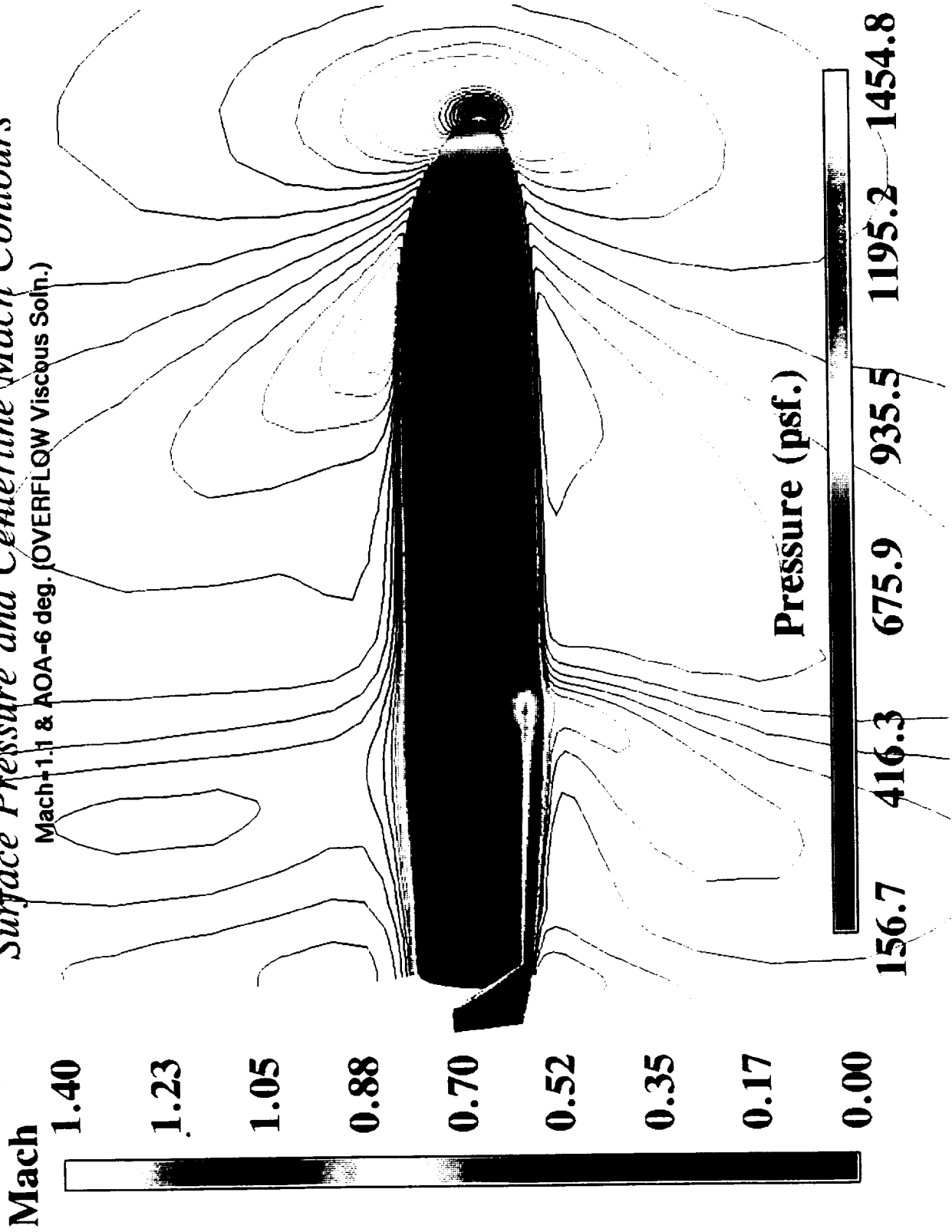
M=1.1 & AOA=6deg. (GASP Soln)





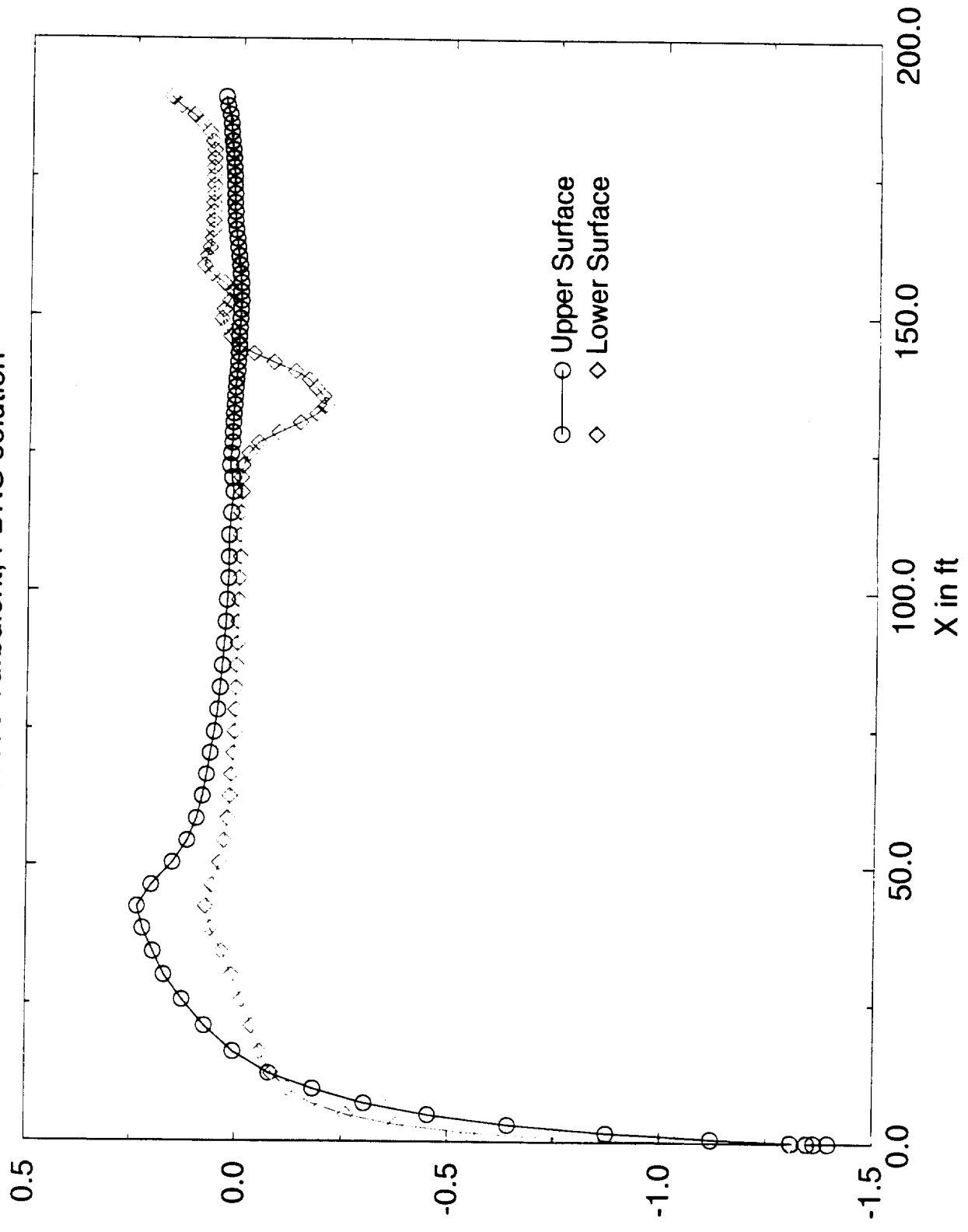
# Surface Pressure and Centerline Mach Contours

Mach 1.1 & AOA -6 deg. (OVERFLOW Viscous Soln.)



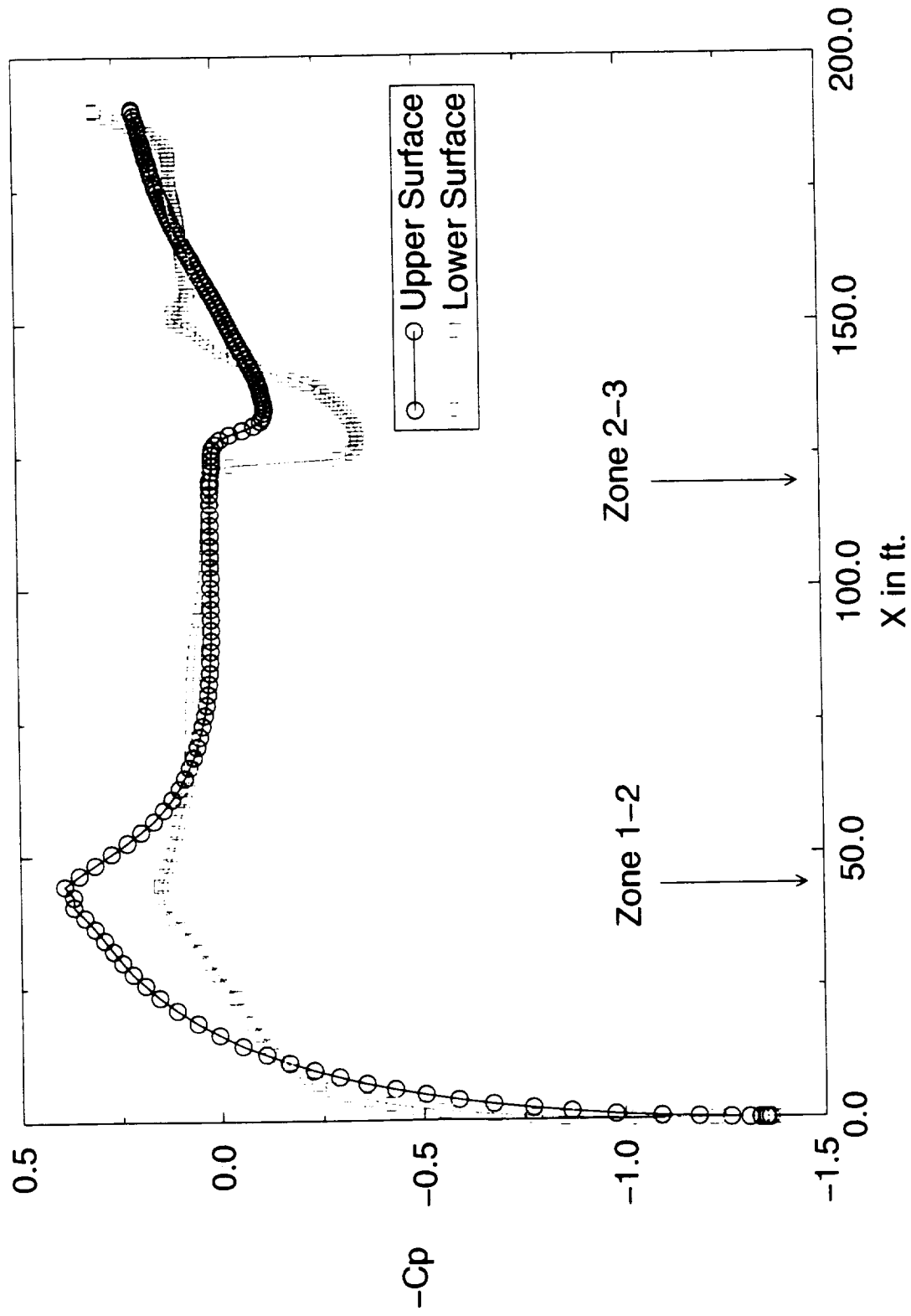
# Cp vs. X (Mach=1.1, AOA=6deg.)

Viscous Turbulent, FDNS solution



# Centerline Surface Pressure Distributions

Mach=1.1 & AOA=6deg.

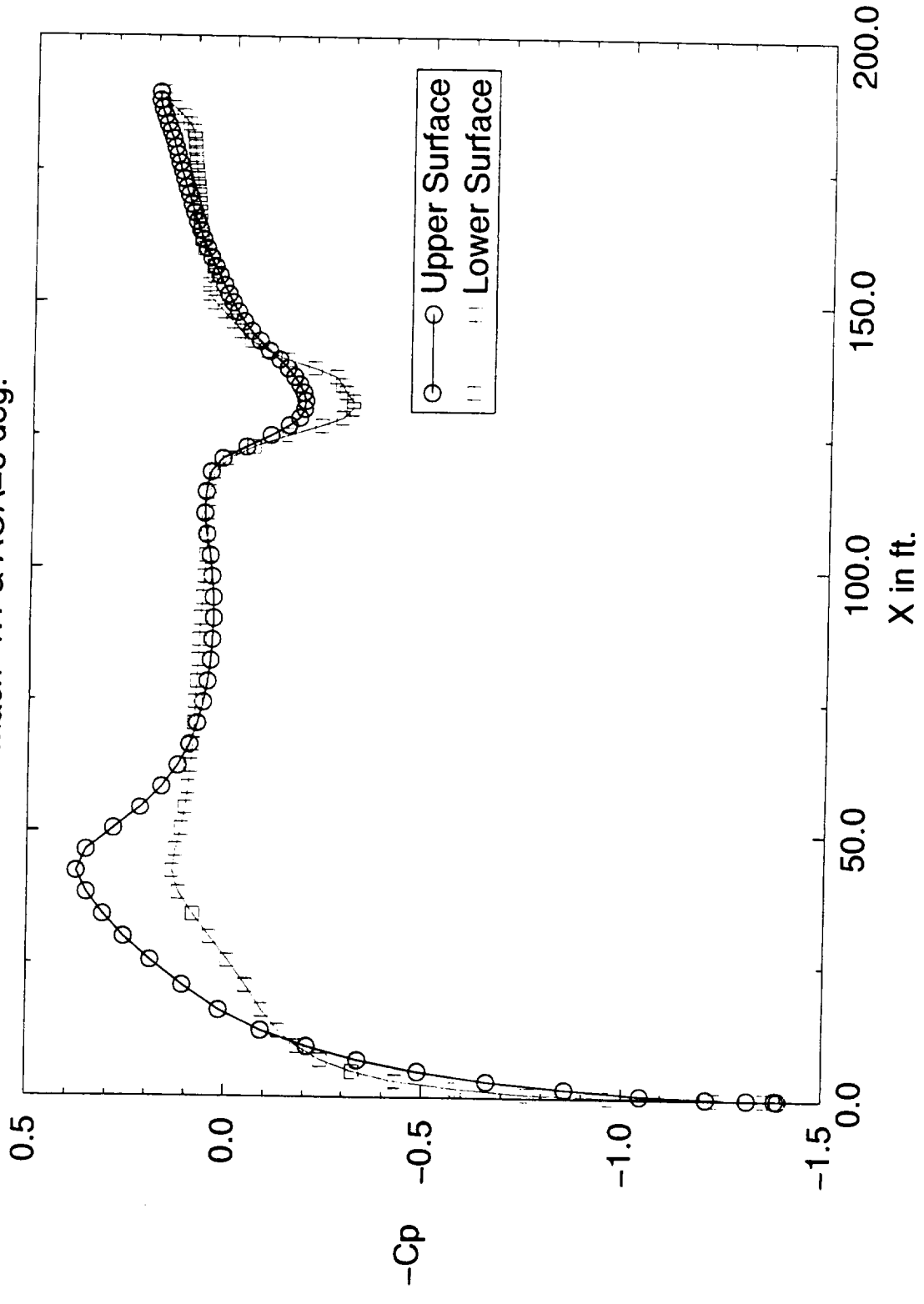


GASP Soln.



# Centerline Surface Pressure Distributions

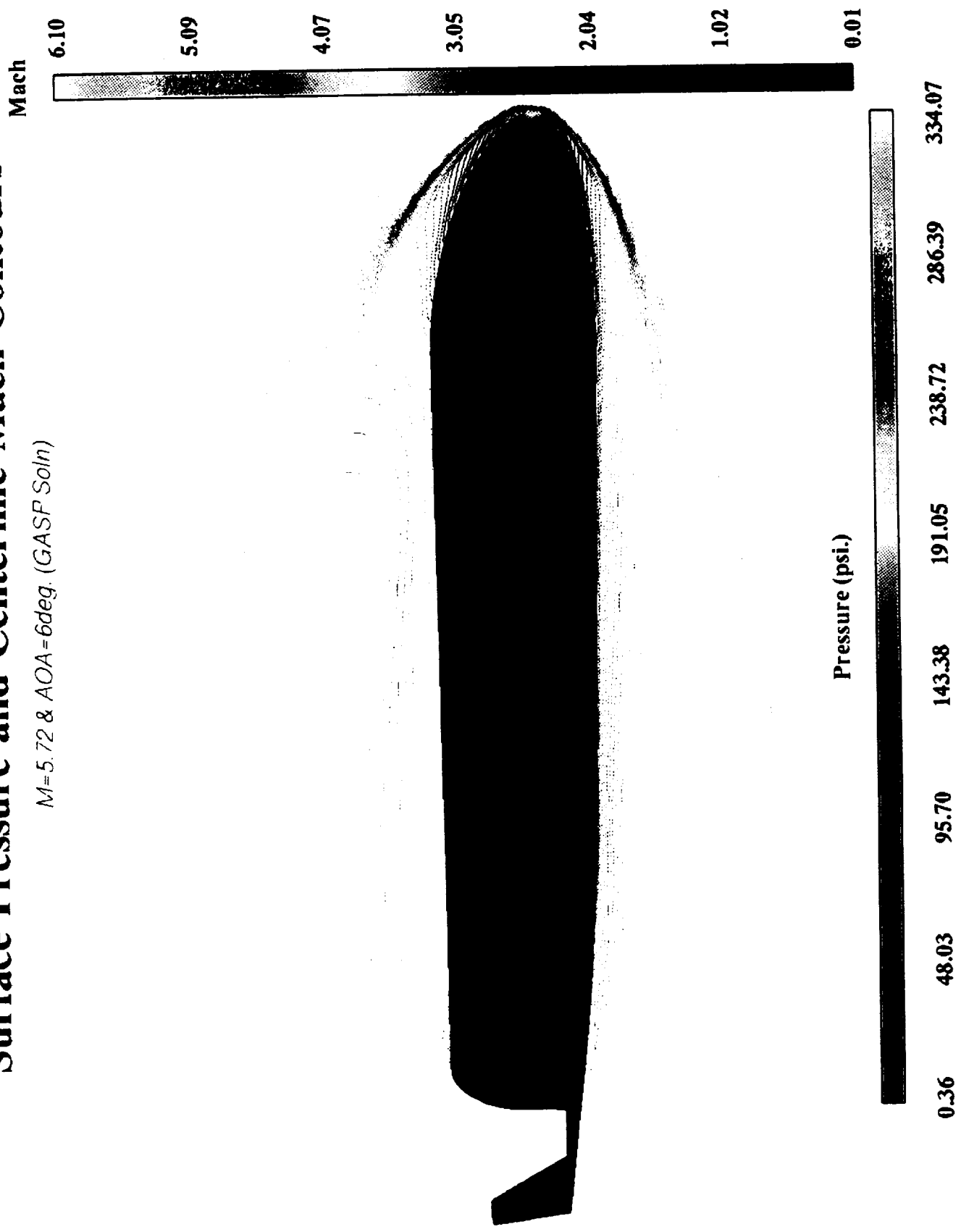
Mach=1.1 & AOA=6 deg.



OVERFLOW Soln.

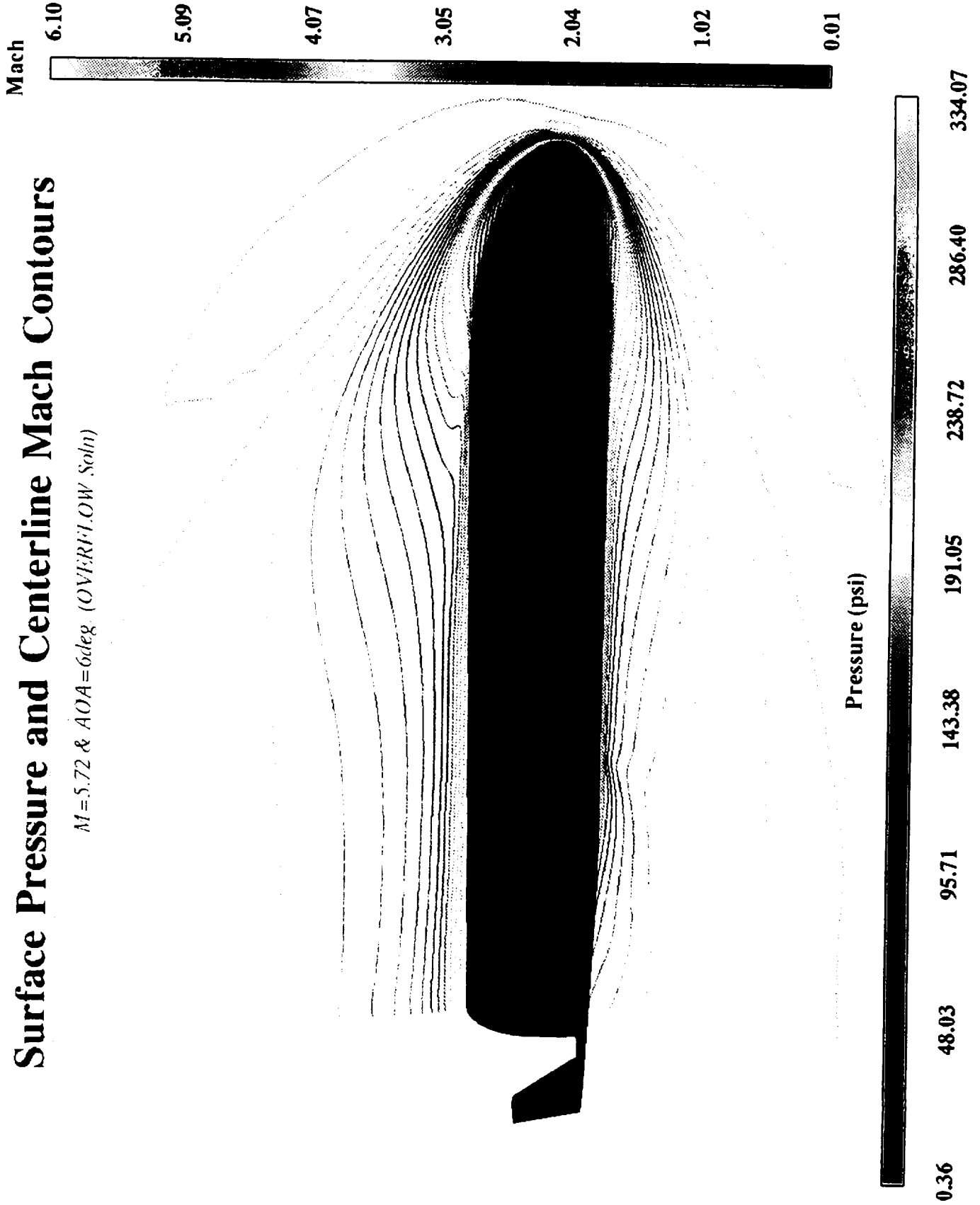
# Surface Pressure and Centerline Mach Contours

*M=5.72 & AOA=6deg. (GASP Soln)*



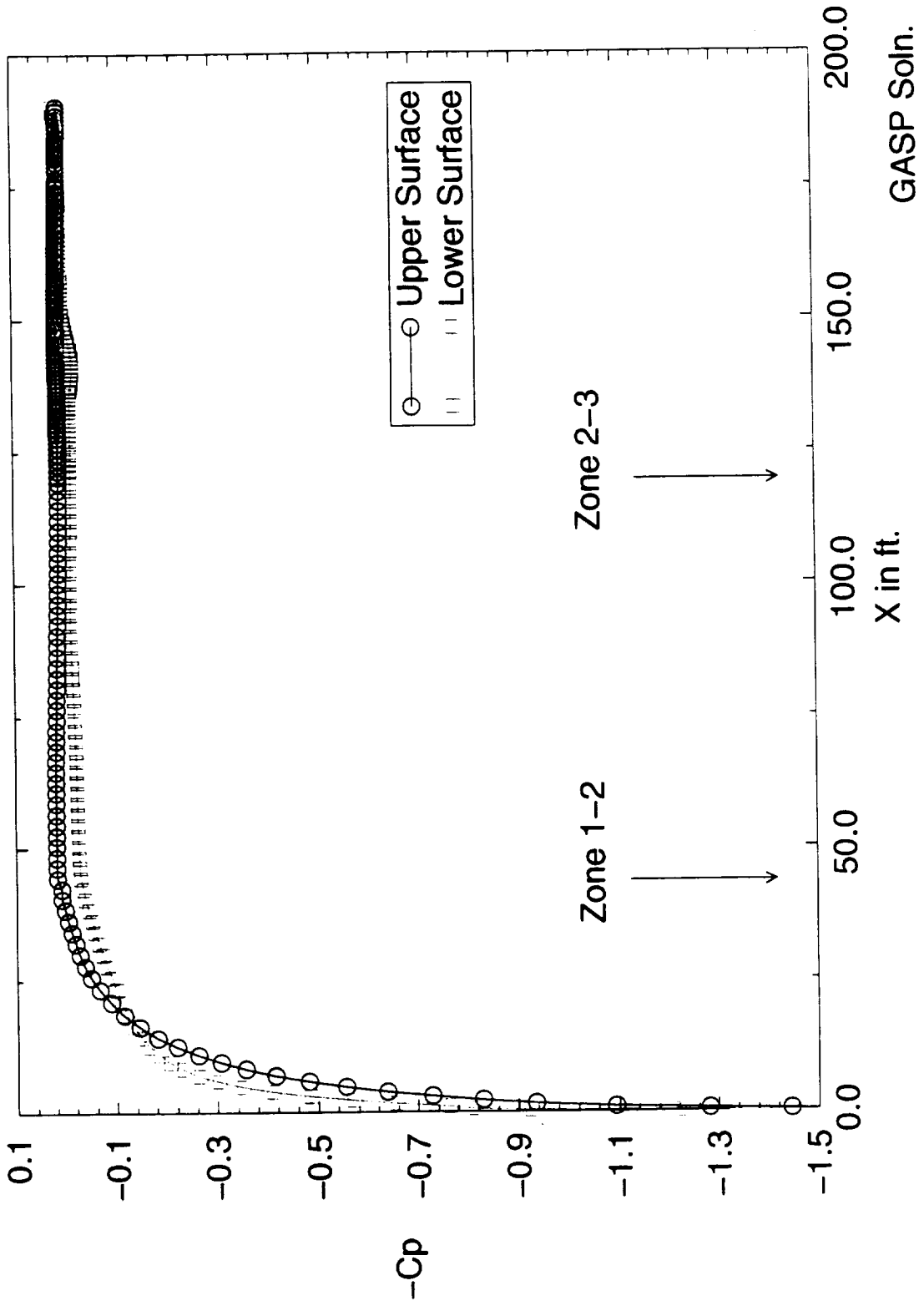
# Surface Pressure and Centerline Mach Contours

$M = 5.72$  &  $AOA = 6 \text{ deg}$  (OVERFLOW Soln)



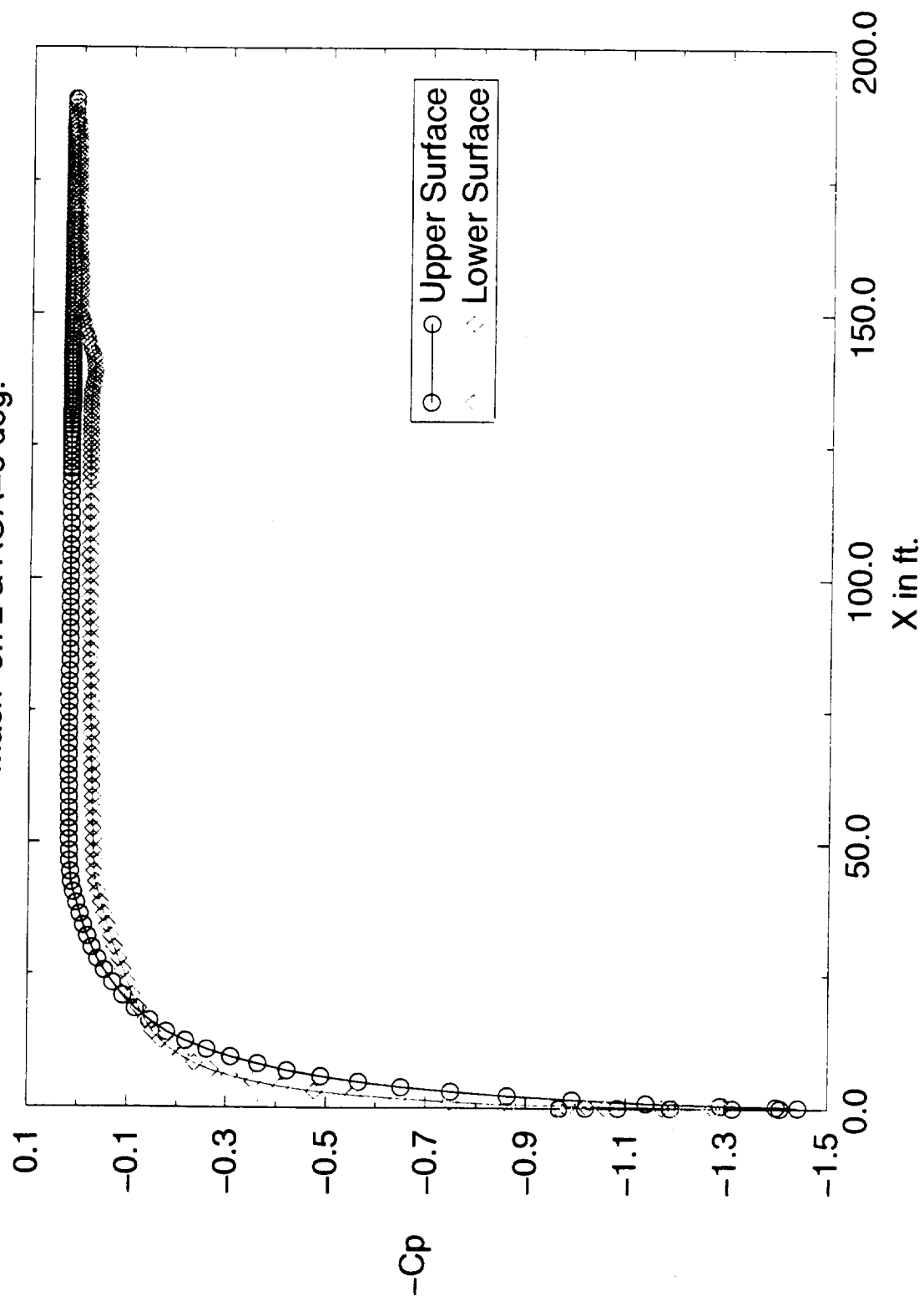
# Centerline Surface Pressure Distributions

Mach=5.72 & AOA=6deg.



# Centerline Surface Pressure Distributions

Mach=5.72 & AOA=6 deg.





# RLV Concept Study Review

## • Predicted aerodynamic coefficients

APAS    OVERFLOW    GASP (inv.)    GASP(vis.)

### *Transonic* ( $M=1.10$ & $\alpha=6^\circ$ )

$C_N$	0.34	0.31	0.32	0.31
$C_A$	0.12	0.23	0.20	0.22
$C_M$	-0.049	-0.035	-0.041	-0.04

### *Supersonic* ( $M=5.72$ & $\alpha=6^\circ$ )

$C_N$	0.07	0.0672	N/A	0.0651
$C_A$	0.07	0.0714	N/A	0.0735
$C_M$	-0.002	-0.0028	N/A	-0.0033

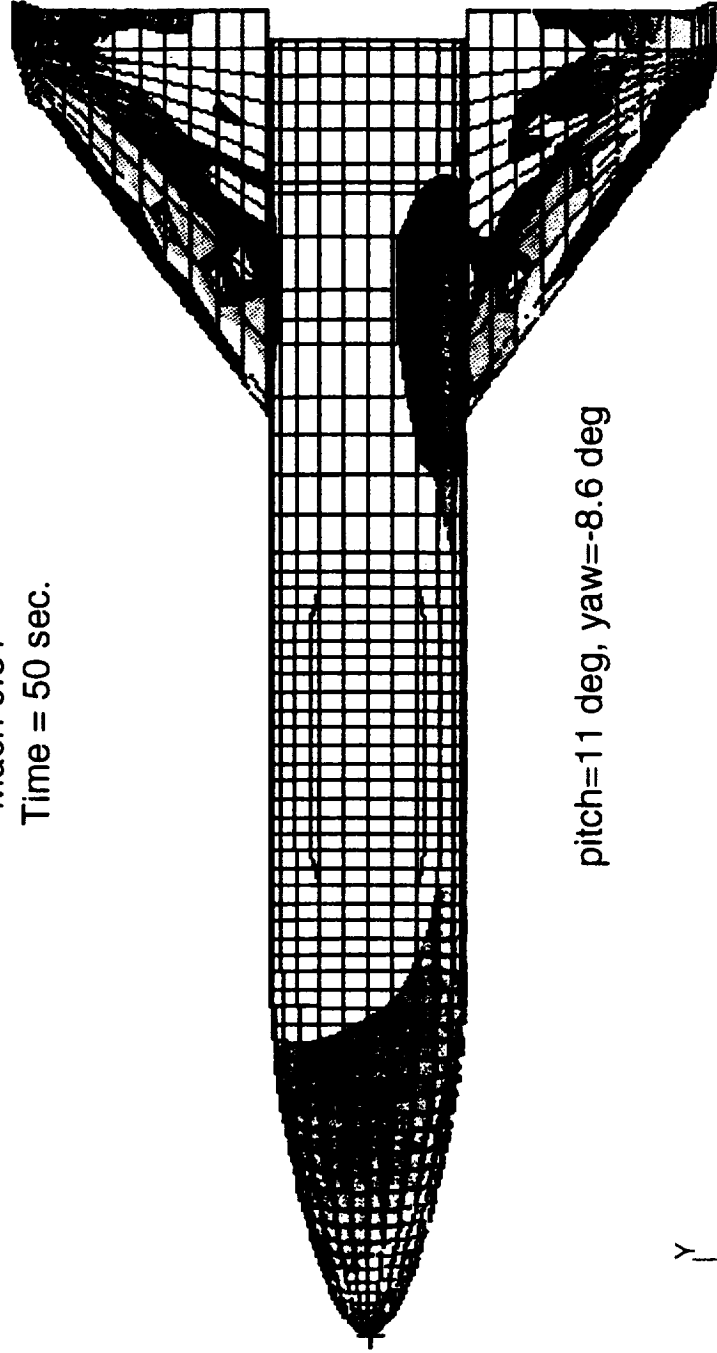
# Surface Pressure

## Ascent Aerodynamics Simulation

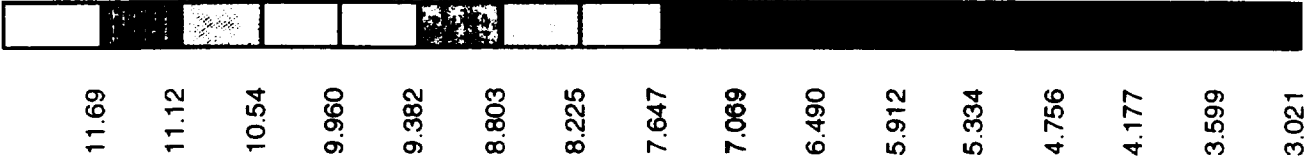
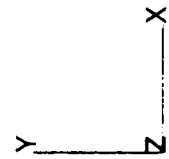
(Mach=0.51, Pitch=11 deg., Yaw=-8.6 deg.)



CFD Pressure Field  
Mach 0.51  
Time = 50 sec.

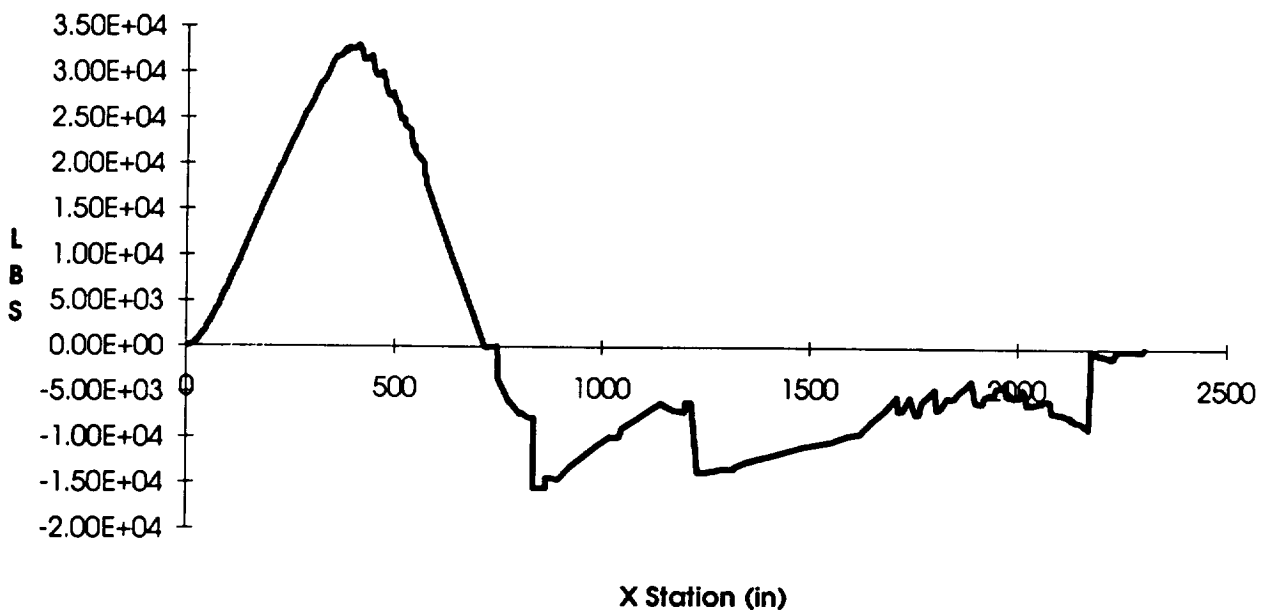


pitch=11 deg, yaw=-8.6 deg

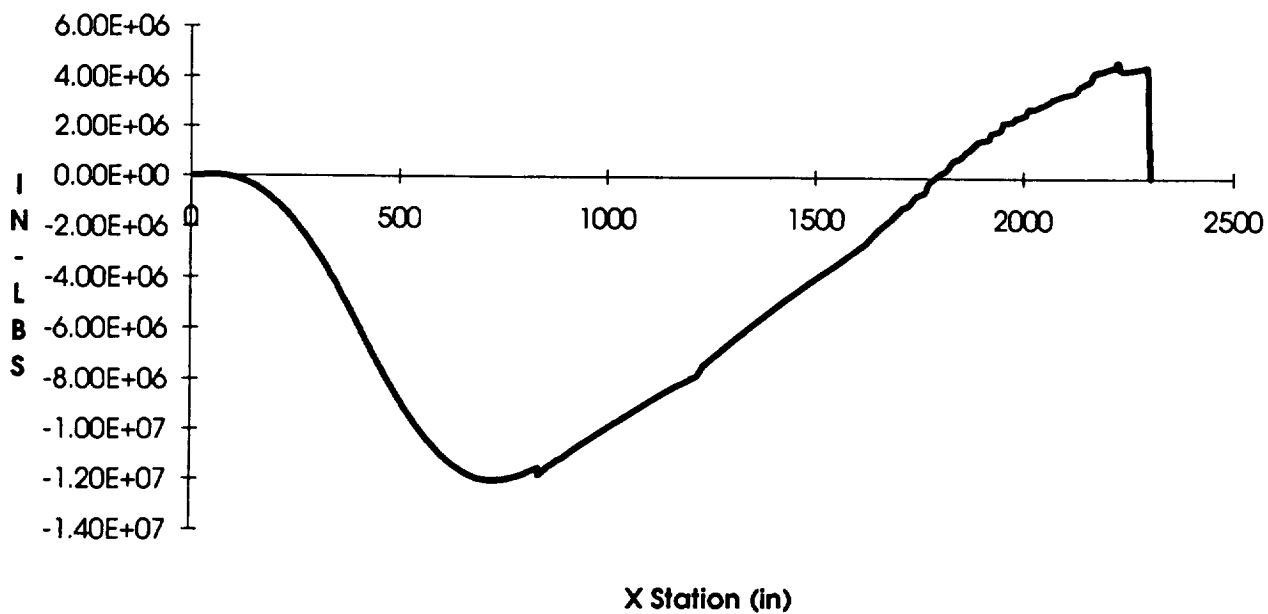




Mach 0.51 T=50 sec. with Trim - Y Shear



Mach 0.51 T=50 sec. with Trim - RZ Moment

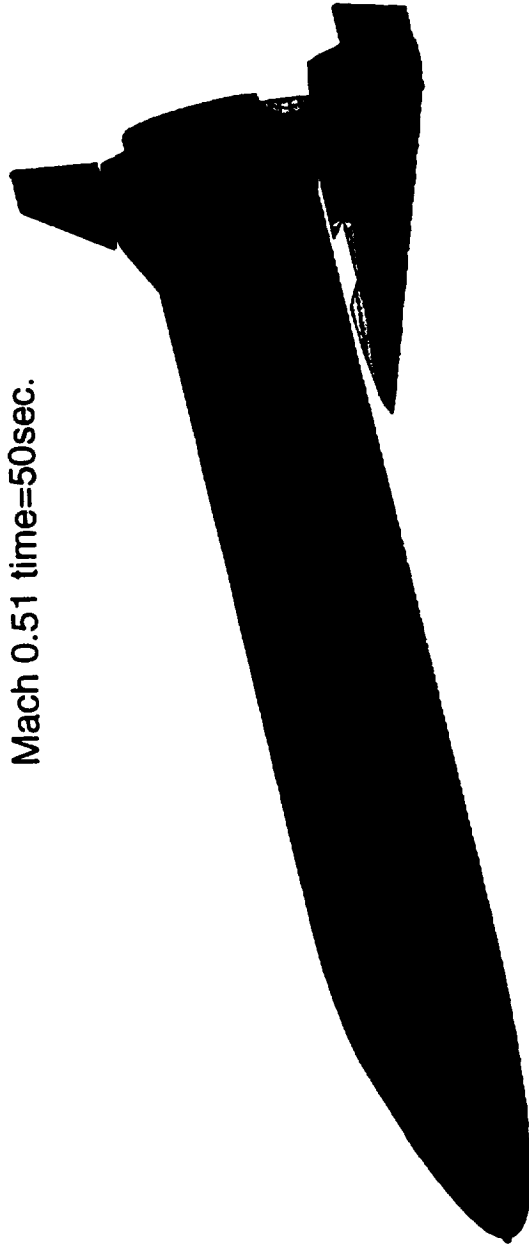


Fringe: LC=2.1-RES=3.1-P3/PATRAN R.1-(Von-Mises)-MSC/NASTRAN-13-Apr-95 10:27:00

### SSTO Winged Body WB001

Von Mises Stresses

Mach 0.51 time=50sec.



- 182849.
- 170670.
- 158490.
- 146311.
- 134131.
- 121951.
- 109772.
- 97592.
- 85413.
- 73233.
- 61054.
- 48874.
- 36694.
- 24515.
- 12335.
- 155.7



# RLV Concept Study Review

## CONCLUSIONS

- Predicted aerodynamic data and surface pressure for WB001 using 3 three codes at several flow conditions
- 3D finite element model and CFD pressure distribution provides the visual representation regarding structural deformations, load paths and stress patterns
- Base flow interactions (plume expansions, base recirculations, etc.) could affect the overall solutions; therefore must be considered in future work

