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Status of Axisymmetric CFD of an Eleven Inch Diameter Hybrid Rocket Motor

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Current status of a steady state, axisymmetric analysis of an experimental 11" diameter hybrid rocket motor internal flow field is given. The objective of this effort is to develop a steady state axisymmetric model of the 11" hybrid rocket motor which can be used as a design and/or analytical tool. A test hardware description, modeling approach, and future plans are given. The analysis was performed with FDNS implementing several finite rate chemistry sets. A converged solution for a two equation and five species set on a 'fine' grid is shown.

Status of Axisymmetric CFD Analysis of an Eleven Inch Diameter Hybrid Rocket Motor

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Status of Axisymmetric CFD Analysis of an Eleven Inch Diameter Hybrid Rocket Motor

- OBJECTIVE
- BACKGROUND
- APPROACH
- STATUS
- FUTURE PLANS

OBJECTIVE

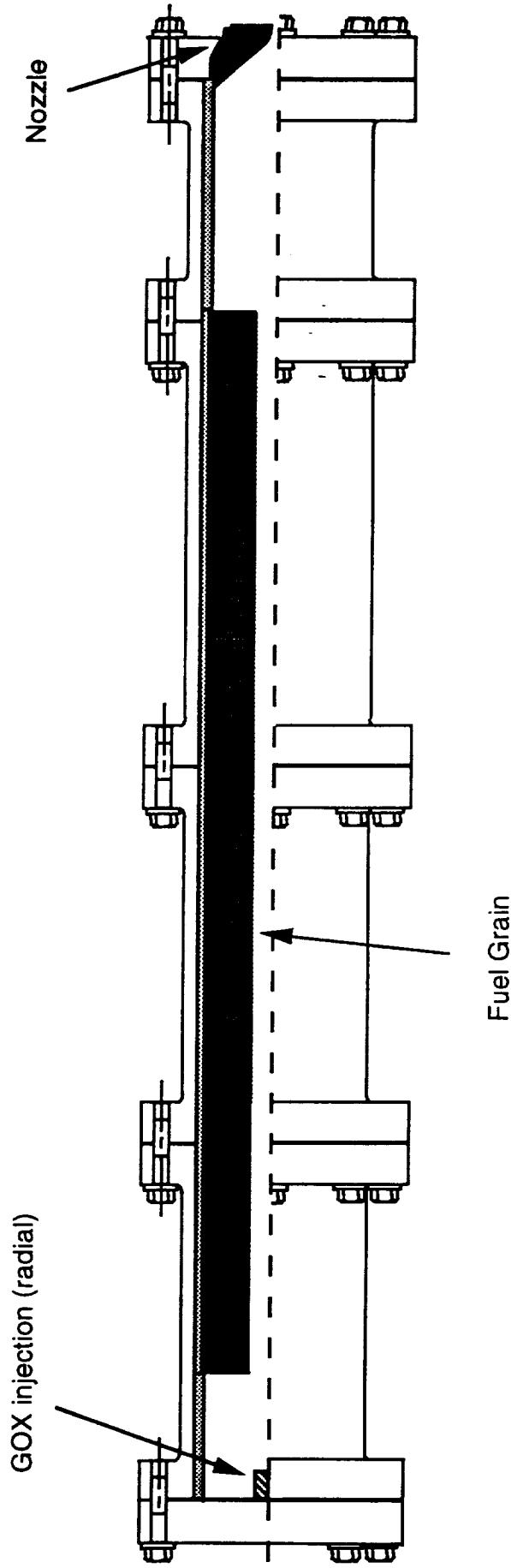
- Develop a steady state axisymmetric model of 11" hybrid rocket motor which can be used as a design and analytical tool.

BACKGROUND

- 11" Hybrid Rocket Motor - solid fuel, gaseous oxidizer
 - fuel
 - solid grain 60% HTPB, 40 % escorez
 - initially at ambient temperature
 - oxidizer
 - GOX injected at ambient temperature
 - pressures of 300 to 1000 psig
 - geometry
 - 11 inch diameter casing, various port designs
 - total fuel grain length varies, 34, 68 or 102 inches
- 20 tests have been conducted with various configurations
 - Modeling test # 2 conditions
 - GOX injection pressure = 300 psi, flow rate = 6.8 lbm/s
 - GOX injected through 12 radial ports
 - overall o/f = 3.04
 - run duration 9.5 seconds
 - nozzle area ratio of 1.56



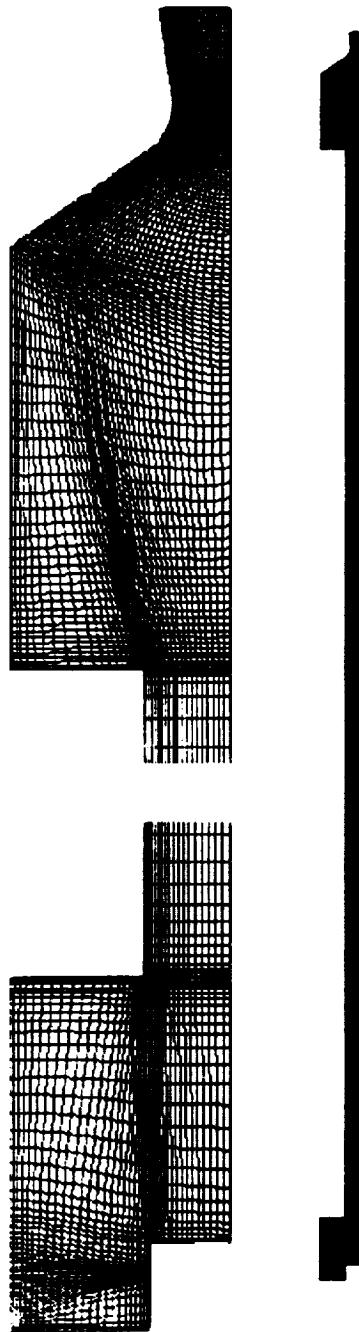
Cross Section of 11" Hybrid Rocket Motor



APPROACH

- Axisymmetric, three zone model
 - steady state, early in test
 - GOX injection ports modeled as equivalent area circumferential slot
300 psia, flow rate=6.8 lbm/s, temperature=517 deg R
 - fuel grain modeled as blowing wall, uniform sublimation rate
flow rate=2.27 lbm/s, temperature=1458 deg R
- Two grids implemented
 - 9800 and 21600 points
- Solution Procedure
 - begin with cold GOX, hot fuel, w/o reaction, subsonic flow
 - turn on chemistry, supersonic exit
- Six chemistry models tried
 - 5 species, 2 equations up to 11 species, 17 equations

Coarse Grid



Fine Grid



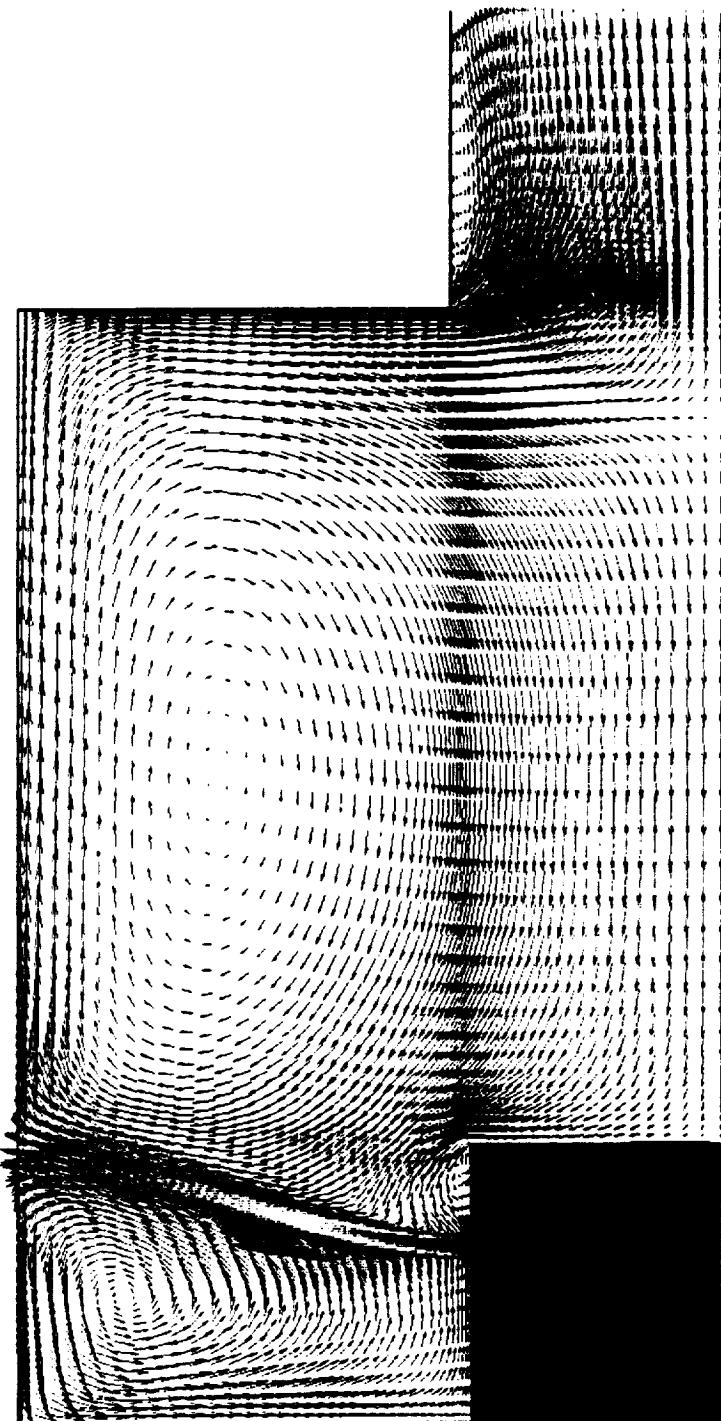
STATUS

- Converged solutions obtained on both grids, grid dependent
- Flow field appears reasonable
 - mass balanced solutions
 - some zone interface effects at zone 1 and 2 boundary
- Temperature is too high, but trends appear correct

VELOCITY COLORED BY VELOCITY MAGNITUDE
Forward Mixing Chamber
(ft/s)

CONTOUR LEVELS

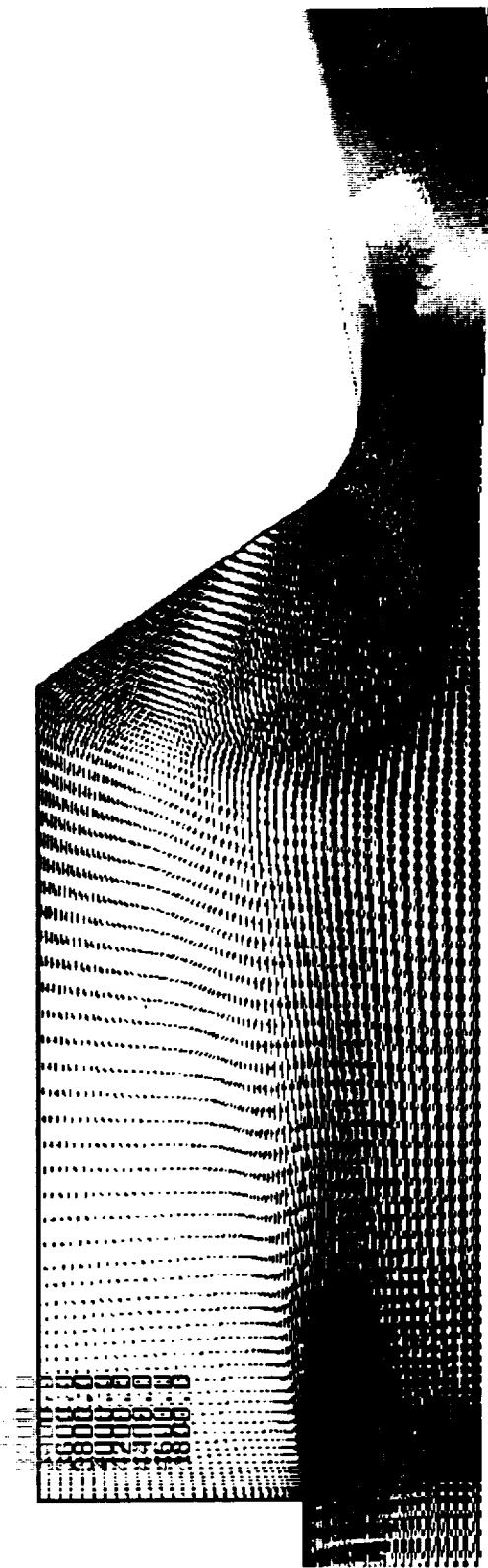
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40.0	140.0
60.0	160.0
80.0	180.0
100.0	200.0
120.0	220.0
140.0	240.0
160.0	260.0
180.0	280.0
200.0	300.0
220.0	320.0
240.0	340.0
260.0	360.0
280.0	380.0
300.0	400.0
320.0	420.0
340.0	440.0
360.0	460.0
380.0	480.0
400.0	500.0
420.0	520.0
440.0	540.0
460.0	560.0
480.0	580.0
500.0	600.0
520.0	700.0
540.0	800.0
560.0	900.0
580.0	1000.0
600.0	1100.0
620.0	1200.0
640.0	1300.0
660.0	1400.0
680.0	1500.0
700.0	1600.0
720.0	1700.0
740.0	1800.0
760.0	1900.0
780.0	2000.0
800.0	2100.0
820.0	2200.0
840.0	2300.0
860.0	2400.0
880.0	2500.0
900.0	2600.0
920.0	2700.0
940.0	2800.0
960.0	2900.0
980.0	3000.0
1000.0	3100.0
1100.0	3200.0
1200.0	3300.0
1300.0	3400.0
1400.0	3500.0
1500.0	3600.0
1600.0	3700.0
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3100.0	5200.0
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3500.0	5600.0
3600.0	5700.0
3700.0	5800.0
3800.0	5900.0
3900.0	6000.0
4000.0	6100.0
4100.0	6200.0
4200.0	6300.0
4300.0	6400.0
4400.0	6500.0
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4600.0	6700.0
4700.0	6800.0
4800.0	6900.0
4900.0	7000.0
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5200.0	7300.0
5300.0	7400.0
5400.0	7500.0
5500.0	7600.0
5600.0	7700.0
5700.0	7800.0
5800.0	7900.0
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6000.0	8100.0
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6200.0	8300.0
6300.0	8400.0
6400.0	8500.0
6500.0	8600.0
6600.0	8700.0
6700.0	8800.0
6800.0	8900.0
6900.0	9000.0
7000.0	9100.0
7100.0	9200.0
7200.0	9300.0
7300.0	9400.0
7400.0	9500.0
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7700.0	9800.0
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7900.0	10000.0



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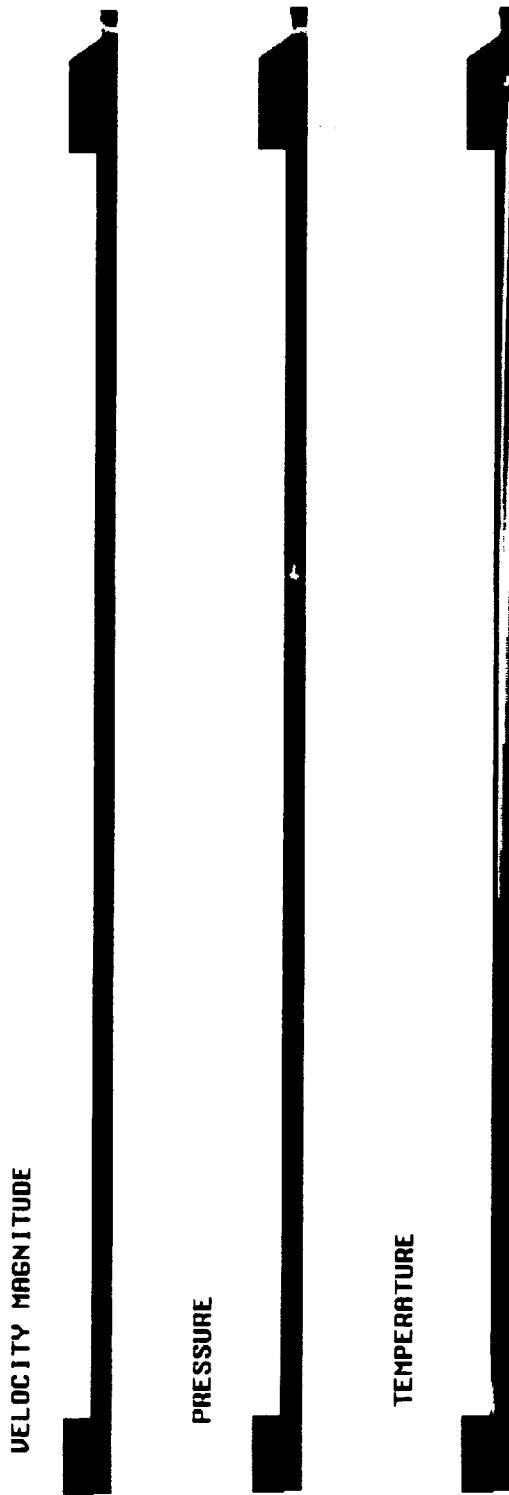
VELOCITY COLORED BY VELOCITY MAGNITUDE Aft Mixing Chamber (ft/s)

CONTOUR LEVELS

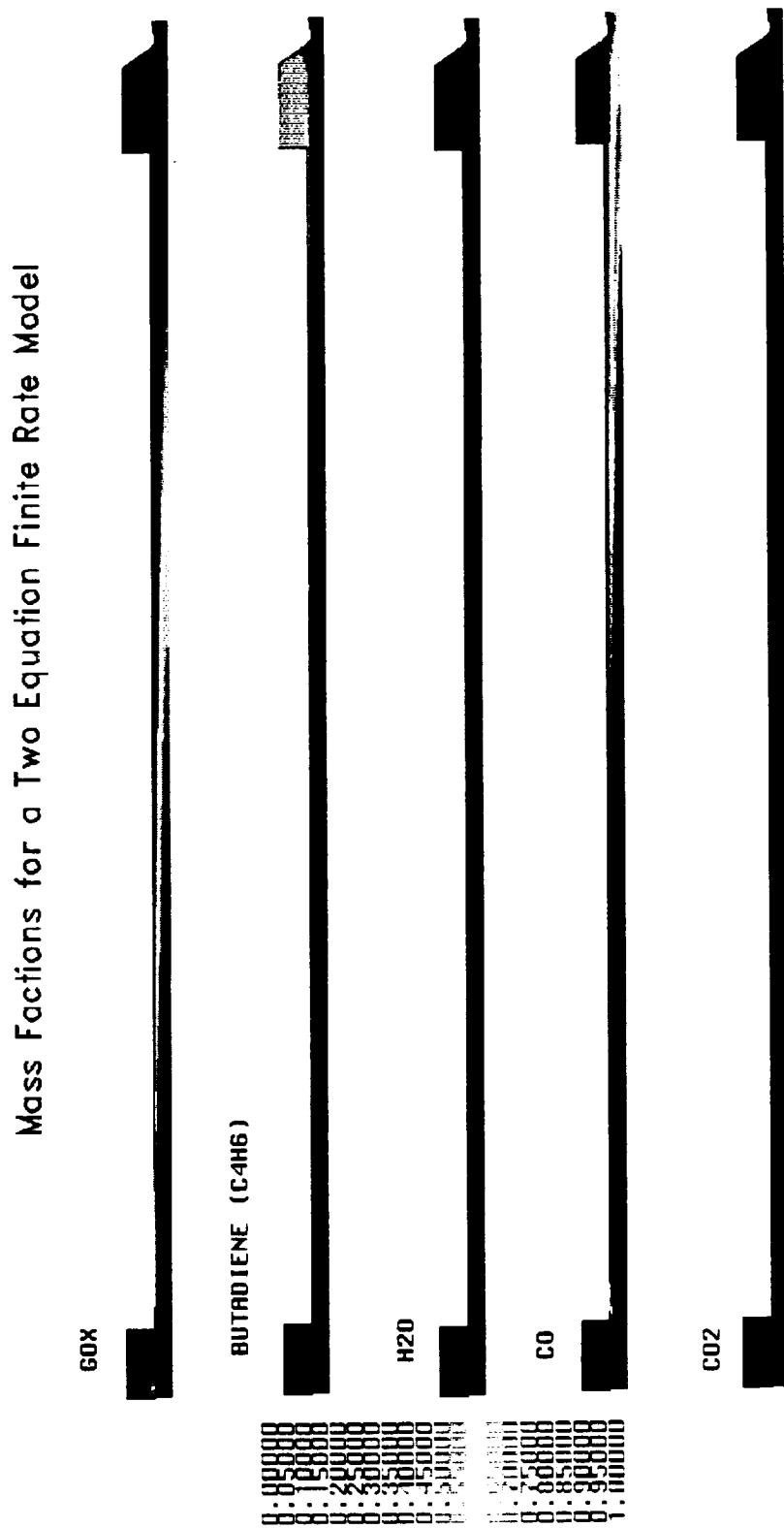


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Fine Grid Results



Fine Grid Results



FUTURE PLANS

- determine 'best' chemistry model
- obtain a grid independent solution
- implement variable fuel sublimation rate in axial direction
- match limited test data