

13214
132116

Overview of CFD Analyses Supporting the Reusable Solid Rocket Motor (RSRM) Program at MSFC

E. Stewart, P. McConnaughey, J. Lin, E. Reske, and D. Doran, NASA/MSFC, R. H. Whitesides, ERC, Inc., Huntsville, AL, and Y.-S. Chen ESI, Huntsville, AL

During the past year, various CFD analyses were performed at MSFC to support the RSRM program. The successful completion of these analyses was realized through the cooperation of ESI, ERC, and The Computational Fluid Dynamics Branch (ED32) at MSFC and involved application of the CFD codes FDNS and CELMINT. The topics addressed by the analyses were; 1. the design and prediction of slag accumulation within the five inch test motor, 2. prediction of slag pool behavior and its response to lateral accelerations, 3. the clogging of potential insulation debonds within the nozzle by slag accumulation, 4. the behavior of jets within small voids inside nozzle joint gaps, 5. the effect of increased inhibitor stiffness on motor acoustics, and 6. the effect of a nozzle defect on particle impingement enhanced erosion. Topics 1, 2, and 5 will be discussed in some detail by other speakers at the conference and are only mentioned here for the sake of completeness. Thus, the emphasis of this presentation will be to further discuss the work involved in topics 3, 4, and 6.

Eric Stewart



National Aeronautics and
Space Administration

RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Branch
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center

Overview of CFD Analyses Supporting the Reusable Solid Rocket Motor (RSRM) Program at MSFC

1154

Presented at 13th Workshop for CFD
Applications in Rocket Propulsion
and Launch Vehicle Technology,
MSFC, AL, April 27-30, 1995

E. Stewart, P. McConnaughey, E. Reske,
J. Lin, and D. Doran, NASA/MSFC,
R. H. Whitesides, ERC, Inc., Huntsville,
AL, and Y.-S. Chen ESI, Huntsville, AL



RSRM CFD Analyses at MSFC

Overview

- Overview of RSRM CFD analyses at MSFC
- Insulation Debond Analysis
- Potential RTV Flaw Analysis
- Nose Inlet Assembly Wetline Investigation
- Future efforts



RSRM CFD Analyses at MSFC

Overview of RSRM CFD Analyses at MSFC

- **Slag (Al_2O_3) behavior and accumulation**
 - 5 inch spin motor design and analysis
 - Accumulation within RSRM at 67 seconds
 - Response of slag pool to lateral accelerations using VOF methodology
- **Increase in Nitrile Butadiene Rubber (NBR) stiffness**
 - Aerodynamic torque on nozzle
 - Potential effect on internal acoustics/pressure oscillations
 - Change in inhibitor deflections
 - Vortex shedding by the inhibitors
- **Code validation for the 8-percent ASRM cold flow model**
- **Insulation debond analysis**
- **Potential RTV flaw analysis**
- **Nose inlet assembly wetline Investigation**



Insulation Debond Analysis

Issues • Prediction of flow/clogging through potential insulation defect flow paths during motor operation

Approach • Use two-phase flow and condensation models to predict propensity for pore clogging during motor operation
- prescribed thermal boundary conditions

Results • Small (0.01") pores probably clog quickly (.05 sec) under severe thermal gradients
• Lower probability of clogging during start pressurization transient

Impact • Joint gap clogging prediction methodology is available to support potential anomalies



- **Results (Problem 1, debond vent to ambient)**

<u>gap width</u>	<u>time to clog</u>
0.010"	0.05 sec.
0.005"	0.02 sec.
0.002"	0.006 sec.

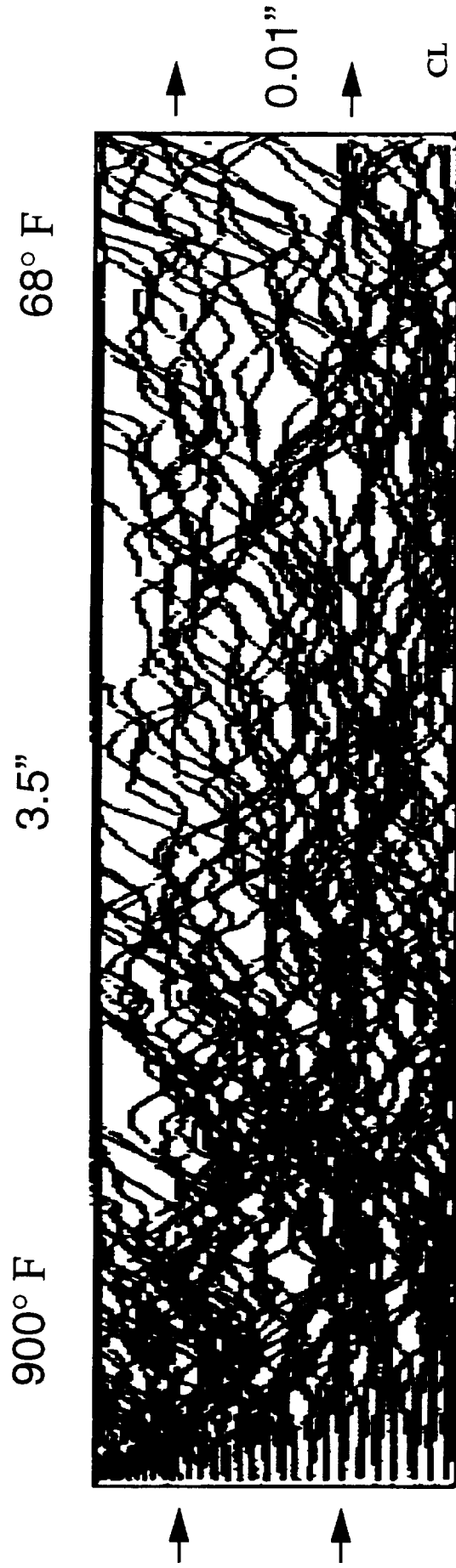
- **Results (Problem 2, start-up transient through debond)**
 - clogging of debond predicted in 0.61 sec. after initiation of particle flow
 - lower mass flow rate (4X less) due to cavity fill results in fewer particles to condense on pore wall



National Aeronautics and
Space Administration

RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Branch
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center



Joint Gap Clogging Prediction



RSRM CFD Analyses at MSFC

Potential RTV Flaw Analysis

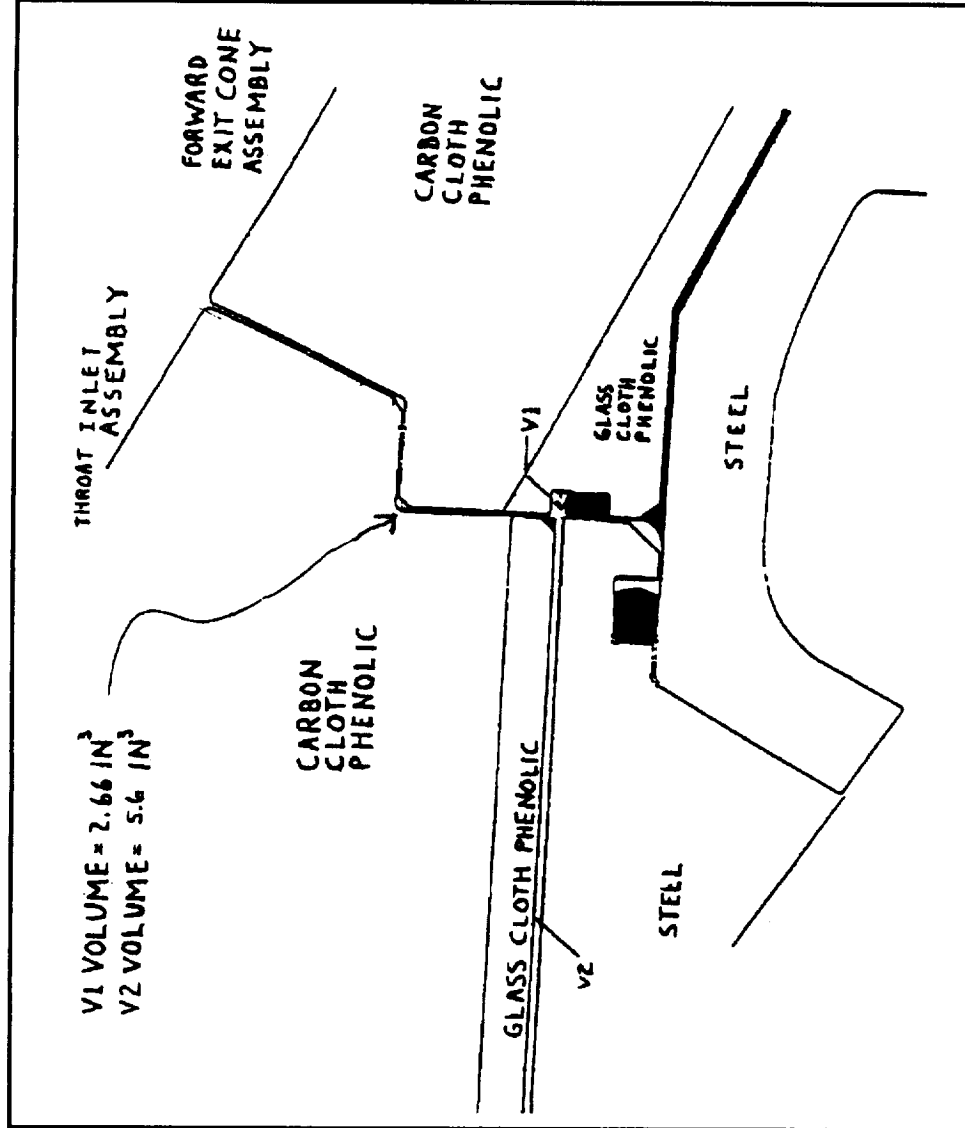
- Issues**
- Hot gas jet impingement environments on O-rings within RSRM nozzle due to potential RTV flaws
 - Predict jet spreading within irregularly shaped cavities
- Approach**
- Predict 3-D Jet Spreading for potential joint gap / cavity flows for input into thermal models
- Results**
- Hot gas jet spreading within joint cavities is smaller than that used in previous non-CFD analyses
- Impact**
- Jet spread width used in thermal models should be 0.7" (rather than 1.25")
 - Jet spreading predictions are available to support potential anomalies



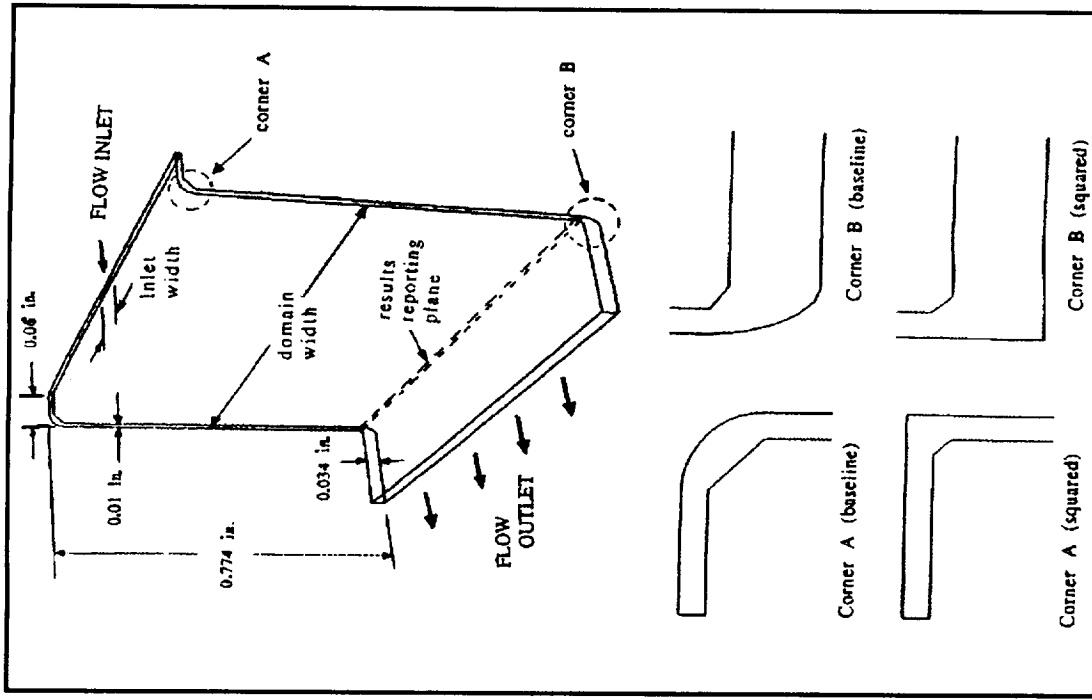
National Aeronautics and Space Administration

RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Branch
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center



Geometry of Internal Nozzle, Joint #4



Computational Geometry



RSRM CFD Analyses at MSFC

- **Analysis matrix and results**

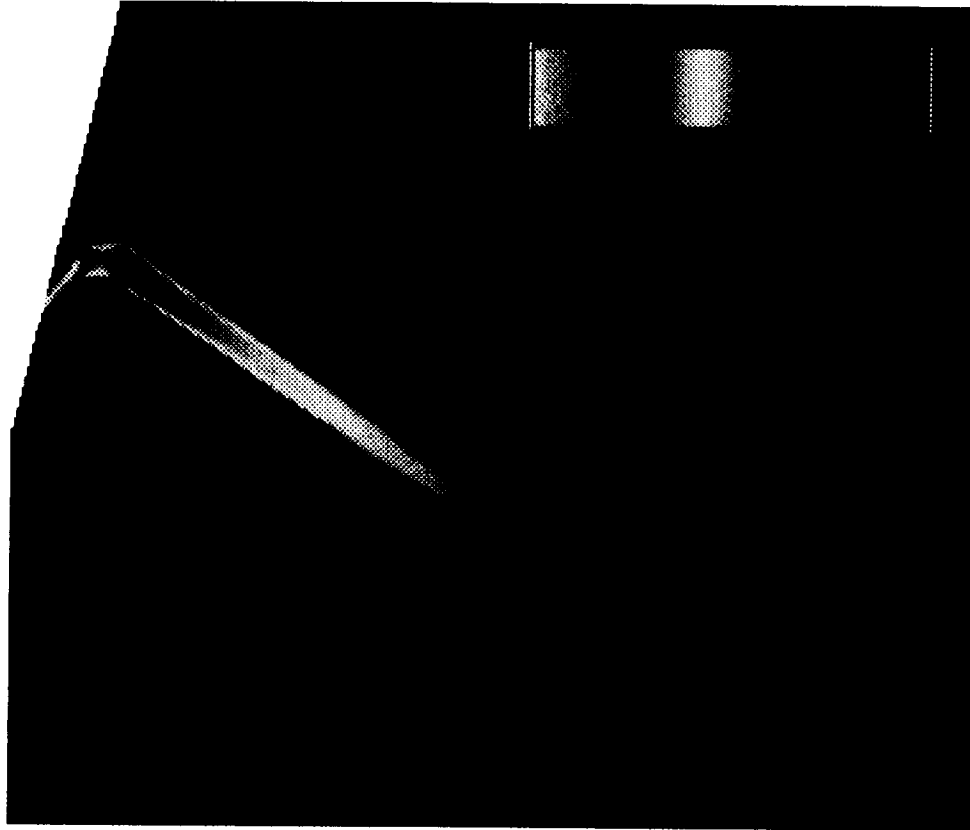
case	flowrate (lbm/s)	domain width (in)	corners	inlet width (in)	jet spread width (in)
1	0.0001	8.0	rounded	0.1	1.5
2	0.0002	8.0	rounded	0.1	1.1
3	0.0005	8.0	rounded	0.1	0.6
4	0.001	8.0	rounded	0.1	0.5
5	0.00155	8.0	rounded	0.1	0.5
6	0.00155	16.0	rounded	0.1	0.5
7	0.00155	8.0	square	0.1	0.75
8	0.00155	8.0	rounded	0.2	0.75



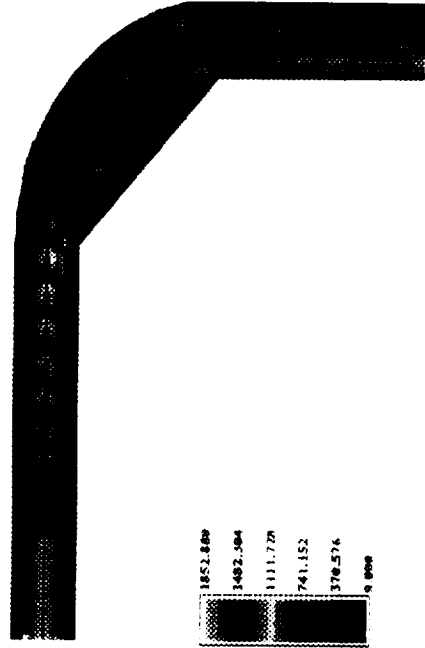
National Aeronautics and Space Administration

RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Brar
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center

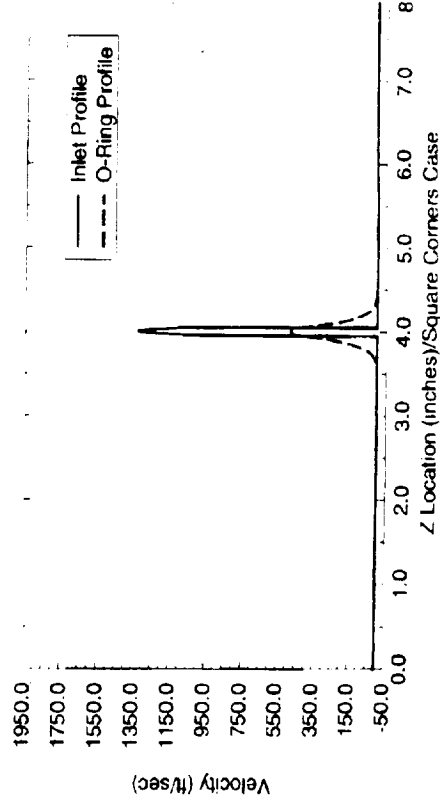


Velocity Magnitudes



1852.889
1492.504
1111.726
741.152
378.574
0.000

Center Line Velocity Profile Through Corner A



Average Velocity Magnitudes



RSRM CFD Analyses at MSFC

Nose Inlet Assembly Wetline Investigation

- Issues**
- Enhancement of nozzle erosion due to presence of defect
 - Effect of defect on slag particle impingement

- Approach**
- Assume wedge shaped nozzle defect
 - Use two-phase flow results to assess flow environment near defect
 - Use current data/experience base to assess potential flow deviations

- Results**
- Size of defect relative to local boundary layer is not sufficient to significantly alter flow external to boundary layer
 - Main source of particle impingement is external to boundary layer
 - Erosion enhancement due to particle impingement is not significantly altered by presence of defect

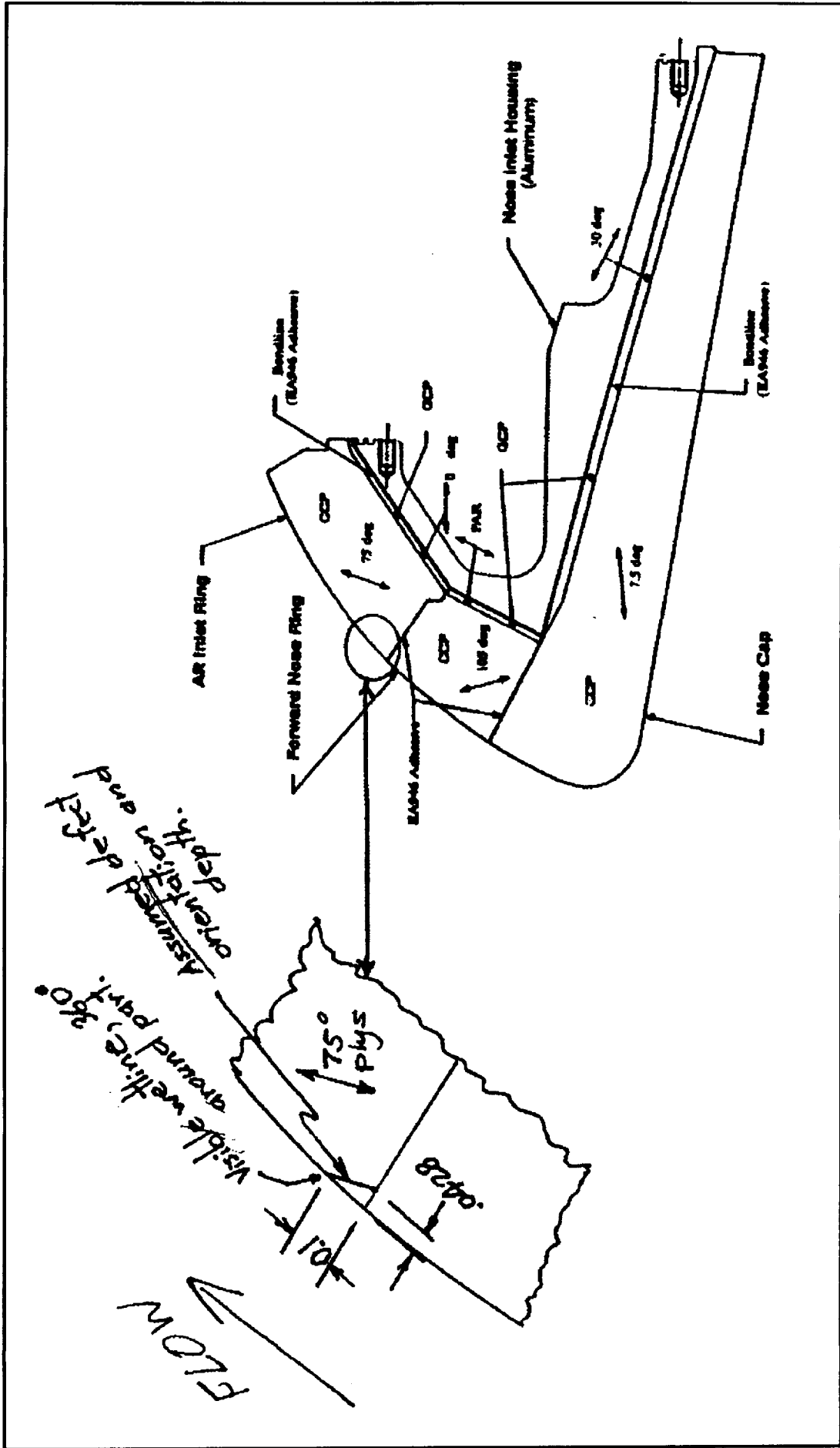
- Impact**
- Recommend nozzle in question for flight



National Aeronautics and
Space Administration

RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Branch
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center



Geometry of Nozzle Nose Region

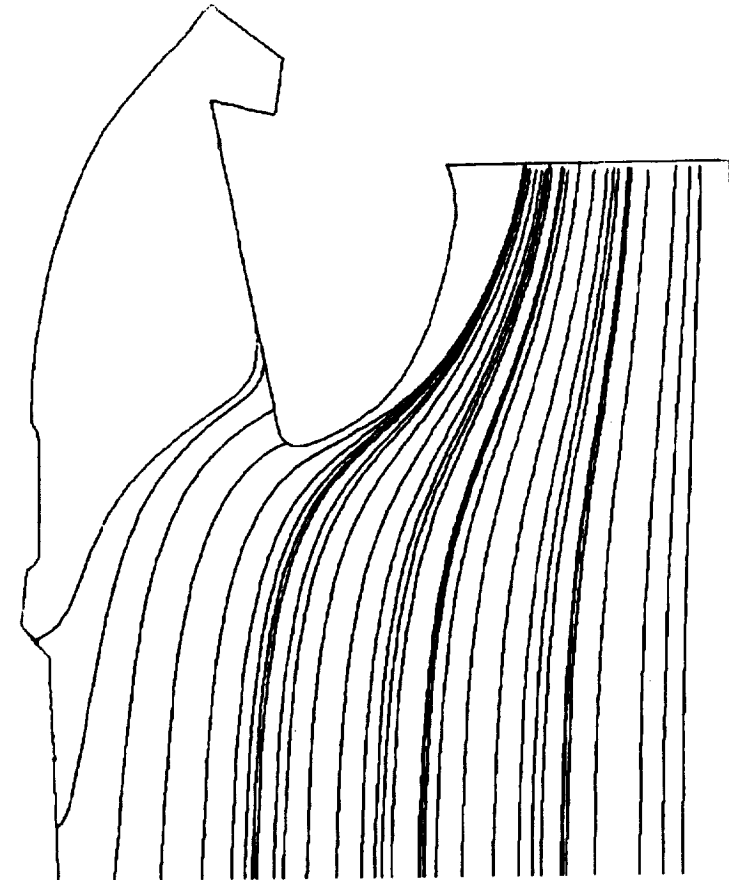


National Aeronautics and
Space Administration

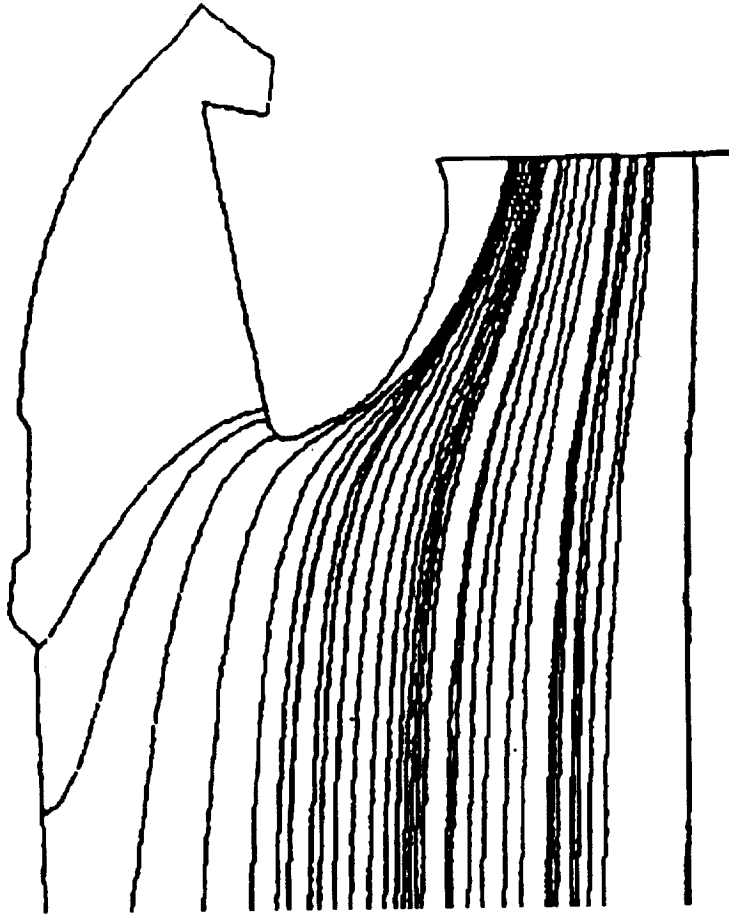
RSRM CFD Analyses at MSFC

Computational Fluid Dynamics Branch
Fluid Dynamics Division
Structures and Dynamics Laboratory
George C. Marshall Space Flight Center

RSRM 67 Sec. Burn Time, 150 Micron Particle Trajectories



ED32 Results



ERC Results



RSRM CFD Analyses at MSFC

Future Effort

- Continue code validation
- Continue to enhance modeling capabilities
 - two-phase flow
 - combustion
 - turbulence
 - slag accumulation
 - unsteady flow
- Improve readiness to address potential anomalies
 - Perform similar analyses at additional burn times

