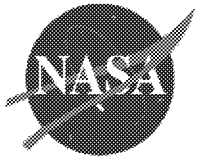
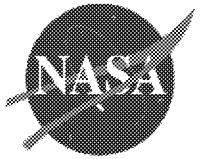


Overview of Fluid Dynamic Activities At the Marshall Space Flight Center

Roberto Garcia
Lisa Griffin
Ten-See Wang
Applied Fluid Dynamics Group

Presented at:
The 10th Thermal and Fluids Analysis Workshop
Huntsville, AL
September 13-17, 1999

Overview

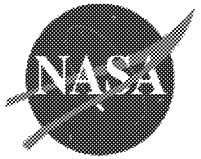


- **Organizational Changes at MSFC**
- **Recent Program Support & Technology Development**
  - Analysis & cold flow testing
  - Fastrac, X-34, X-33, RLV, LFBB
- **Ongoing Activities**
  - RLV focused technology, RBCC concepts development, methodology & code development
- **Future Activities and Direction**
  - Hardware design and development
  - Tools Development
- **Concluding remarks**
  - Constraints, cooperation, opportunities

Organizational Changes at MSFC

- **Center Reorganization Completed in May 1999**
  - Increase focus on the center's assigned roles and missions
    - Center of Excellence for Propulsion
    - Space Transportation Systems Development
    - Microgravity Research
    - Space Optics Fabrication, Metrology, & Testing
  - Strengthen MSFC Product Lines
    - Space Transportation, Flight Projects, Science
  - Maintain Strong Engineering Capability
- **Product Line Dedicated Functions Assigned to Product Line Directorate**
- **Maintained Focused, Cross Functional Engineering Disciplines in Engineering Directorate**

Organizational Changes at MSFC



- **Fluid Dynamics in Space Transportation Directorate**
  - Discipline primarily supports space transportation product line
  - TD63: Fluid Physics and Dynamics Group (bldg. 4203)
    - Acoustics, aerothermal analysis, dynamic data reduction and analysis, plume induced environments, cold-flow testing PIs
  - TD64: Applied Fluid Dynamics Analysis Group (bldg. 4203)
    - Develop and apply computational fluid dynamics (CFD) analysis
  - TD74: Experimental Fluid Dynamics Group (bldg. 4732)
    - Maintain, operate, & develop cold-flow experimental facilities
- **Other Disciplines (Thermal, Stress, etc.) in Engineering Directorate**
  - Support broadly distributed among product lines

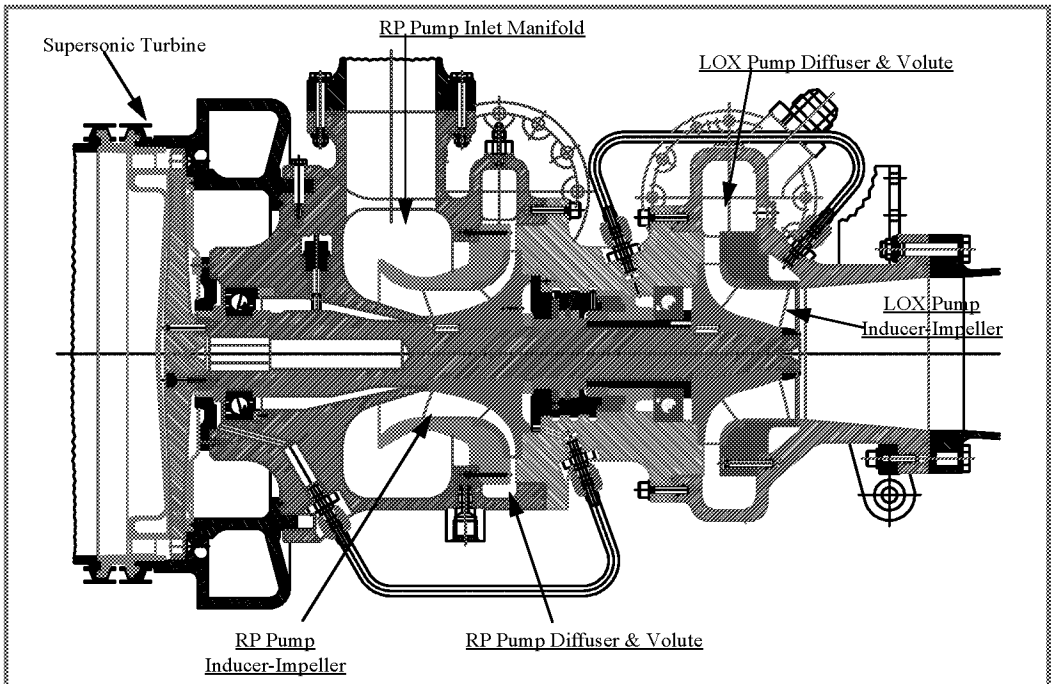
Recent Program Support & Tech. Dev.

- **Fastrac Low-Cost Engine Technology Demonstrator**
  - Primary propulsion for X-34 vehicle
  - Hydrodynamic design and analysis of both pumps
    - All the primary flow paths in the LOX and RP-1 pumps
    - Water flow test of LOX pump
      - **Verify non-cavitated performance, determine suction capability**
      - **Steve Skelley presentation Tuesday morning (Fluids 3a)**
  - Aerodynamic design and analysis of the turbine
    - Single stage supersonic turbine w/ exit guide vanes
    - First time accurate, full NS, rotor stator analysis
      - **Lisa Griffin presentation Tuesday morning (Fluids 3b)**
  - TCA and GG performance and environments predictions
    - Injector patternization water tests
    - Finite rate combustion devices analysis
      - **CFD baselined as performance prediction method**

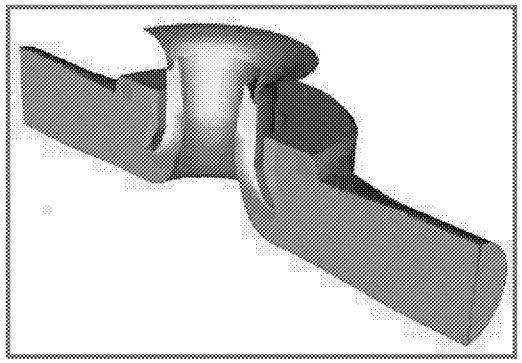
Space Transportation Directorate

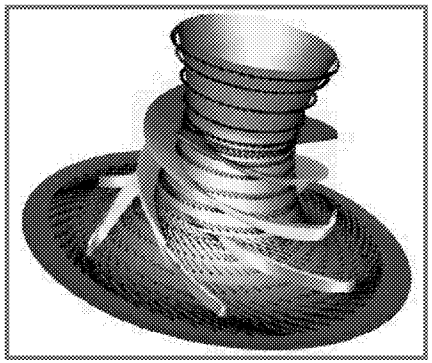
Recent Program Support & Tech. Dev.

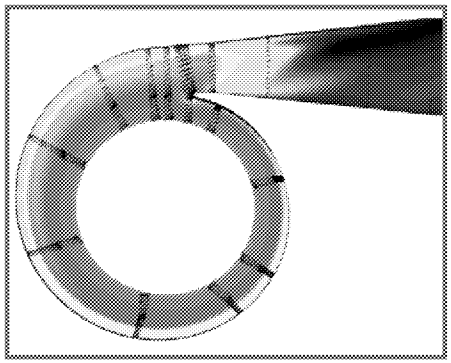
Fastrac Turbopump Cross-section



Recent Program Support & Tech. Dev.

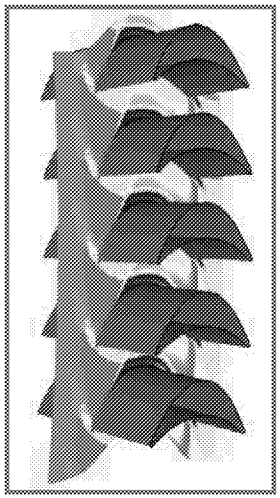


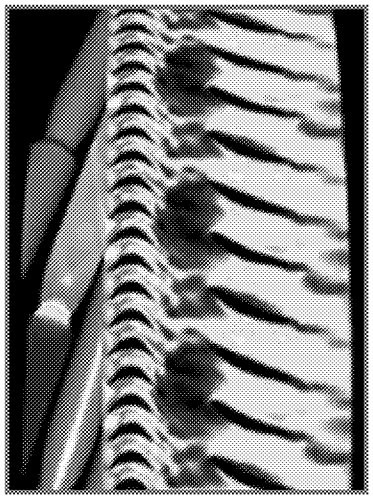


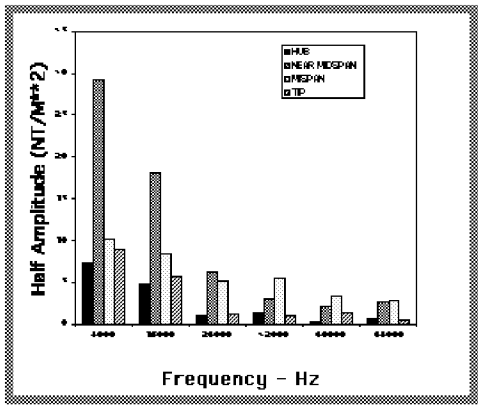


Pump flow path design and analysis

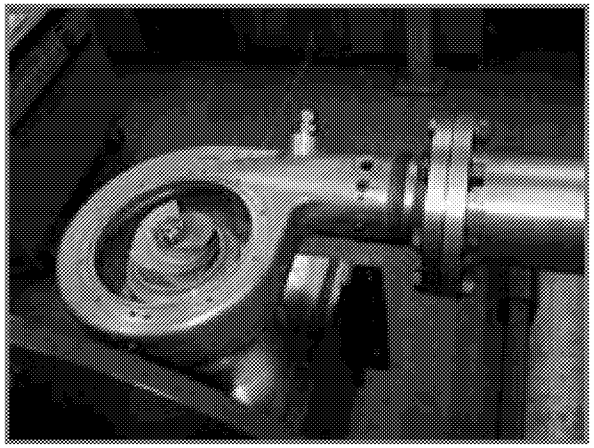
Turbine flowpath design and time accurate analysis



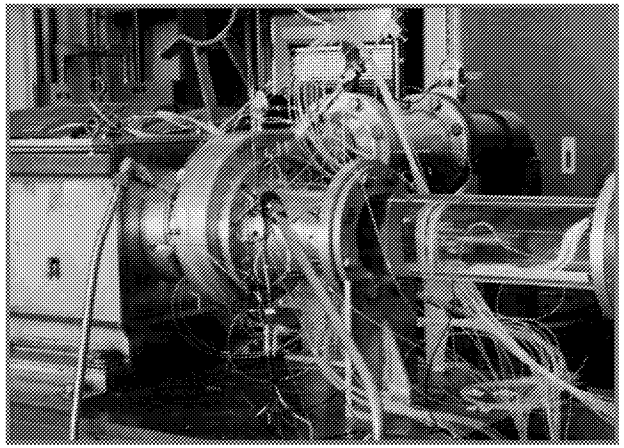


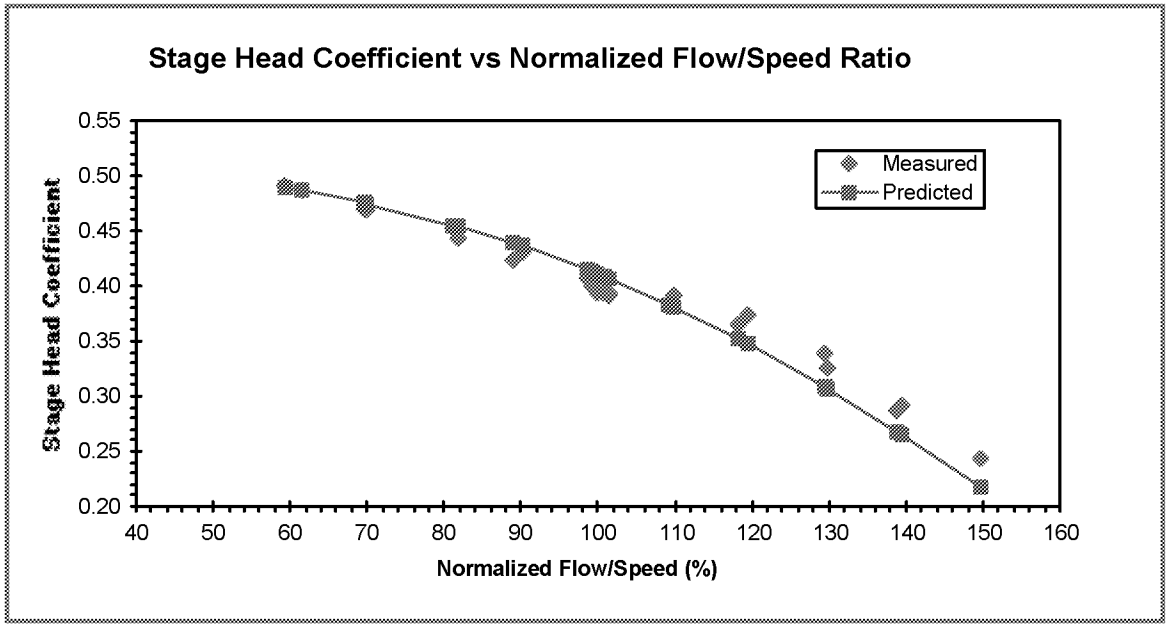


Recent Program Support & Tech. Dev.



Fastrac LOX pump
cold flow testing





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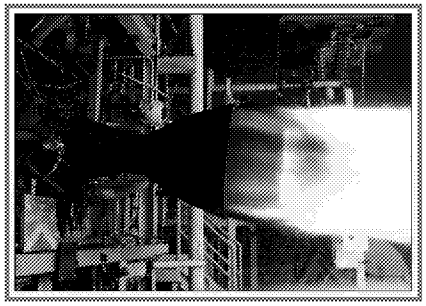
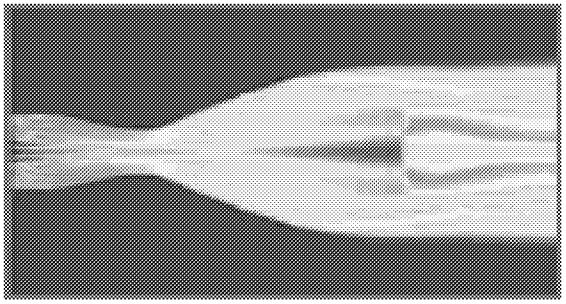
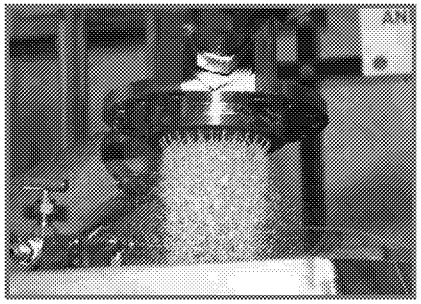
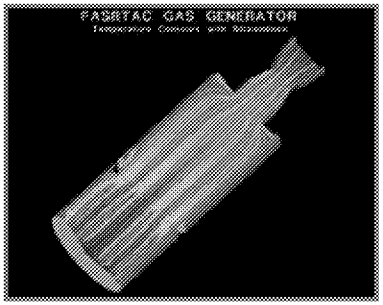




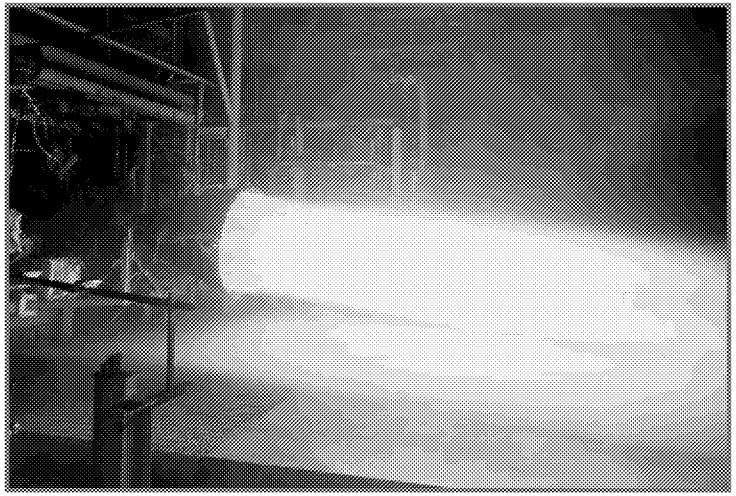


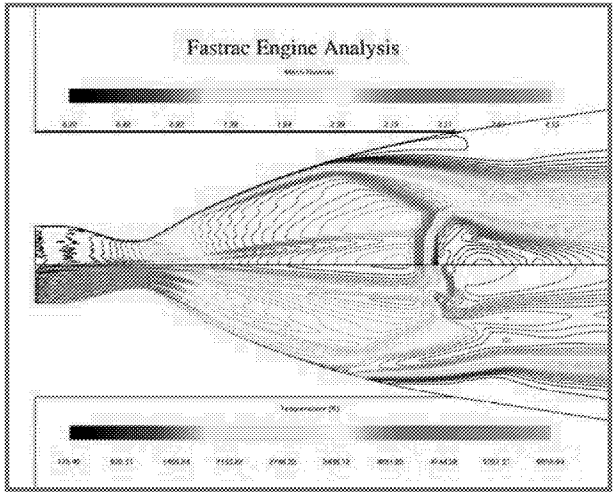
Fastrac TCA performance prediction with 15:1 nozzle

Patternization tests and performance prediction

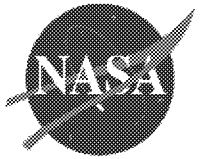


Fastrac TCA performance prediction with 30:1 nozzle



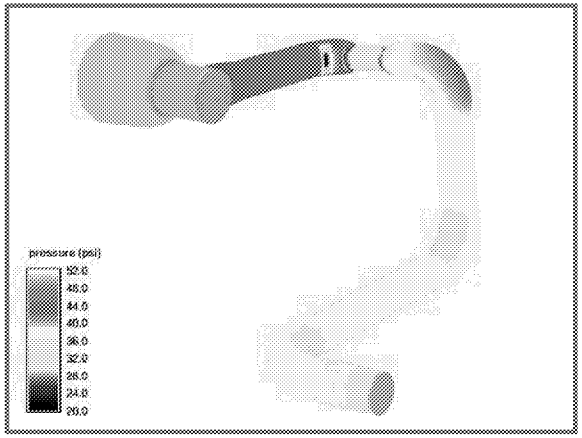


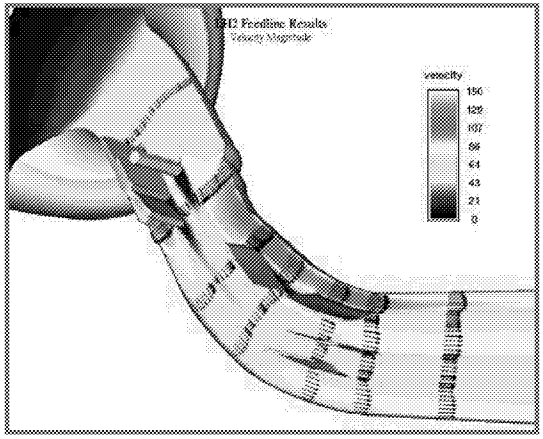
Recent Program Support & Tech. Dev.



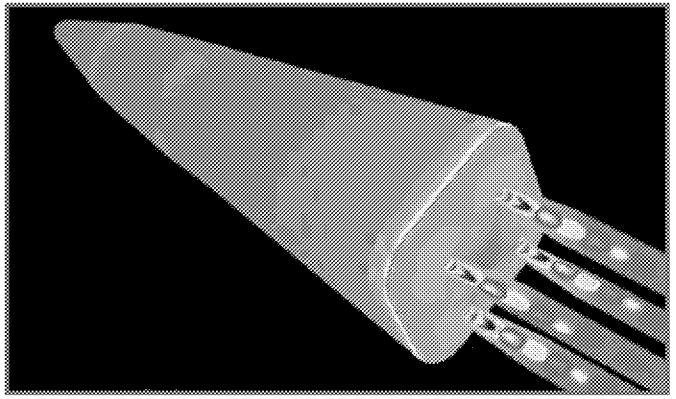
- **X-34 Pathfinder Vehicle Design Support**
  - Propulsion system feedlines flow analysis
    - Assure pump inlet flow distortion within acceptable limits
  - Plume induced heating on the vehicle
    - Initial predictions refined with component test data
  - Sonic boom prediction for environmental impact statement
- **X-33 / RLV Vehicle Design Support**
  - Assessment of 3 phase-1 concepts: lifting body, winged body, Delta-Clipper
  - Extensive wind tunnel tests for aerodynamic configuration development
    - Critical impact on resolving transonic pitching moment issue

Recent Program Support & Tech. Dev.

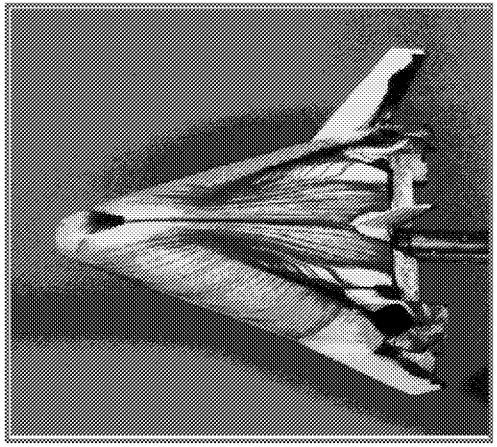


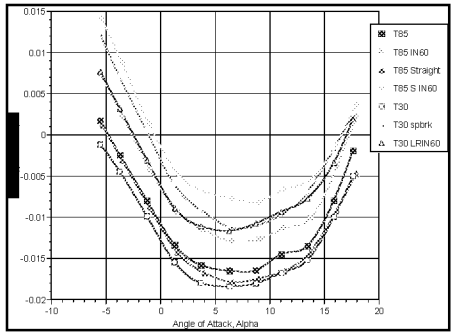


X-34 and X-33 feedline analysis

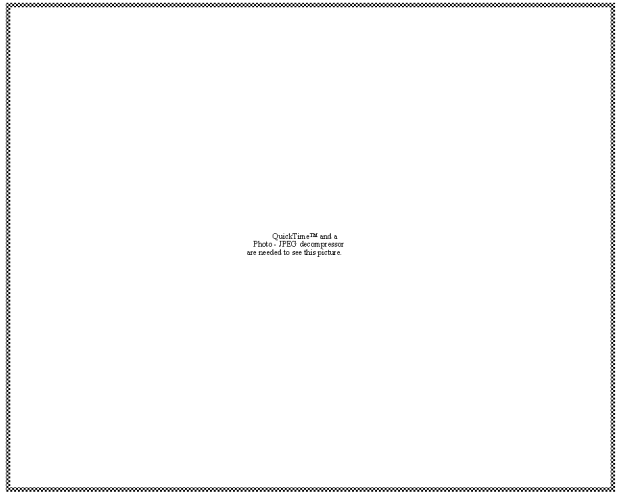


RLV Phase-1 Concepts





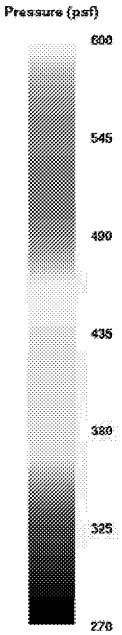
X-33 and RLV Aerodynamic Testing



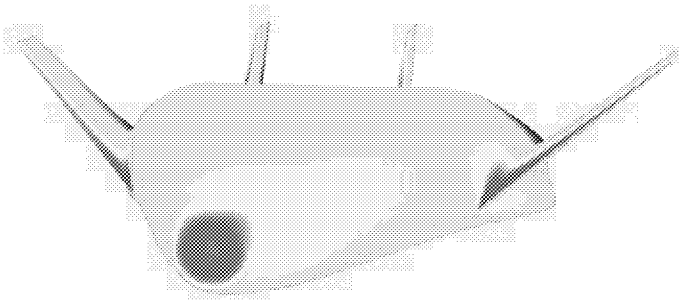
Recent Program Support & Tech. Dev.

- **X-33 / RLV Vehicle Design Support (continued)**
  - Ascent loads with and without plume
    - Aerodynamics load benchmark with LaRC jet-effects tests
    - Plume induced thermal loads
      - **CFD used to supplement empirical data base**
    - Base heating hot-fire short duration tests
  - LH2 feedline hydrodynamic design, analysis, & cold flow test
    - Tight packaging, close-coupled valve, J-2 turbomachinery
  - X-33 sonic boom prediction for environmental impact statement
- **Liquid Fly-Back Booster Wind Tunnel Tests**
  - Fly-back, liquid propulsion boosters under consideration for Shuttle upgrades
  - Support aerodynamic configuration development
    - Using wind tunnel data for CFD code assessment

Recent Program Support & Tech. Dev.

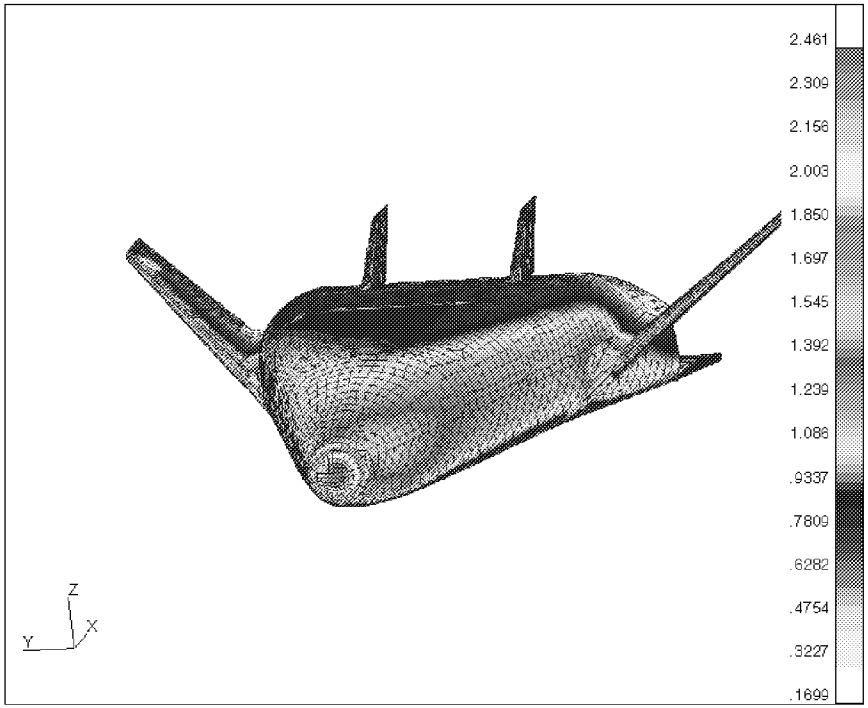


CFD External Pressures

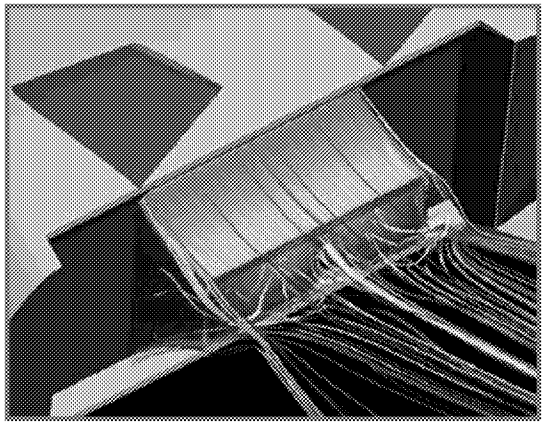


Interpolate CFD onto
Finite Element Model

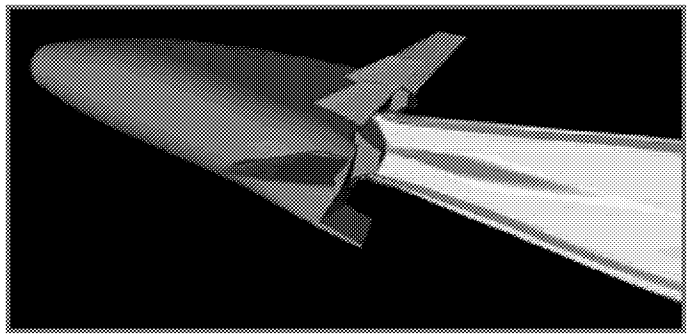
External Applied CFD Pressures onto Finite Element Model

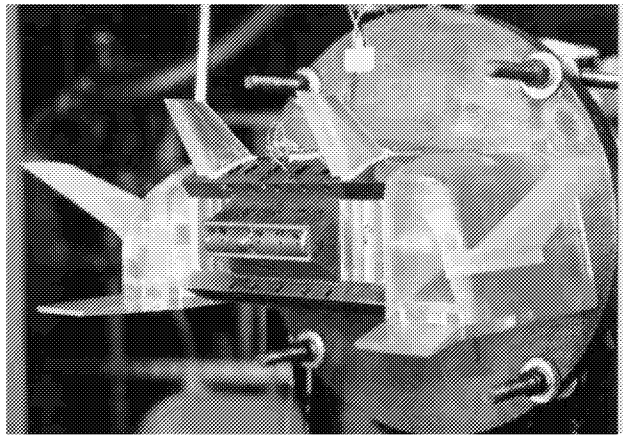


Linear Aerospike Plume-Induced X-33 Base-Heating



Sea level, no bleed

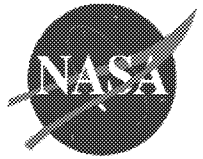




Short Duration hot-fire of base flows

At an altitude of 3.7km w/ base bleed

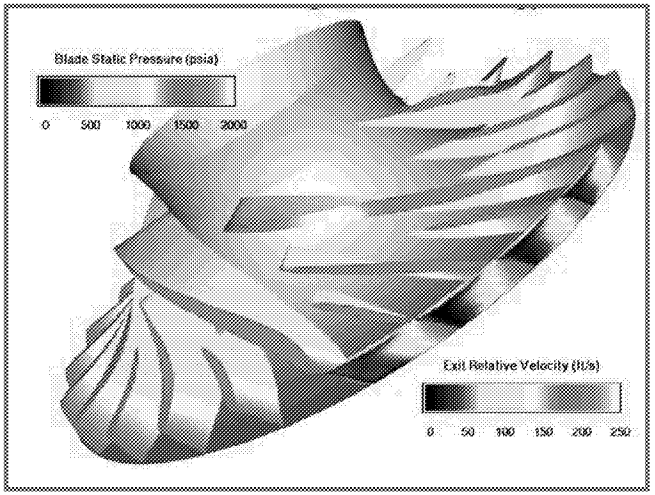
Ongoing Activities



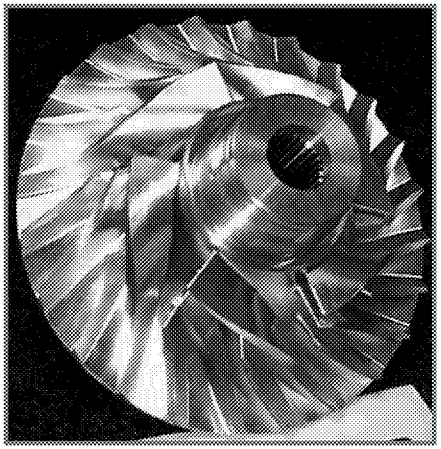
- **RLV Focused Technology**
  - Awarded two tasks to develop RLV turbomachinery technology
  - Turbine optimization task
    - Eliminate dependence on availability of composites &/or increase Isp
      - **Daniel Dorney presentation Tuesday morning (Fluids 3a)**
  - Unshrouded impeller technology development task
    - Increase stage loading without sacrificing efficiency
      - **George Prueger presentation Tuesday morning (Fluids 3a)**
- **Rocket Based Combined Cycle Concepts Development**
  - Trailblazer LOX-LH2 and DRACO LOX-Hydrocarbon concepts
  - Code benchmark for ejector mode operation
      - **Joe Ruf presentation later this morning (Fluids 1b)**

Space Transportation Directorate

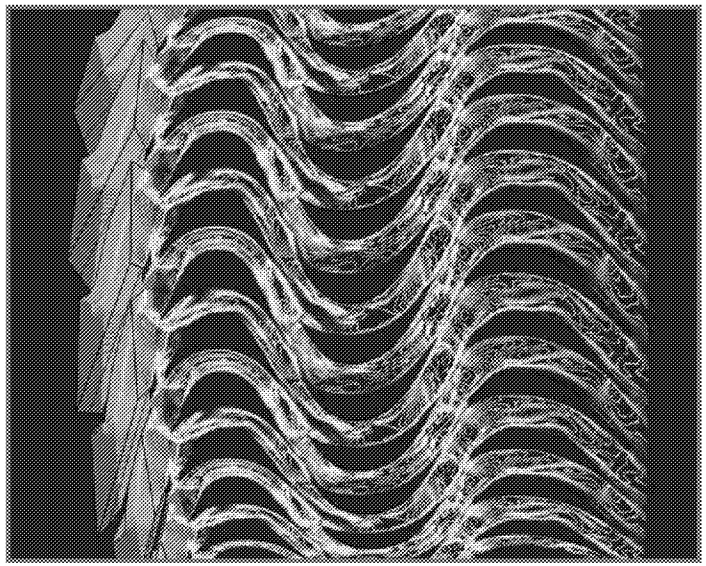
Ongoing Activities



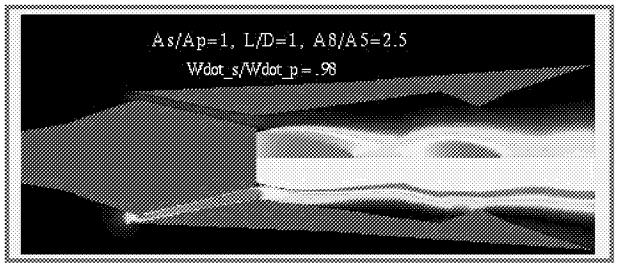
RLV Focused Technology
Unshrouded Impeller Tech.



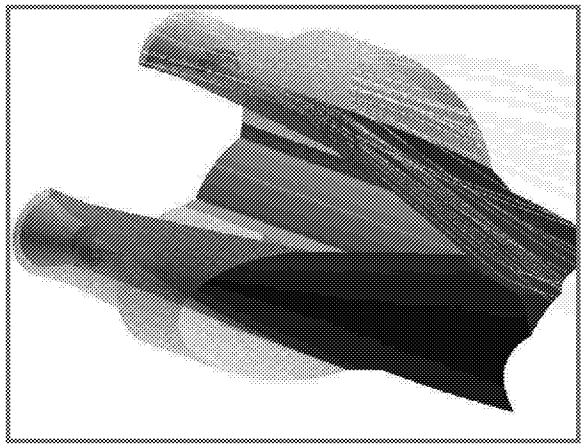
RLV Focused Technology
Turbine Optimization



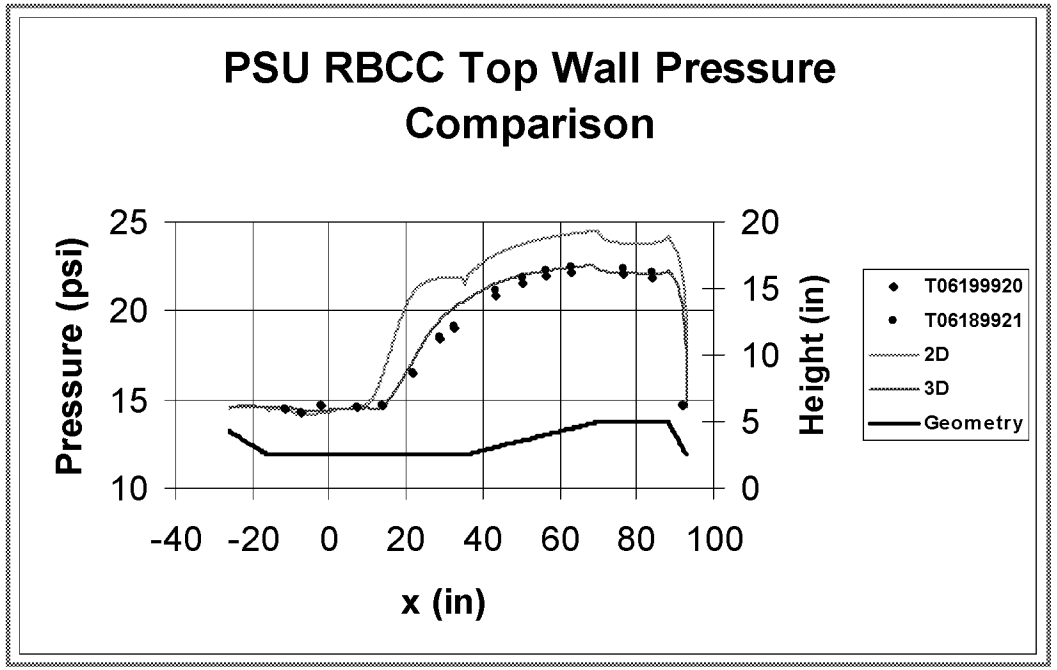
Ongoing Activities



Ejector concept parametrics



Trailblazer nozzle
concept assessment

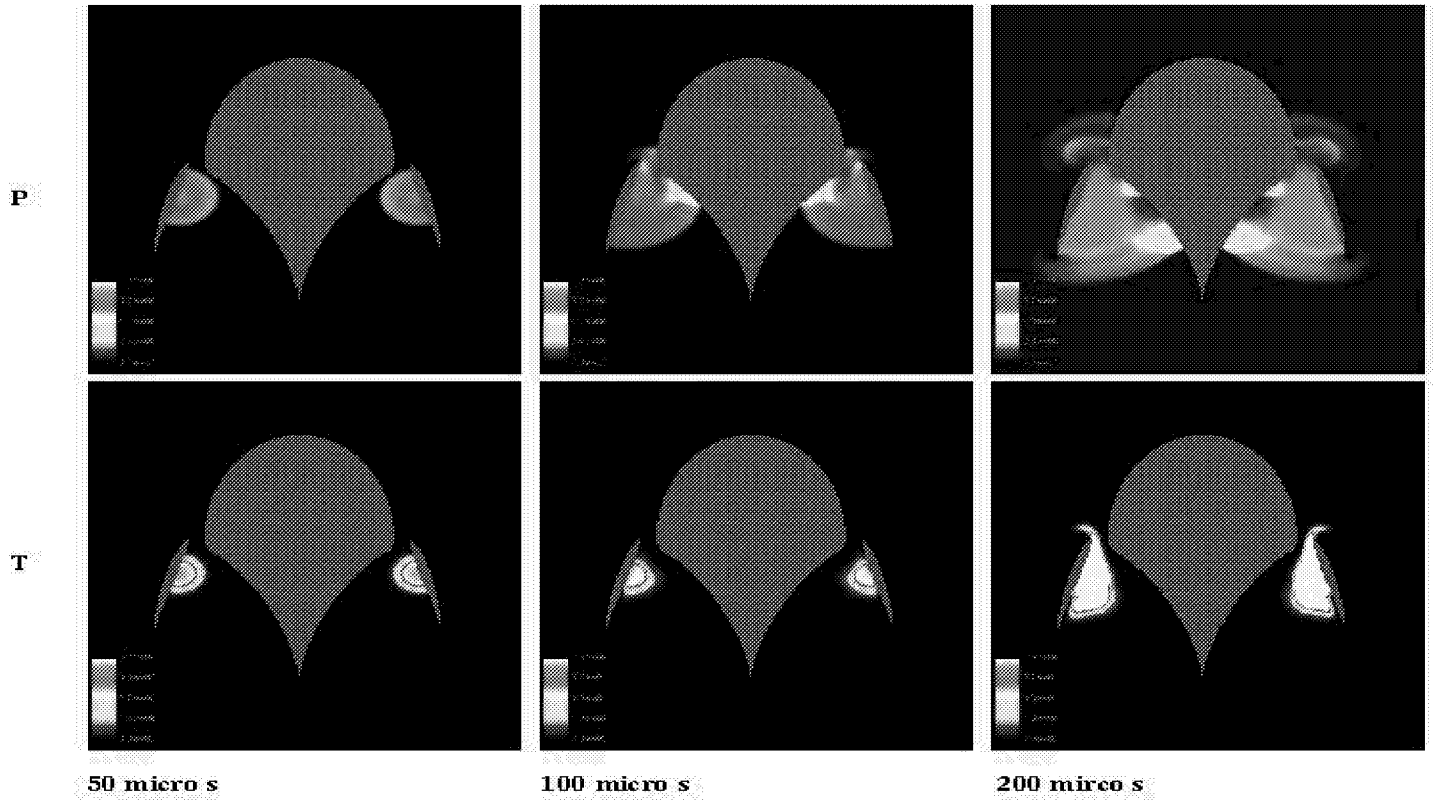


Ejector mode code benchmark
Using Penn State data

Ongoing Activities

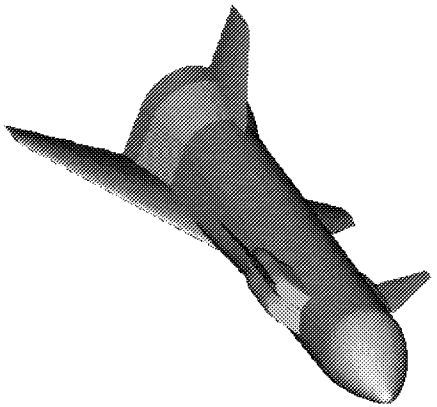
- **Methodology and Code Development**
  - Assessing & developing codes to support advanced propulsion concepts
    - Pulse detonation wave engine code assessment
    - Laser-light craft performance prediction code development
    - Defining requirements for high temperature, ionized flows
  - Demonstrating coupled fluids-thermal analysis capability in support of RBCC concept development
  - Assessing available unstructured grid generation capability
  - Developing optimization techniques
    - **Kevin Tucker presentation this afternoon (Fluids 2a)**
  - Assessing and demonstrating CART3D
    - Inviscid, Cartesian vehicle aerodynamic code
      - **Michael Aftosmis presentation later this morning (Fluids 1b)**

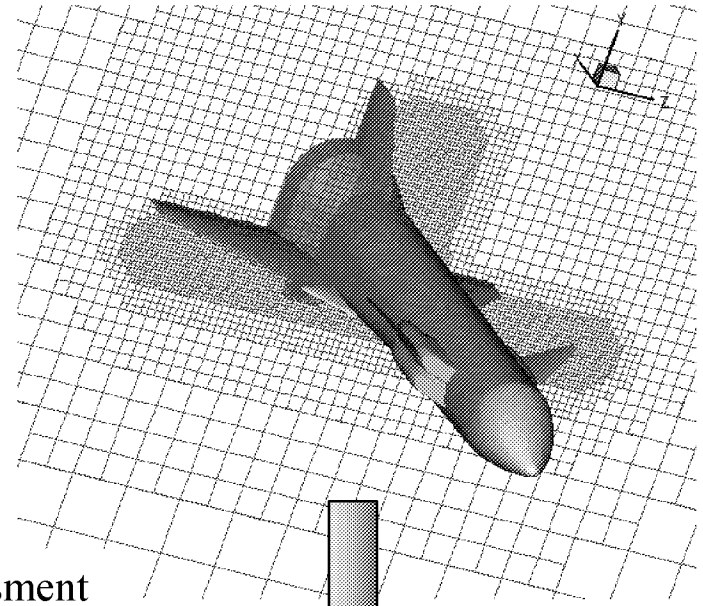
Performance Modeling of Laser Light Crafts



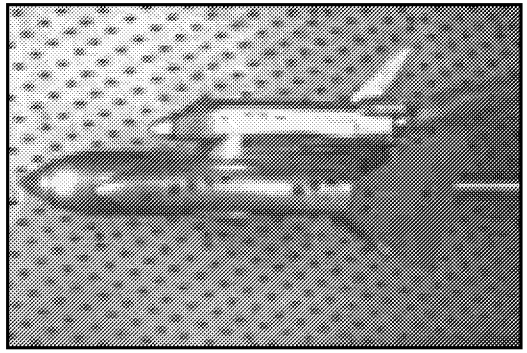
NASA/MSFC/ED32 Laser Lightcraft Thermo-Fluid Field Simulation

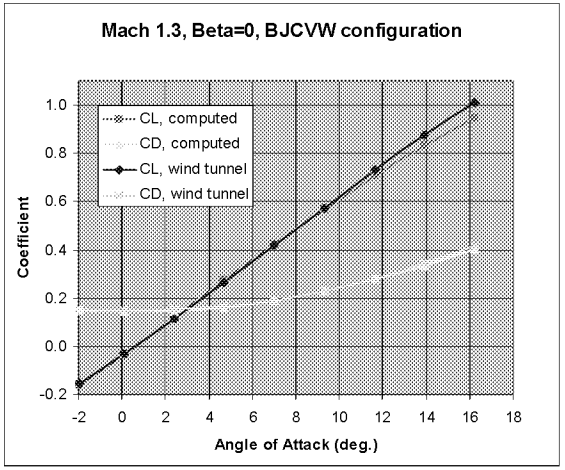
Ongoing Activities





LFBB used for CART3D Assessment

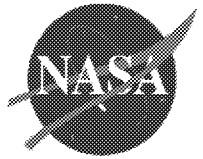




Future Activities and Direction

- **Hardware Design and Development**
  - RLV engine preliminary design (next 12 months)
    - Aerodynamic design and cold flow tests
    - Propulsion system environments
  - Support detail design of RBCC concepts (next 3 years)
    - DRACO flow path development and flight experiment
    - Trailblazer detail design
    - Combustion devices and turbomachinery supporting technologies
      - **Long life, wide flow range capabilities, low weight**
  - Spaceliner 100 Technology Roadmap
    - 5, 10, and 20 year goals
    - Hardware and supporting code technology
    - RBCC part of roadmaps 10 year goals
    - Laser light crafts part of 20 year goals

Future Activities and Direction



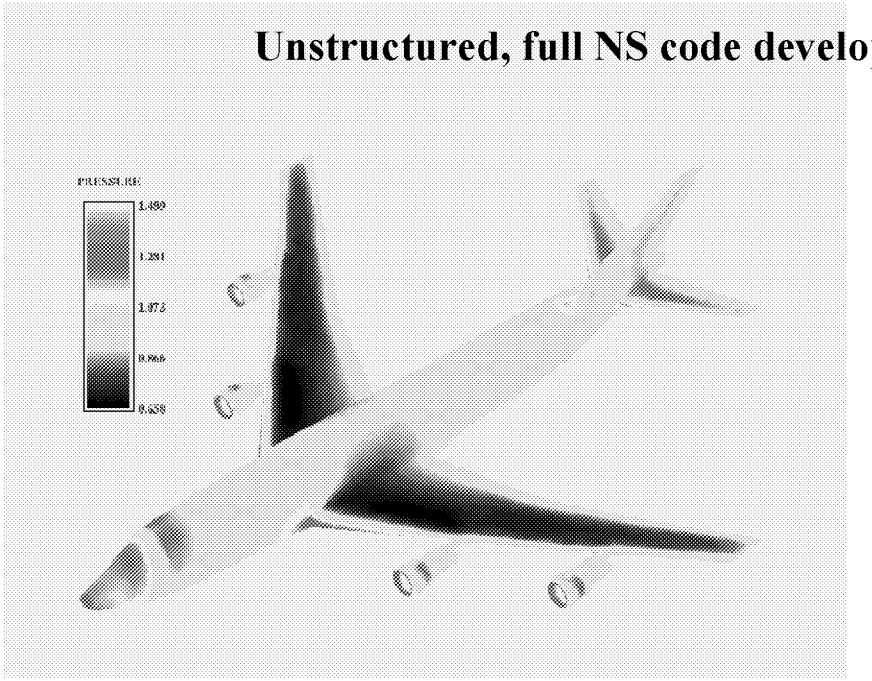
- **Tools Development**
  - Fast, efficient incompressible flow analysis code (Pearl)
  - Time accurate, rotor-stator incompressible flow analysis capability
    - **Cetin Kiris presentation Tuesday morning (Fluids 3a)**
  - Improvements to hydrocarbon combustion modeling capability
    - Increase code efficiency, expand physics
  - Increase flexibility and capability at cold flow test facilities
    - On-rotor measurements, broader speed range for pump testing, allow nearly simultaneous testing of turbine and nozzle test facility
  - Unstructured, full NS code development w/ finite rate capability
    - **Y. S. Chen presentation this afternoon (Fluids 2a)**
  - Advanced Engineering Initiative (AEI)
    - Code improvements, automation, & integration into design system
    - Develop, demonstrate, and implement MDO capability

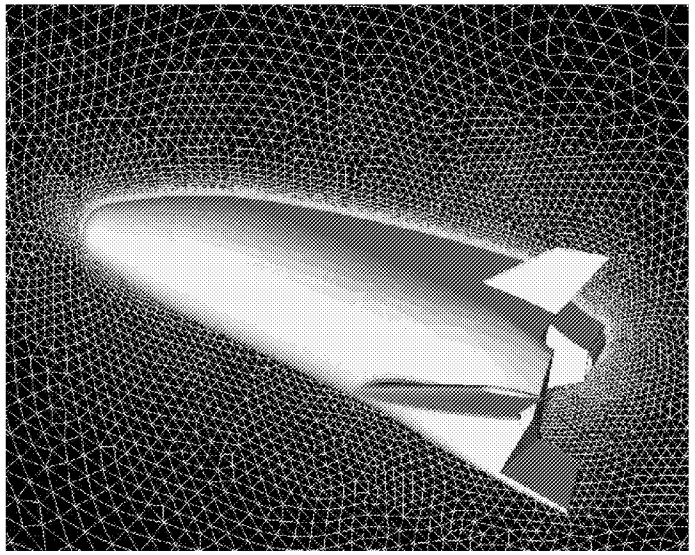
Future Activities and Direction

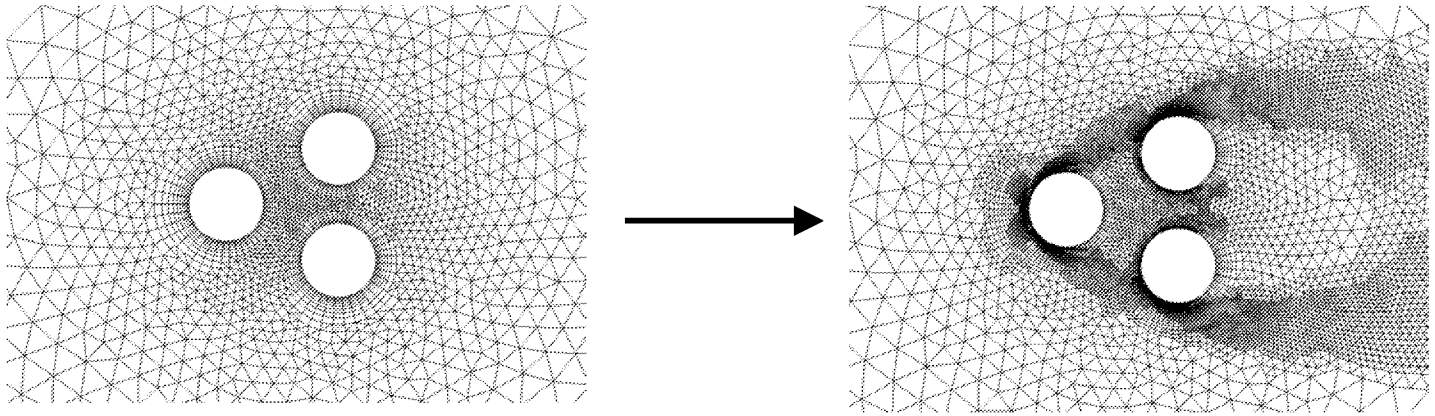
Space Transportation Directorate

NASA

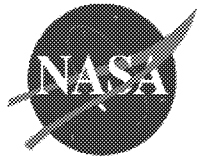
Unstructured, full NS code development w/ finite rate capability







Concluding remarks



- **Constraints**
  - Budget situation currently tenuous
    - New starts will suffer if budget cuts not addressed
- **Cooperation**
  - Leveraging from each others activities necessary
    - Maximum benefits from invested funds, builds political support
- **Opportunity**
  - Future hardware development becoming more reliant on high fidelity analysis
    - Required to achieve the necessary system operational characteristics
    - Budget constraints, public relations (political) consequences of failure
  - In the midst of major leap forward in fluid analysis capabilities