Aerodynamics and Acoustics of Modern Engine Test Cells: Computational Methods, Model Tests and Full-scale Measurements

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Agenda

ASE Business Overview

Test Cell Evaluation Techniques

Understanding of Test Cell Modeling

- **Aerodynamics**
- **Acoustics**

Presentation of Recent Study Results

Q & A

ASE Overview - Test Cell

- **Design and development of state-of-the-art test cells since 1967**

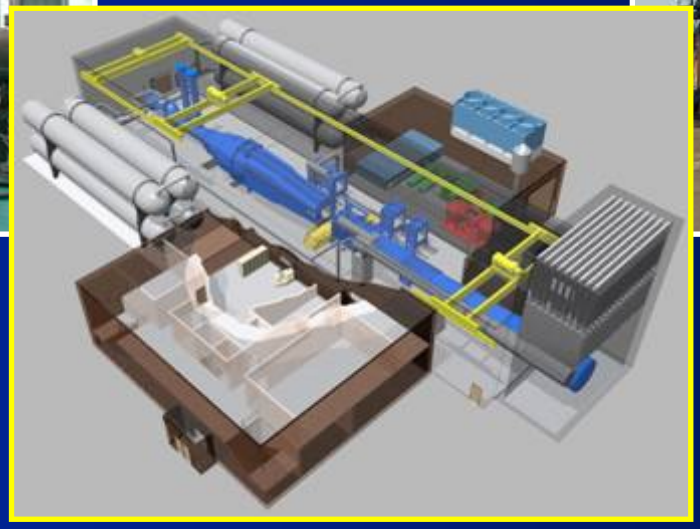
13M x 13M engine test facility

7M x 7M test facility for regional Jet

ASE Overview – Wind Tunnel

Design and development of state-of-the-art Aerodynamic Ground Test Equipment since 1952, as Fluidyne

Storage Heater for Hypersonic (P=15kg/cm^2, 1,700k)



Trisonic Wind Tunnel (0.3< M< 4.0)

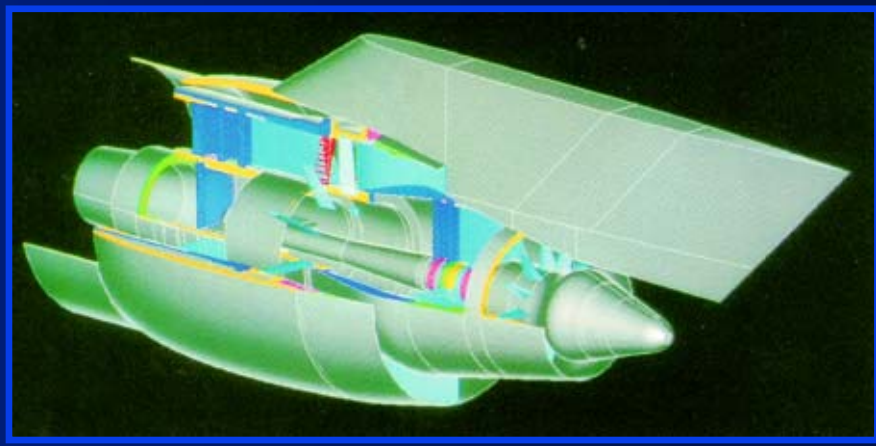
Cross Wind Blower (1,400 kg/sec at 20 to 50 knots)

ASE Overview - Aero Test Group

Capabilities Include:

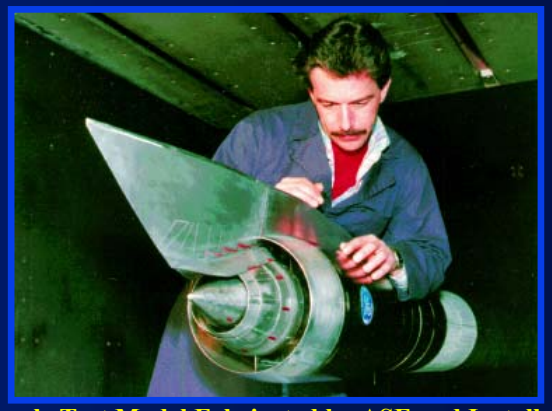
- **Subscale Model Test Program Development and Management**
- **Subscale Model Design**
- **Subscale Model fabrication**
- **Wind Tunnel Testing: Subsonic to Hypersonic**
- **Turbine Engine Components Aerodynamic Testing**
- **Icing Research and Environment Simulation Testing**
- **Test Data Analysis, Interpretation, and Reporting**
- **Test facilities Construction and Maintenance**

Subscale Model Design



ASE Aero Test Laboratory
(2,790 Square Meter Facility in Plymouth, MN)

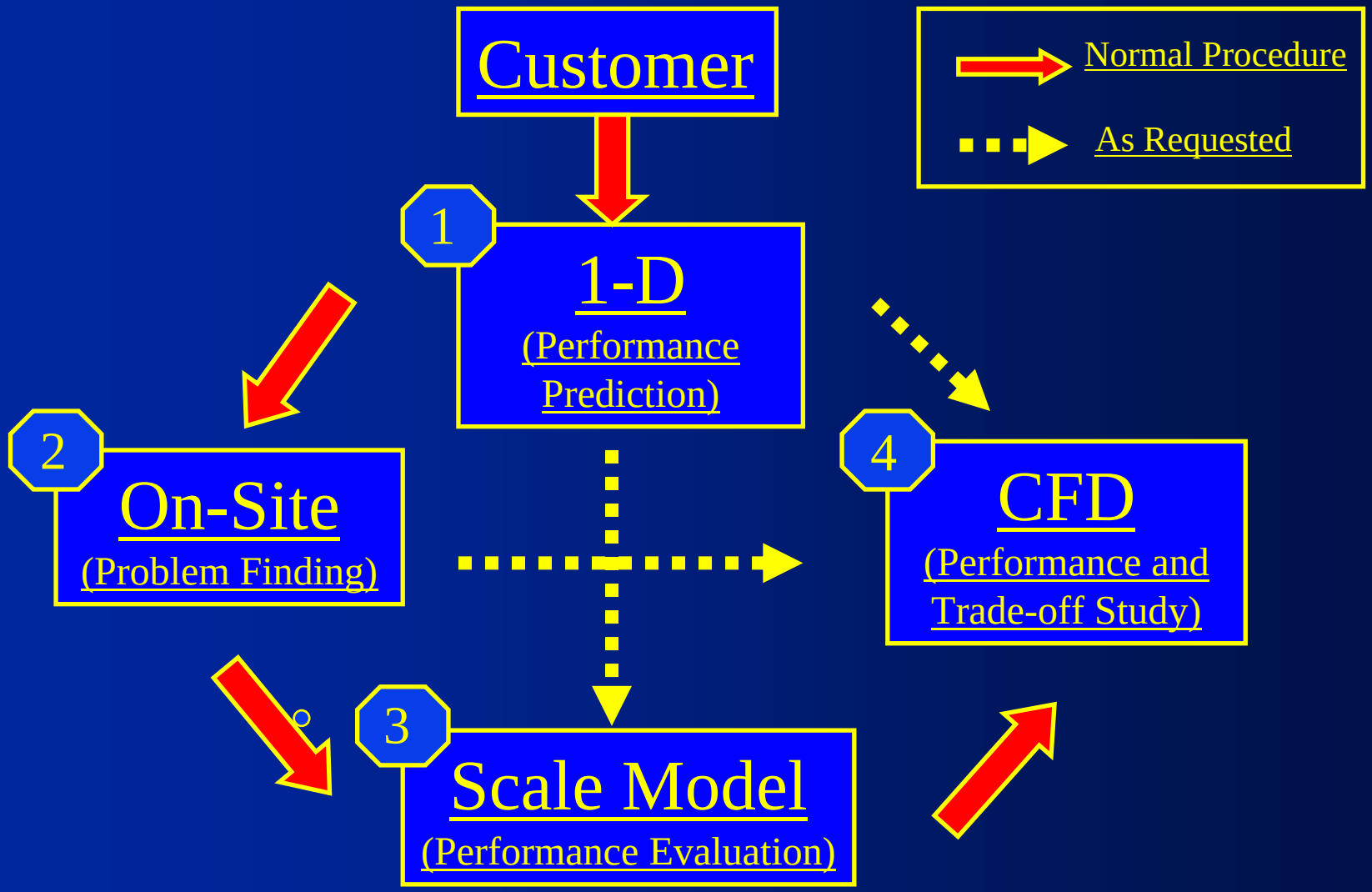
3-D CAD Drawing used to Fabricate Subscale Model of Turbine Engine for Wind Tunnel Testing



Subscale Test Model Fabricated by ASE and Installed in ASE's 5.5-Ft Transonic Wind Tunnel

"Excellence in Test Facilities"

ASE Test Cell Evaluation Techniques



Step 1 – One Dimensional Predication

Analytical Assessment based on customer supplied cell dimensions and known engine operation characteristics

- **ASE developed, one dimensional test cell model, using TK Solver™ evaluates up to 200 test cell parameter inputs and outputs**

- **ASE developed a noise model based on theory, scale model and full scale tests to predict test cell noise**

ASE-Fluidyne's Test Cell Modeling Timeline

1970's

- ASE-Air Portugal Test Cell

1980's

- US Navy Pegasus Engine at St. Louis
- US Navy J79 at NAS Dallas
- US Navy Miramar-cross wind performance

1990's

- HAESL-13m cell, before and after
- R&D-Infrasound Control Devices
- SIA proposed test cell
- IAI Cell inlet improvements
- R&D-Square tube
- Ejector Performance

2000+

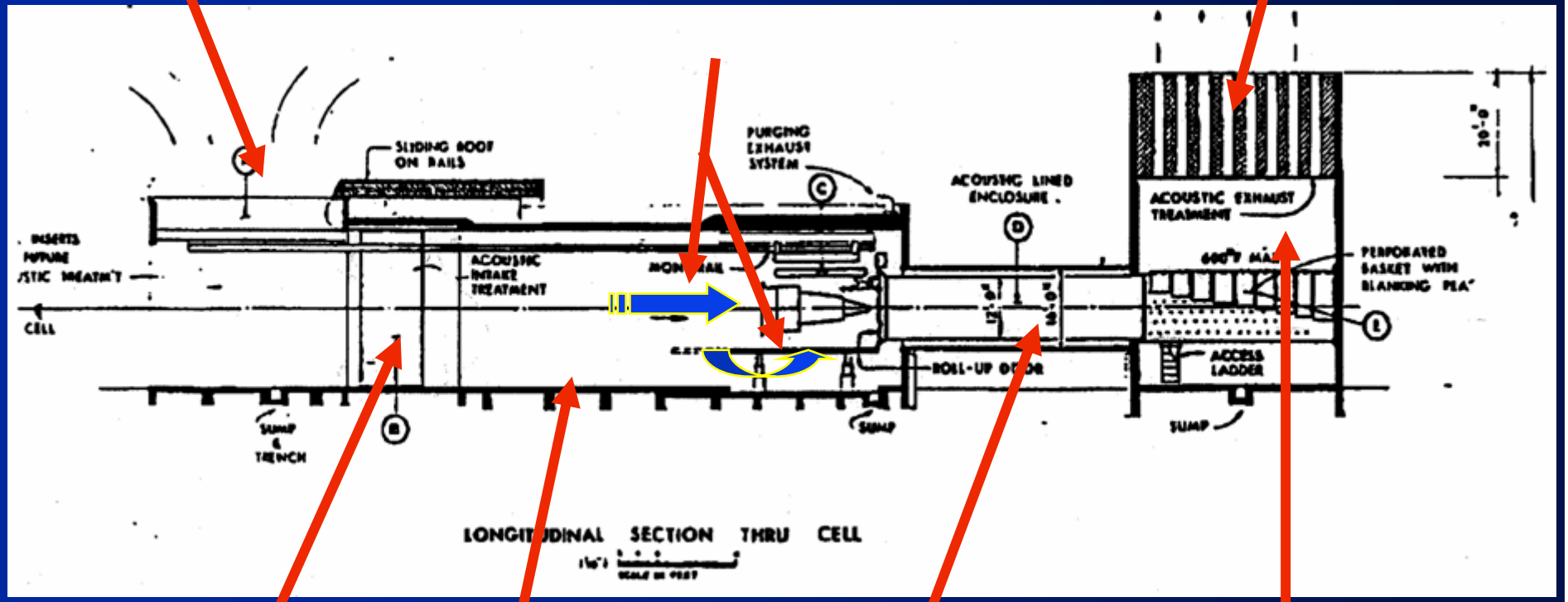
- KHI Cell 5 renovation- before and after
- Varig Cell Renovation
- RR-MRR Brazil-Proposed Facility
- RR East Kilbride – Proposed Facility
- R&D Hot Flow Testing
- R&D-Alt. Silencer designs-aero performance
- GE-Kelly and Evendale
- RRC-Lift Fan for JSF

What can we learn from 1- D Modeling?

Inlet. Treatment Velocity

Bypass Ratio

Exh. Treatment Velocity



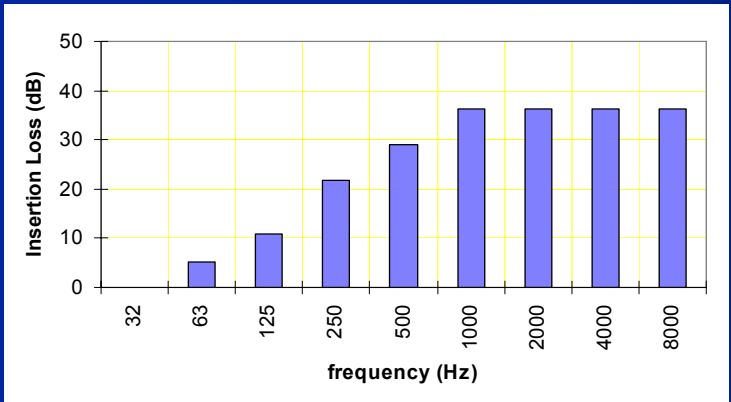
Inlet Treatment Velocity

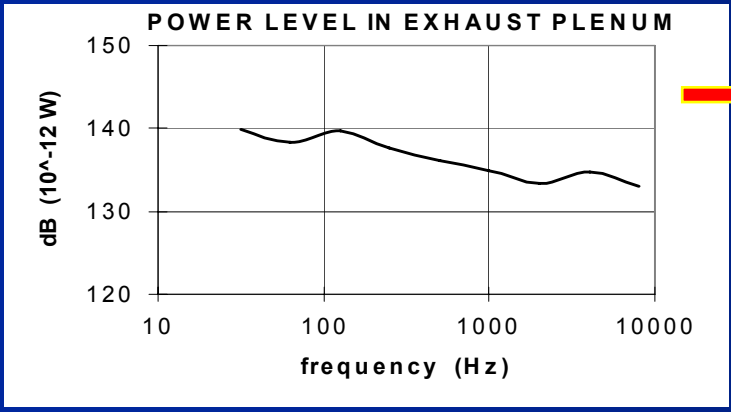
Cell Depression

Pressure recovery

Exh. Treatment Temperature

Sample of Acoustic Calculation Flow Chart for Exhaust Treatment





Stack Directivity

Divergence

Absorption

Reverberation

wall transmission

horizontal directivity

A-weight

Step 2 – On-Site Airflow and Acoustic Evaluation

Full scale measurement of customer test cell

Always – **Provide customer with written test plan for review and approval**

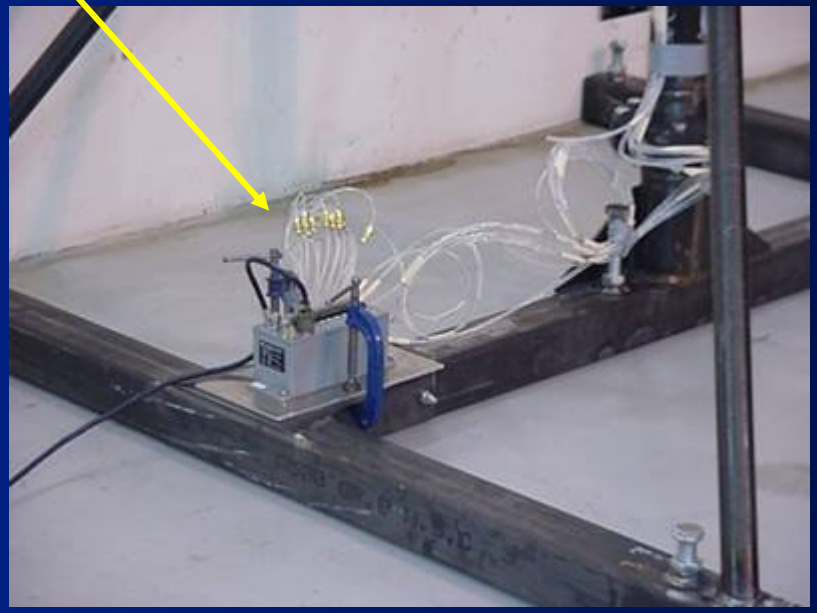
Always – **Measure inlet flow velocity, and temperature conditions at plane midway between the engine inlet and screens/baffles**

Often – **Measure exhaust gas temperatures via rack or available bulk measurement point**

As required – **Measure augmentor tube flow velocity and temperature profile**

Inlet Airflow Measurement

Pressure/Temperature Scanning Module- permits rapid data collection



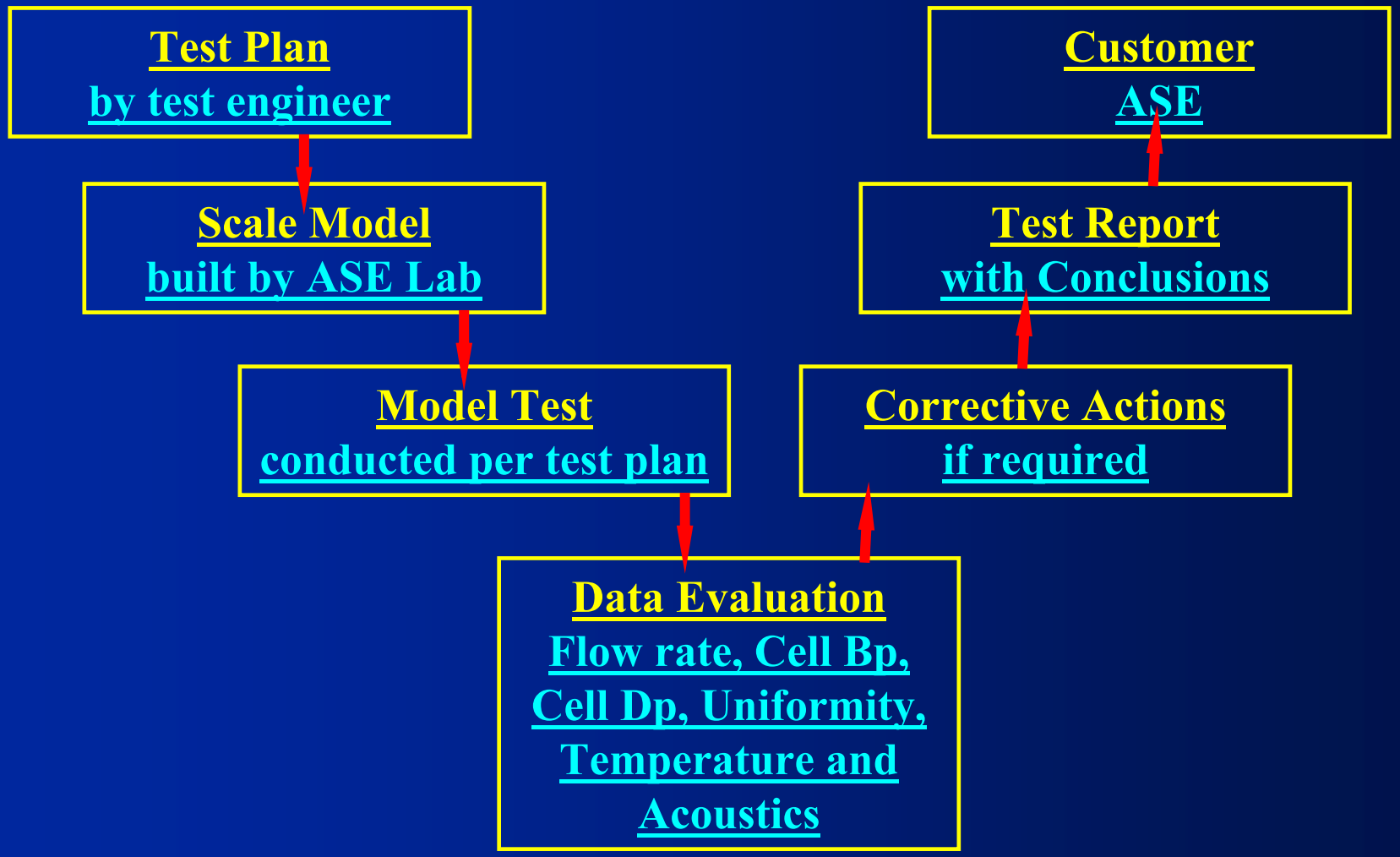
ASE's Probe Stand measures Inlet velocity, local pressure and temperature

On-site Smoke Survey

Sufficient Bypass Airflow
No Recirculation Observed

Vortex in Action
Lack of Inlet Turning Device

Step 3 – Laboratory Scale Model Study



Potential Topics in Model Study

Aerodynamics
(Flow Management Devices)

- Inlet Egg Crate
- Turning Vanes
- Baffles/Bar Silencers
- Screens
- Augmentor
  - Entrance Bellmouth
  - Tube Size
  - Target design

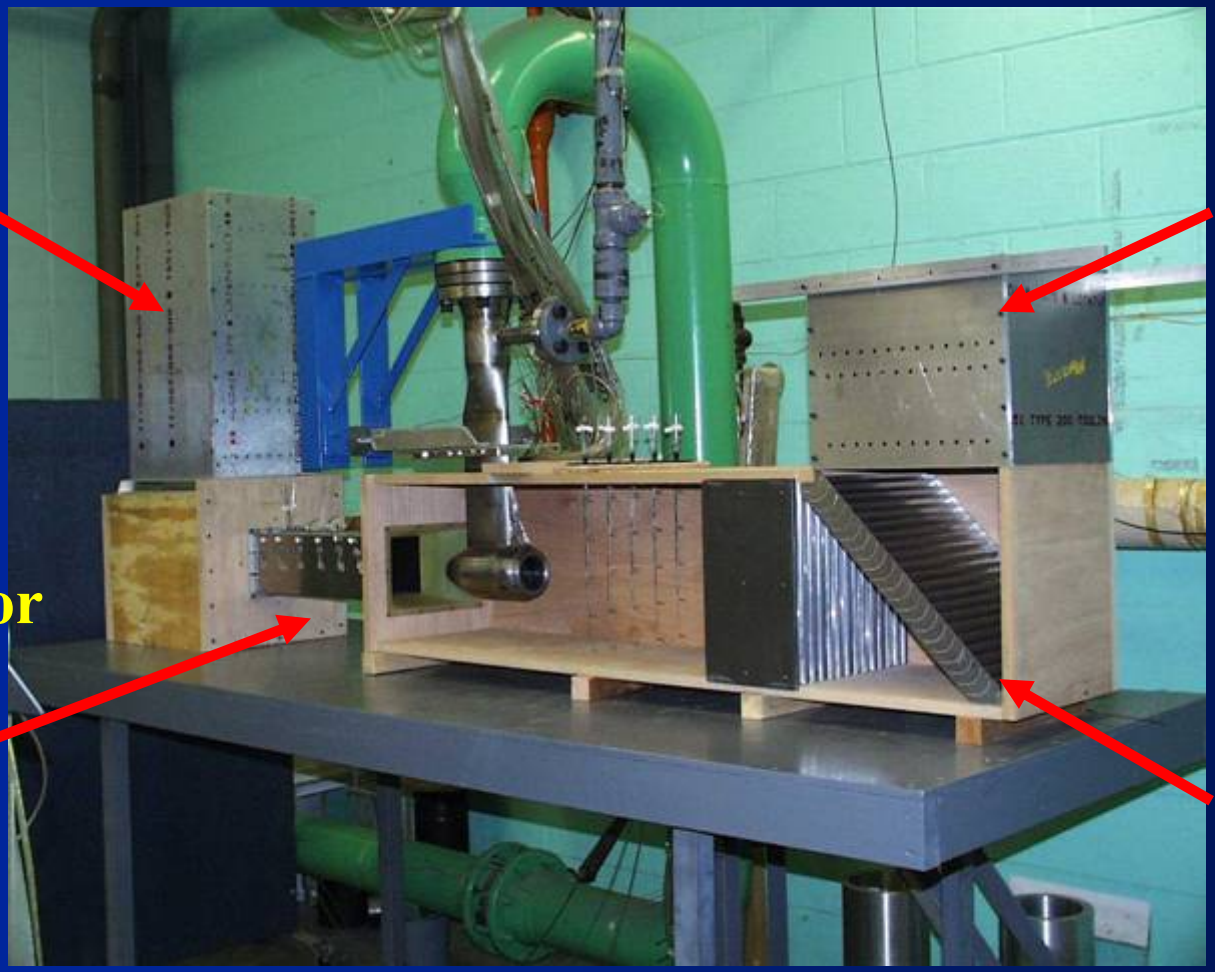
Acoustic
(Infrasound Control)

- Infrasound Mechanism
- Control of Aeroacoustic Energy
  - Entrance Bellmouth
  - Ring Diffuser
  - Termination
  - Stack Geometry

Scale Model Building Blocks

Exhaust Stack Module

Augmentor tube module-
square tube shown



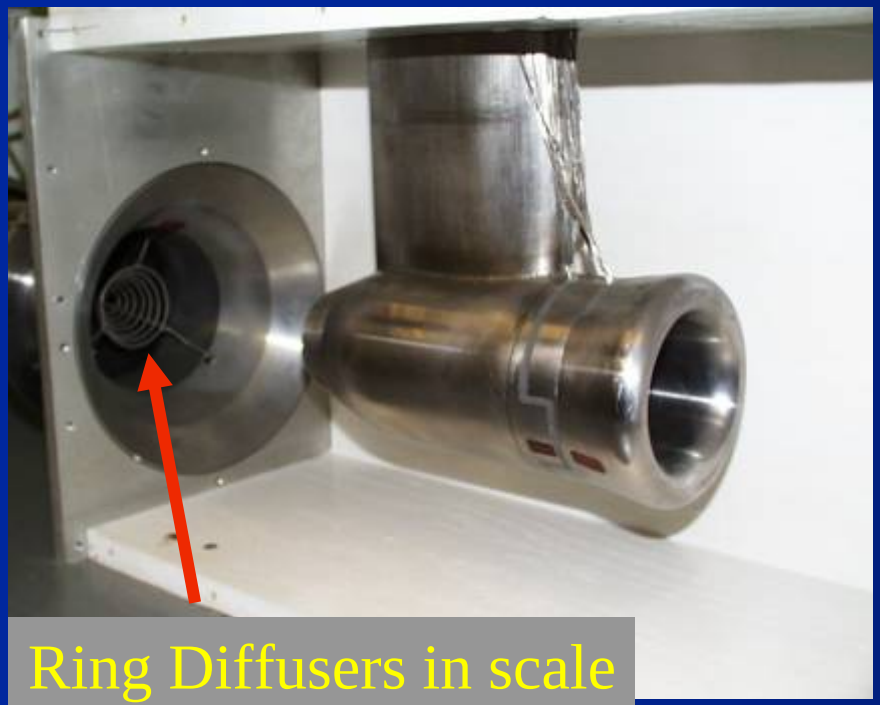
Inlet acoustic treatment

Turning vane module

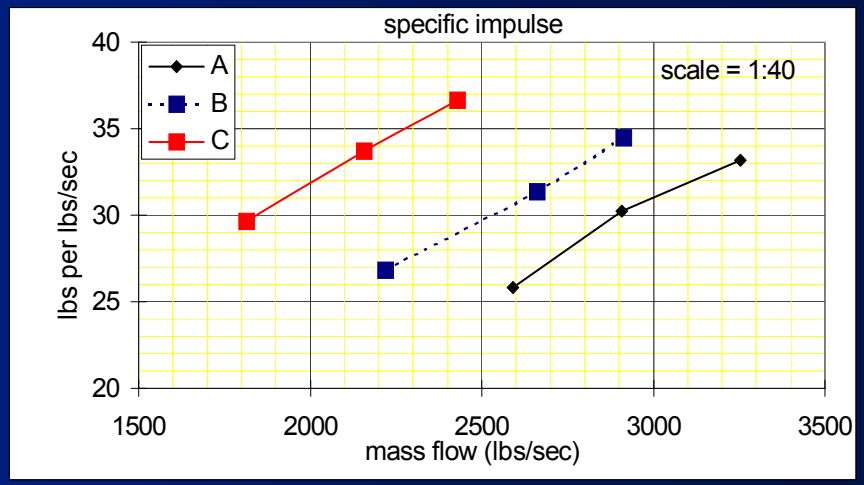
ASE has a head start on modeling your test cell

Engine Simulator with Ring Diffuser

- Ejector Driven With Unique Vacuum Capability To Correctly Simulate Both Mass Flow And Thrust
- Interchangeable Inlets And Nozzles To Simulate Several Engine Types

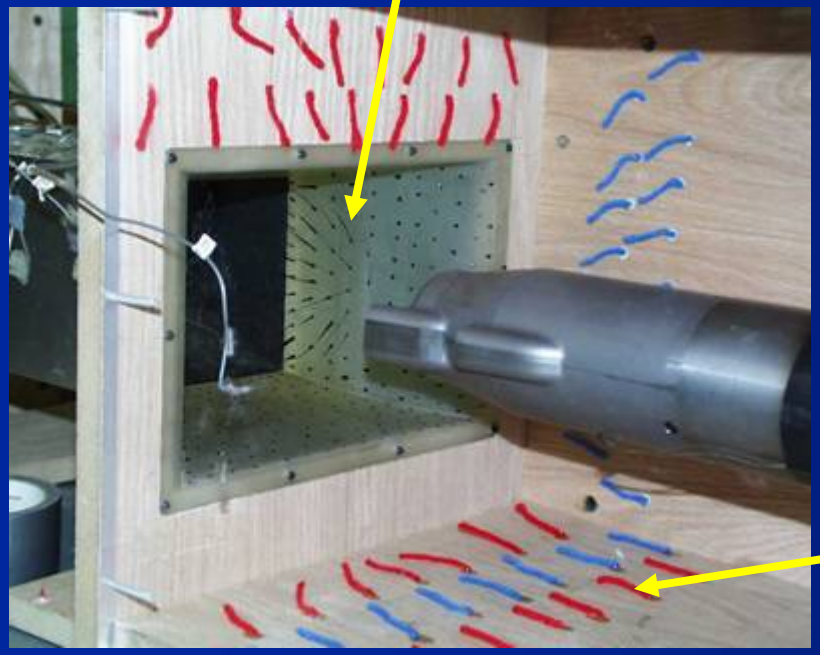


Ring Diffusers in scale



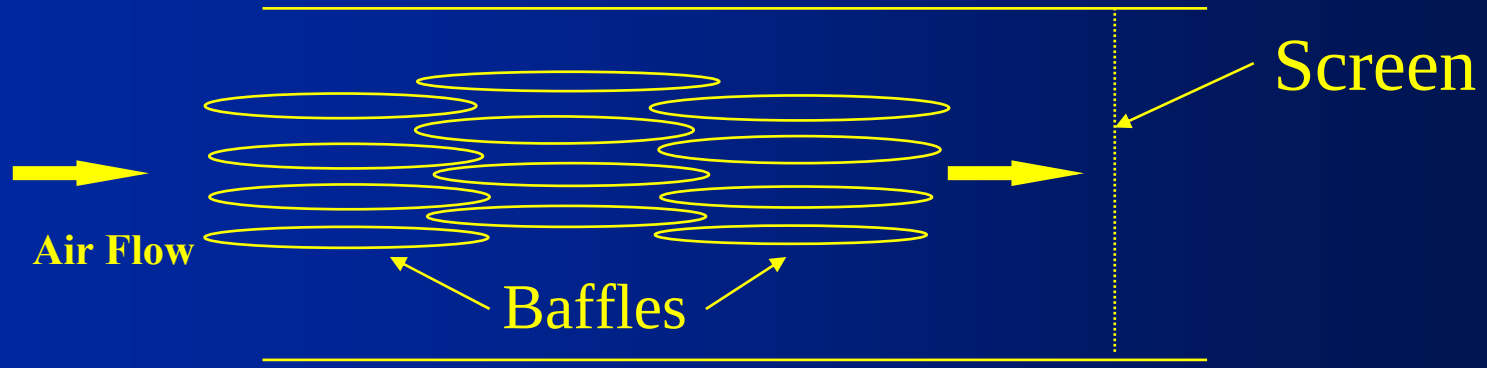
Flow Visualization Results

Ink blot streams

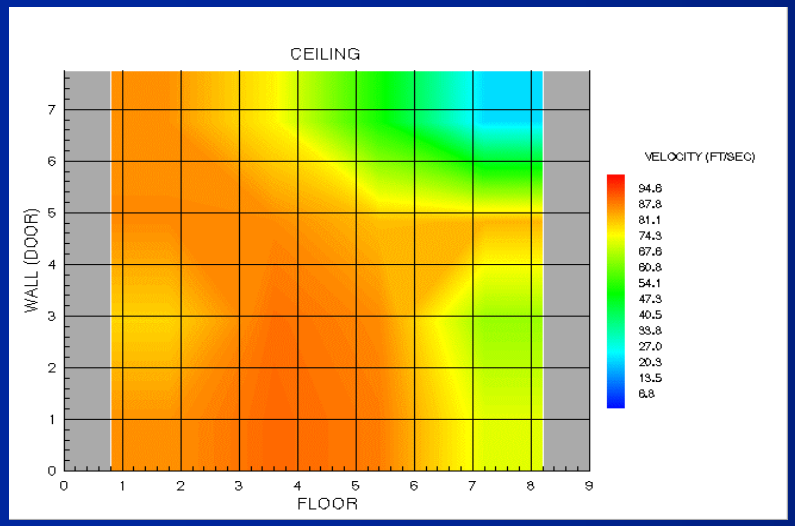


Tufts

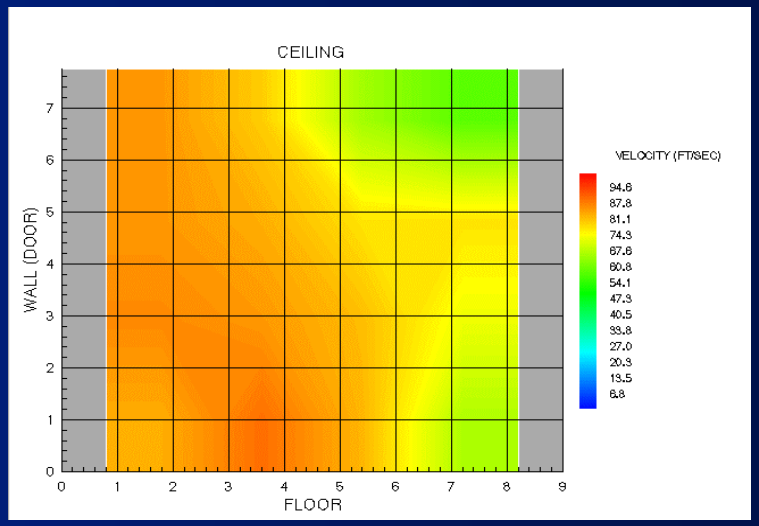
Model Study – Sample Results



Baffles only



Baffles and 1 Screen



Typical Test Matrix in Model Study

Example

				TABLE 1				
7020 KHI 1/43 Test Program								P. Chu
Data Point	**Thrust**	**Sleeve Position**	**Collector Bell Position**	Ring Diffuser	Cross Wind	Acoustic Measure.	Inlet Stack Grid 60%	Remark
1.01	H_500	Max forward 40 % Closed	Baseline	No	No	Yes	No	System Check Out
1.02	M_390					-		
1.03	L_245							
2.01	H_390	Max forward 40 %	Baseline	No	No	Yes	No	
2.02	M_373					-		
2.03	L_246							
2.04	H_390					No		
2.05	M_390					No		
3.01	H_390	Max forward 40 %	Baseline	No	No	Yes	Yes	No Vacuum
3.02	M_390					-		
3.03	L_246					-		
3.04	H_390					No		
3.05	L_246					No		
4.01	H_390	Max forward 40 %	Baseline	No	Yes	No	Yes	
5.01	H_390	Max AFT 60% Cl	Baseline	No	No	Yes	Yes	
5.02	L_246					-		
5.03	H_390					No		
5.04	L_246					No		
6.01	H_390	Mid 50% Closed	Baseline	No	No	Yes	Yes	
6.02	L_246					-		
6.03	H_390					No		
6.04	L_246					No		
7.01	H_390	Mid 50% Closed	1-1/2m forward	No	No	Yes	Yes	
7.02	L_246					-		
7.05	H_390					No		
7.06	L_246					No		
8.01	H_390	Mid 50% Closed	1-1/2m forward	Yes	No	Yes	Yes	
8.02	L_246					-		
8.03	H_390					No		
8.04	L_246					No		
9.01	H_390	Mid 50% Closed	Baseline	Yes	No	Yes	Yes	
9.02	L_246					-		

Model Variables:

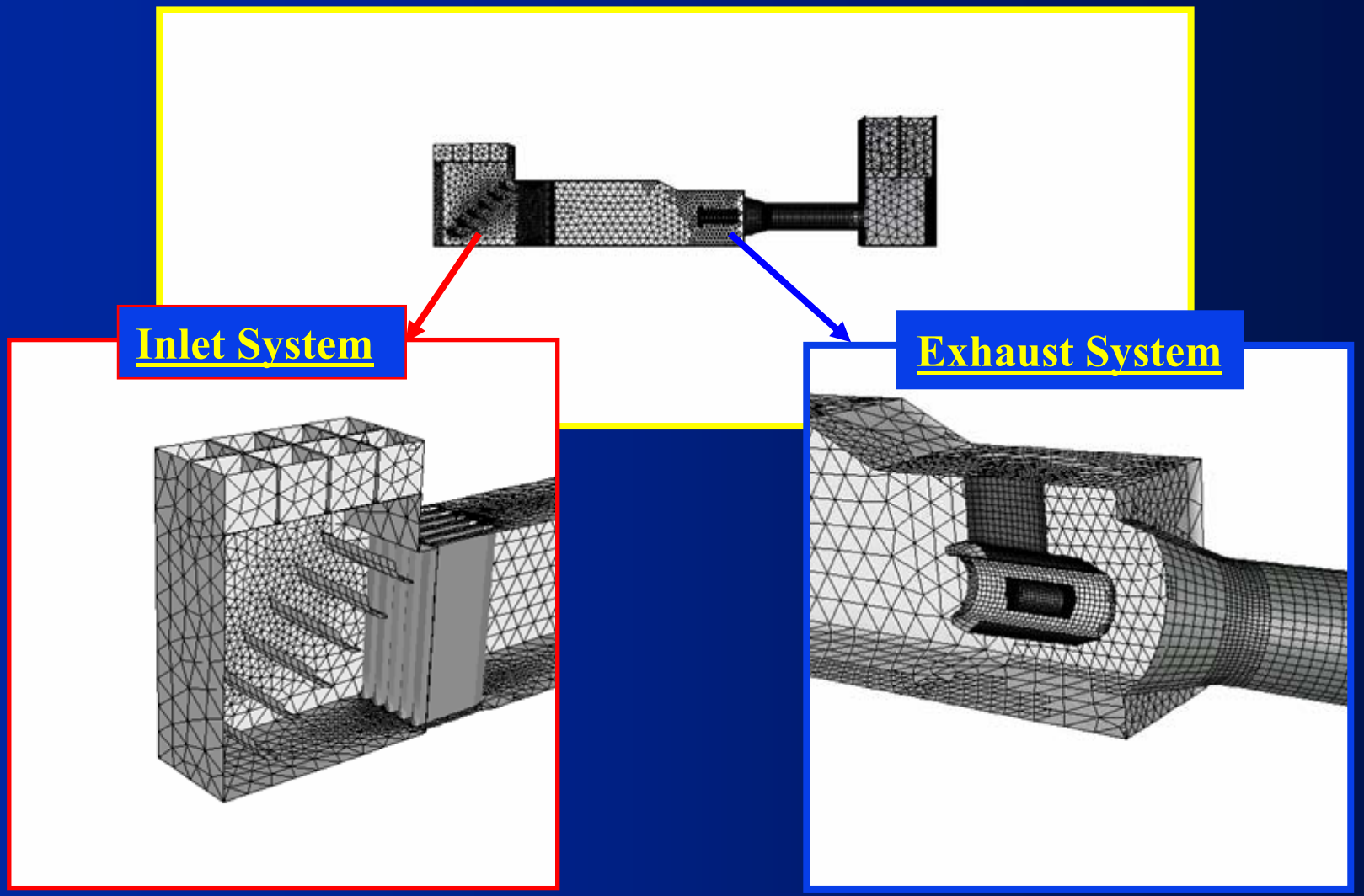
- Engine Thrust (2)
- Collector Positions (2)
- Ring Diffuser
- Blast basket sleeve position (3)

Data Collected:

- Engine inlet/exhaust flows
- Cell velocity distribution and flow
- Audible and Infrasound spectra
- Test cell static pressures

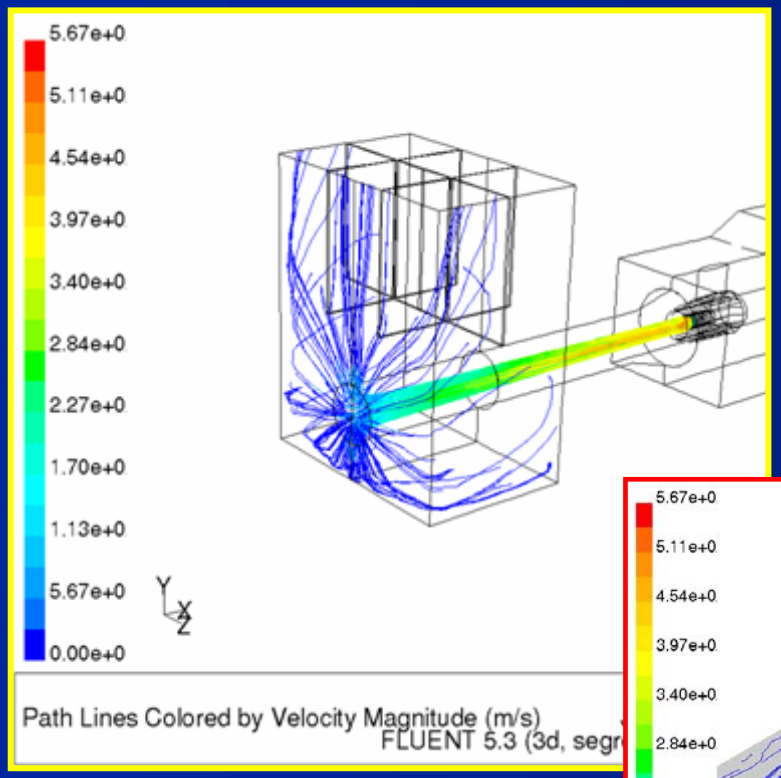
34 Data points collected

Step 4 – Computational Fluidynamic (CFD)

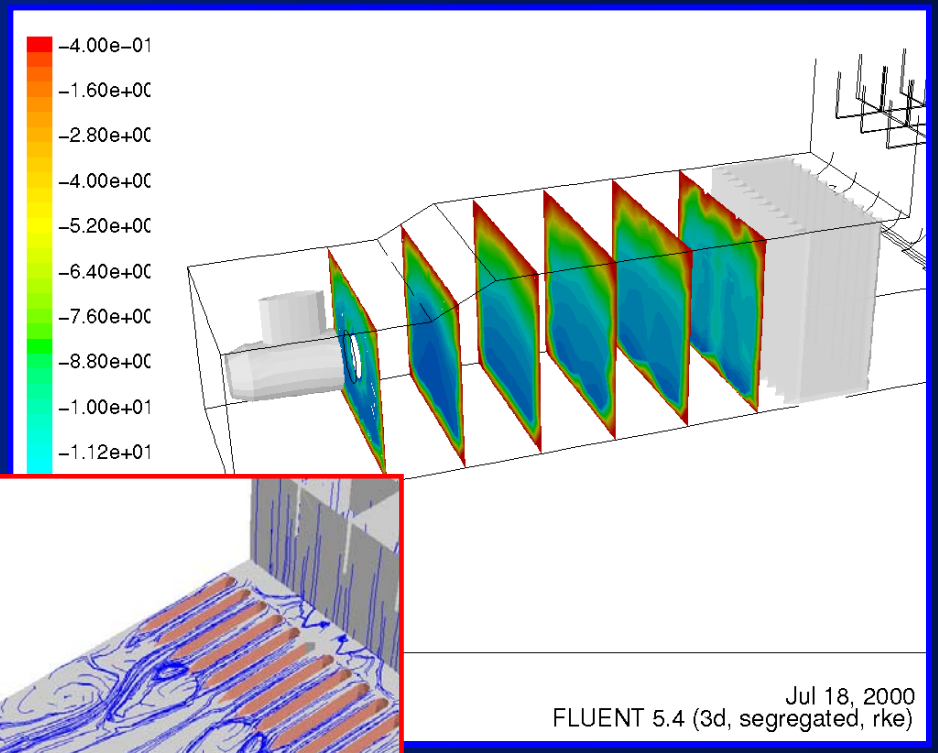


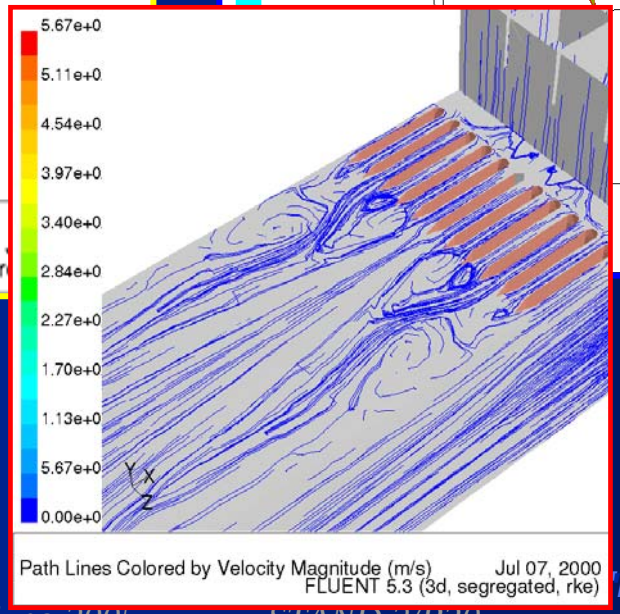
Sample of CFD Results

Exhaust Air Distribution



Front Cell Airflow Distribution





Wakeflow behind baffles

What can we gain from the CFD?

Reduced Design Cycle Time

Improved Designs

Simulation of full-scale tests

Troubleshooting

Summary

ASE has invested substantial resources in developing both Modeling and Measurement techniques to enhance our understanding of test cell Aerodynamics and Acoustics.

ASE is dedicated to helping our customers to best use their current test cells and to satisfying the needs of their future growth.

ASE will continue to advance our knowledge in Aerodynamics and Acoustics through education, training, and in-house R & D programs.