Active Flow Control Technology for Aeronautical Applications

Catalin Nae

INCAS – National Institute for Aerospace Research

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"Elie Carafoli"
B-dul Iuliu Maniu 220, sector 6, Bucharest, ROMANIA
www.incas.ro

Profile :

- State owned company
- Founded in 1950
- 150 employees
- Leading research establishment for aerospace research in Romania

Major activities :

- ✓ Main design authority and system integrator
- ✓ Aerodynamic design
- ✓ Structural design and analysis
- ✓ Experimental wind tunnel validation
- ✓ Global performance analysis

- ❖ Research and development in aeronautics

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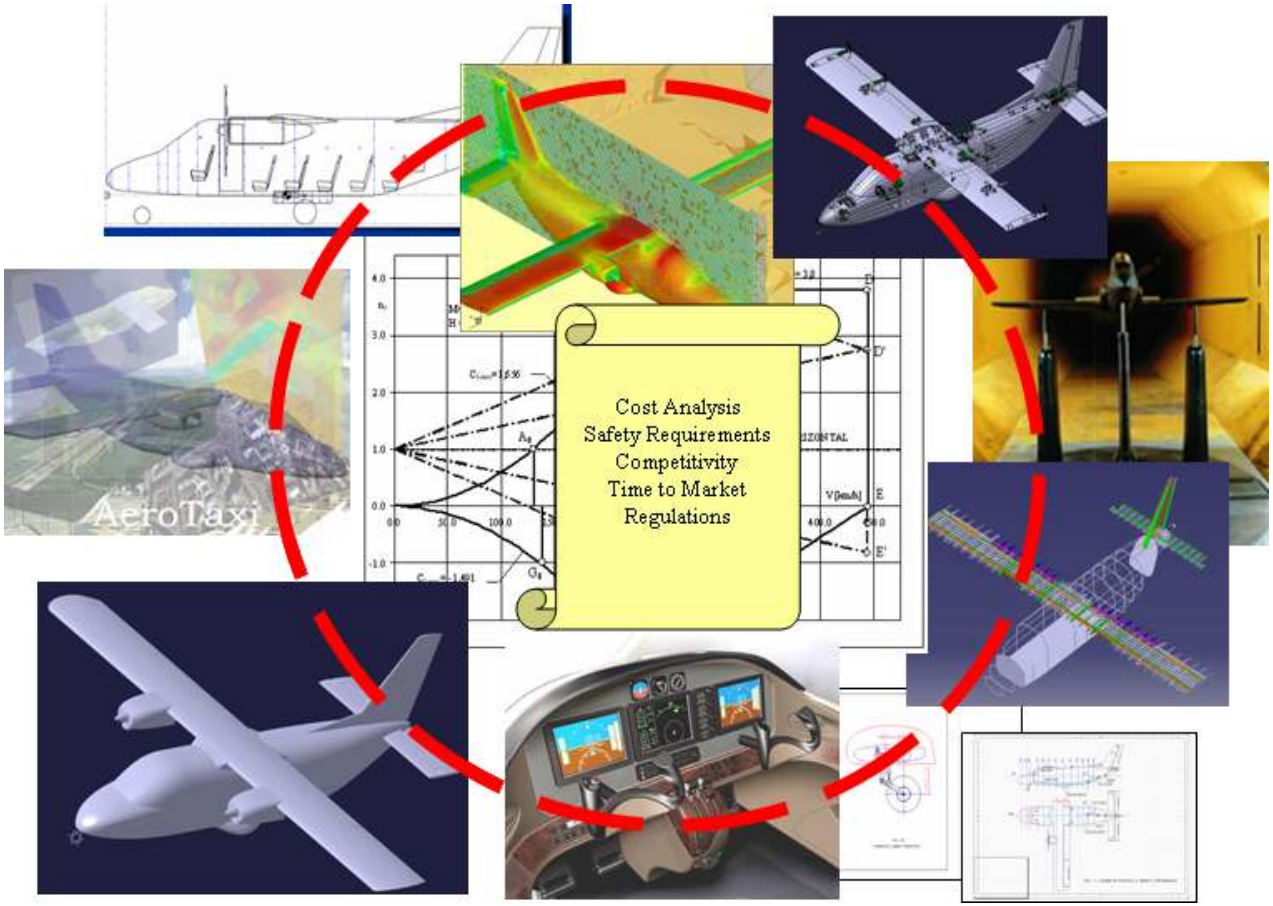
Development strategy :

- ➢ Reorganization as public research company
- ➢ Maintaining capabilities in key sectors for product development
- ➢ Development of existing research infrastructure
- ➢ New capabilities and expertise

Major capabilities :

- ✓ Aerodynamic design
- ✓ Wind tunnel testing
- ✓ Global performance analysis

- ❖ System design and integration for civil and military aeronautical products



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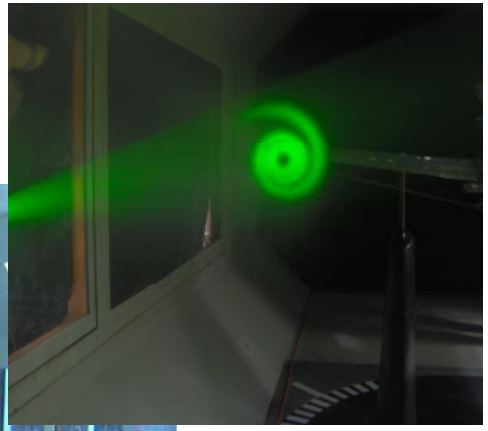
Subsonic Wind Tunnel

• Atmospheric pressure continuous type facility
• Maximum speed of 110 m/s
• Usual Reynolds number up to 1.5 million.

Equipment:

•Traditional type facility
•6 component pyramidal type balance
•Standard pressure acquisition systems.
•New data acquisition technologies
•Laser visualization systems
•CTS system
•Aeroacoustics and airframe noise evaluation



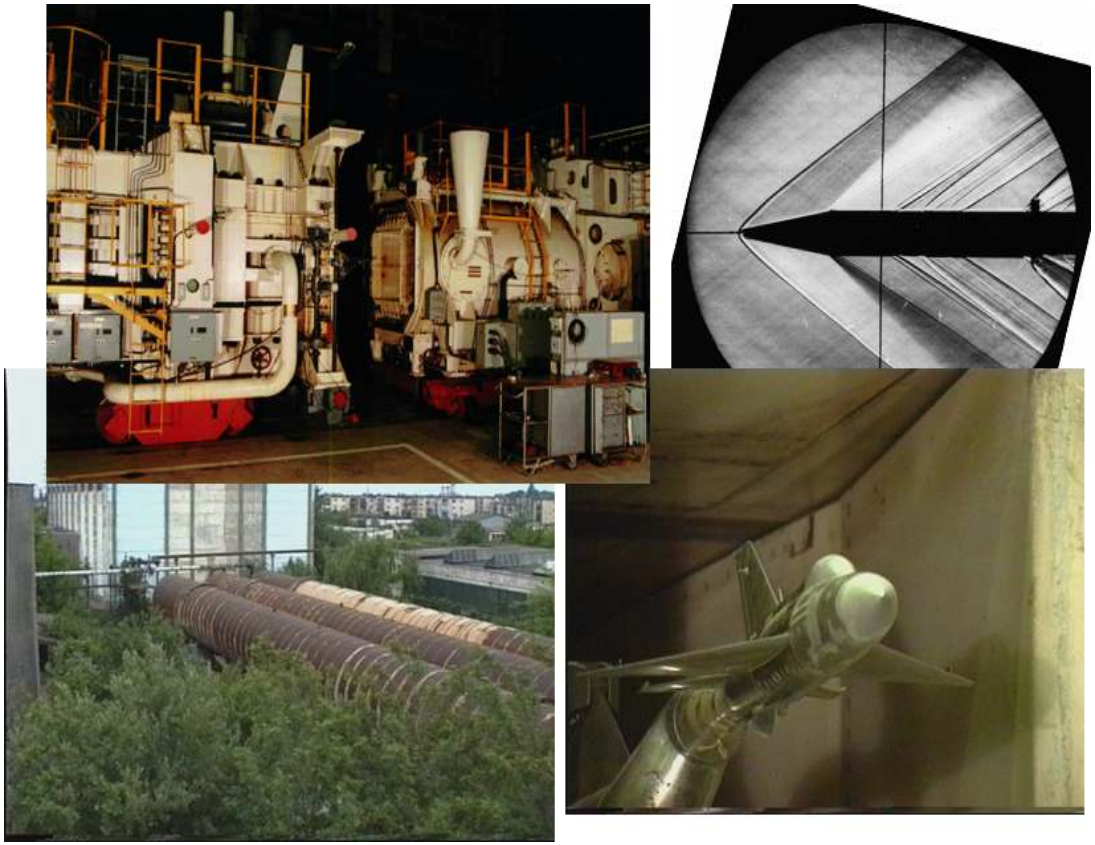
Supersonic Wind Tunnel

• blowdown type 1.2m x 1.2m test section
• Mach number capability : 0.1 … 3.5
• Reynolds number up to 100 millions

• Interchangeable porous transonic test section
• Variable porosity from 0.01% up to 9%
• Interchangeable complex 2D 0.8m x 1.2m test section

Equipment:

• Sting mounted, internal balance
• Side-wall, half model balance
• 800 mm schlieren system
• CTS system
• PIV under development.



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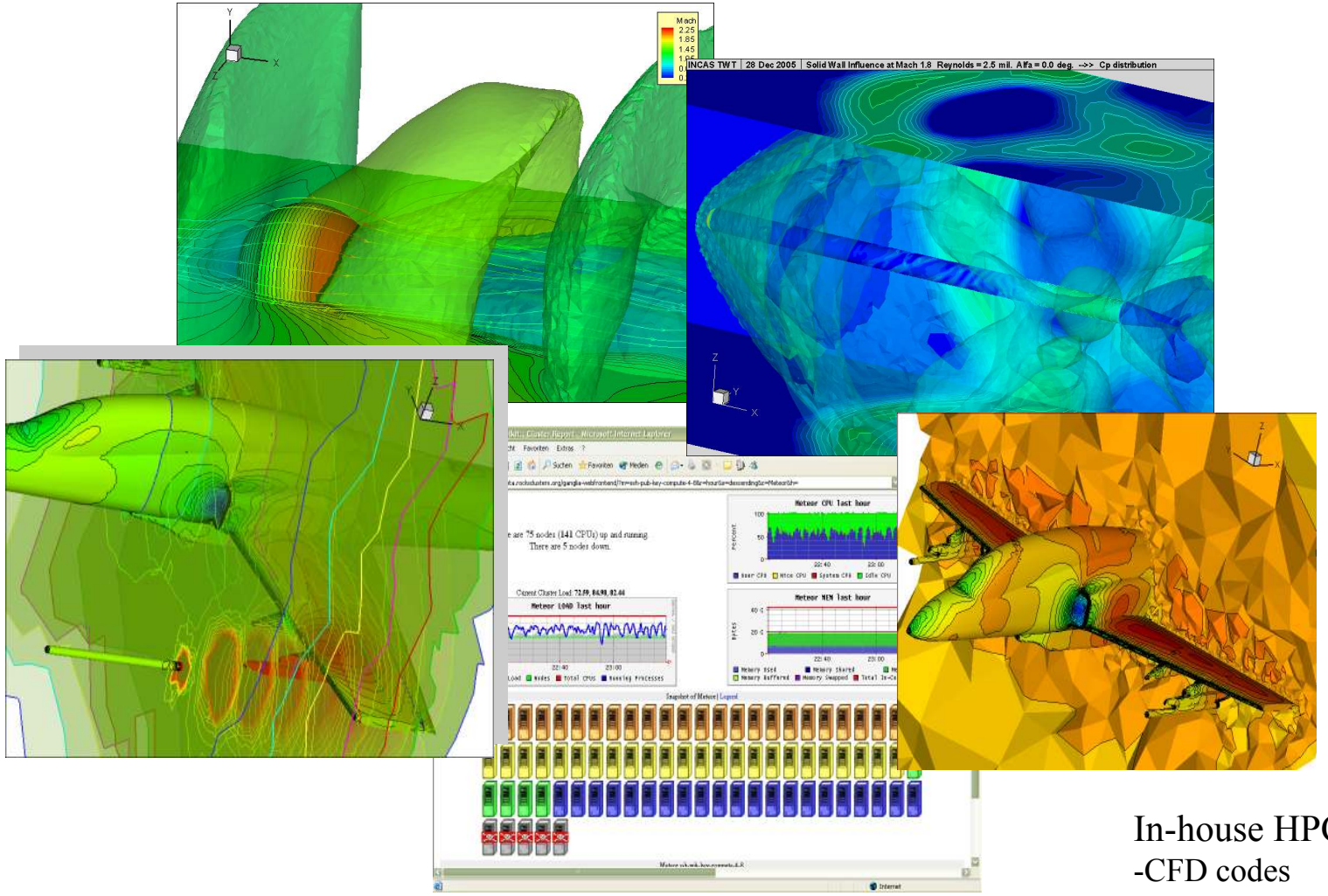
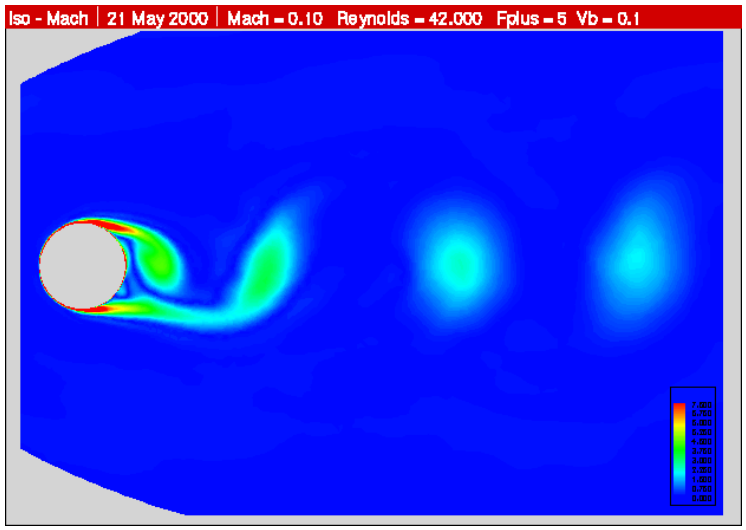
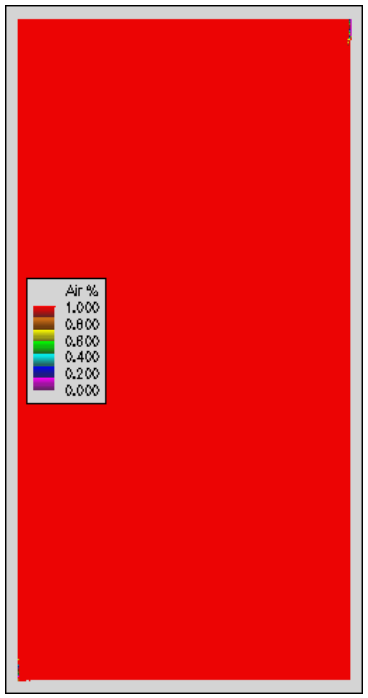
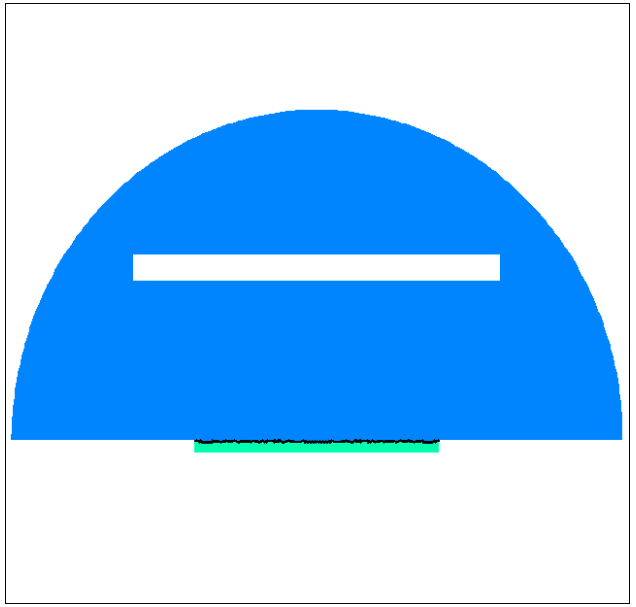


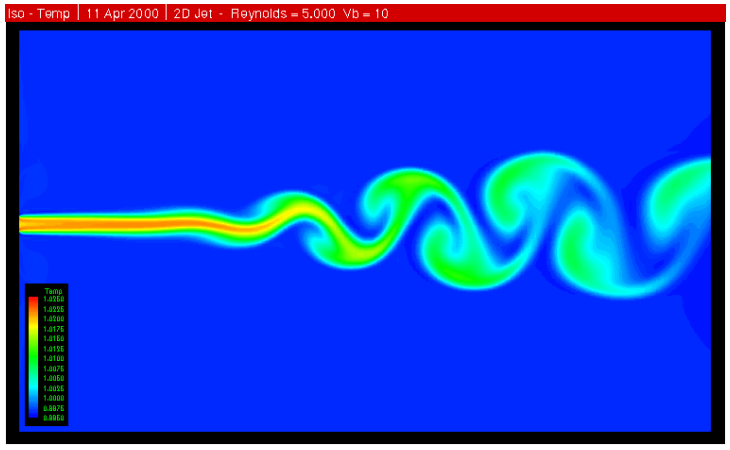
In-house HPC capabilities
-CFD codes
-Cluster computing (Grid)

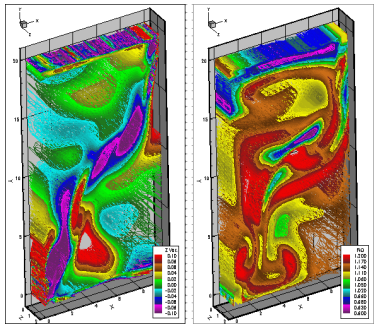
Some examples ….

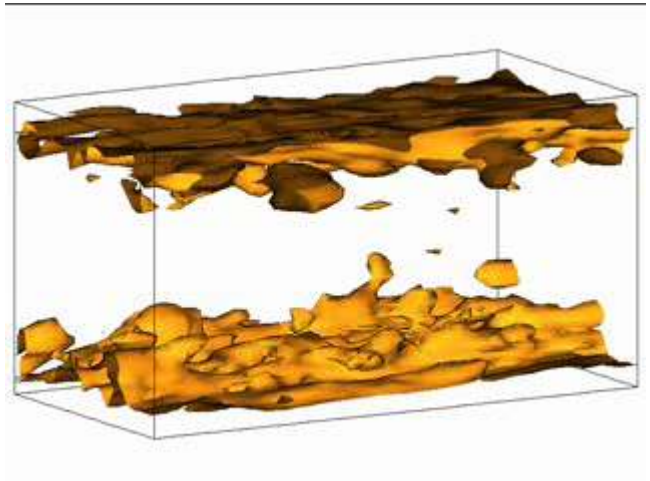




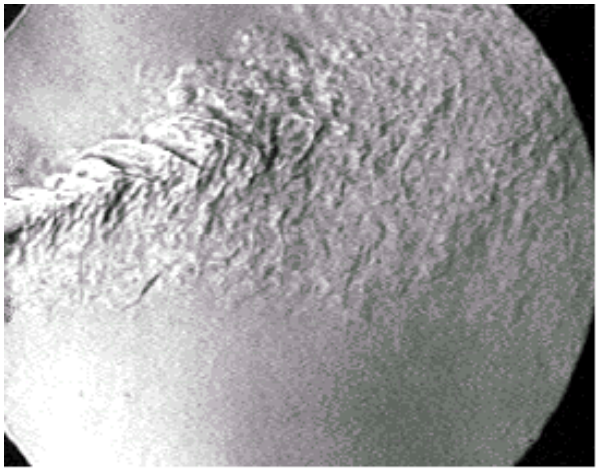


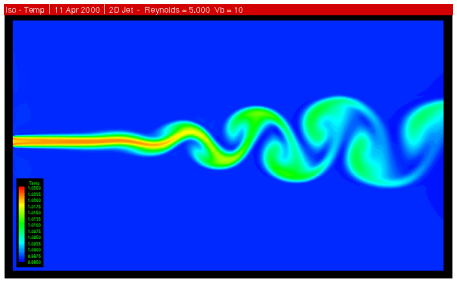


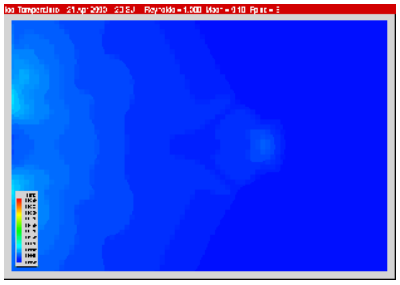


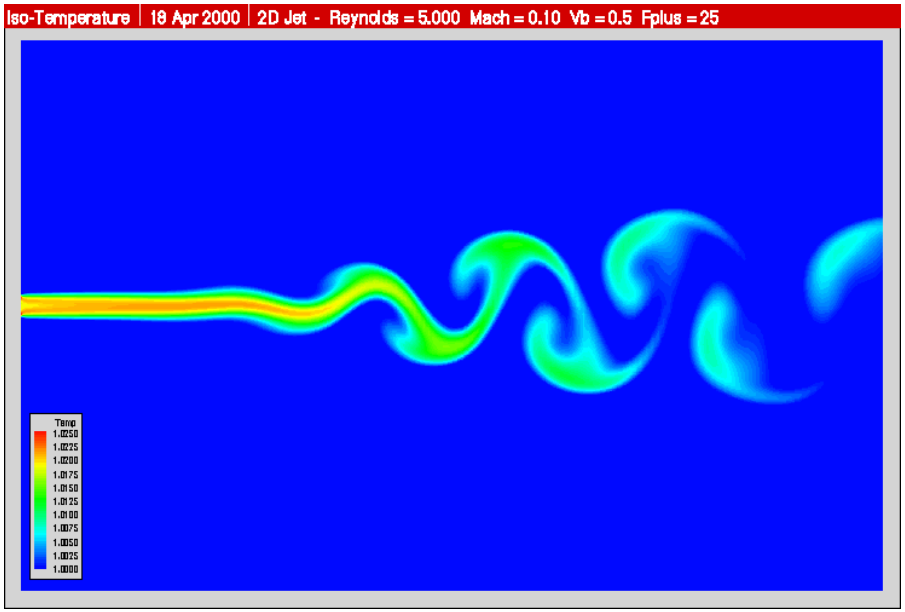


Fluidic interaction – jet vectoring







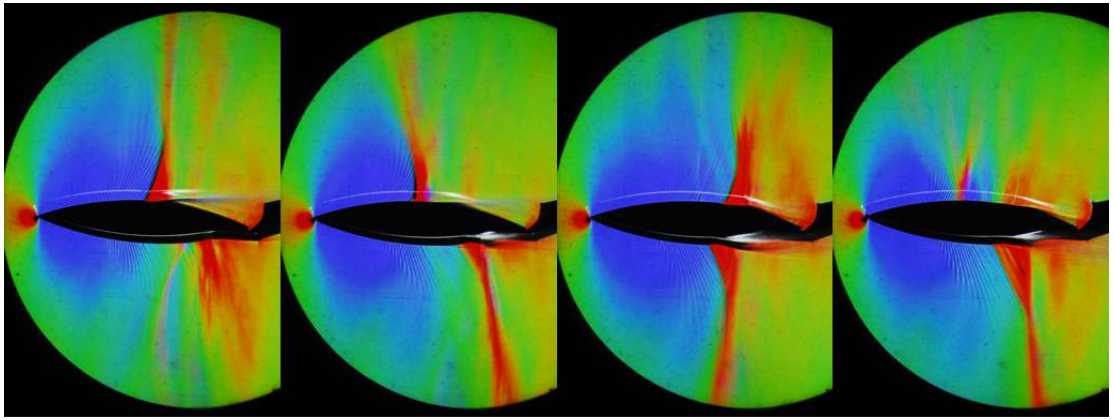


A buffeting experiment

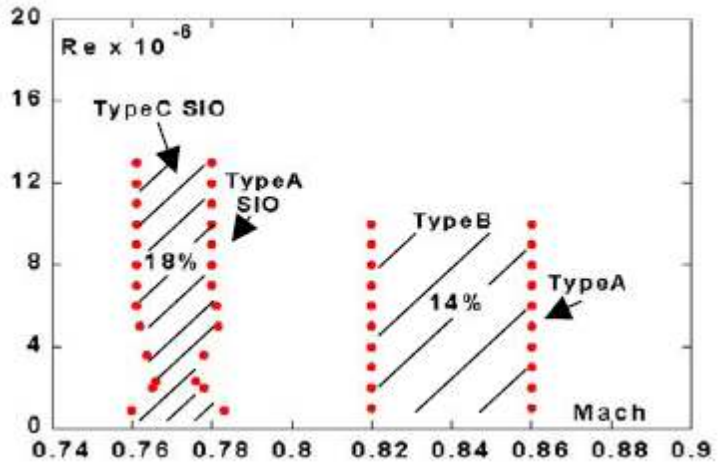
Mach 0.748, Reynolds 8 mil.

Mach 0.755, Reynolds 8 mil.

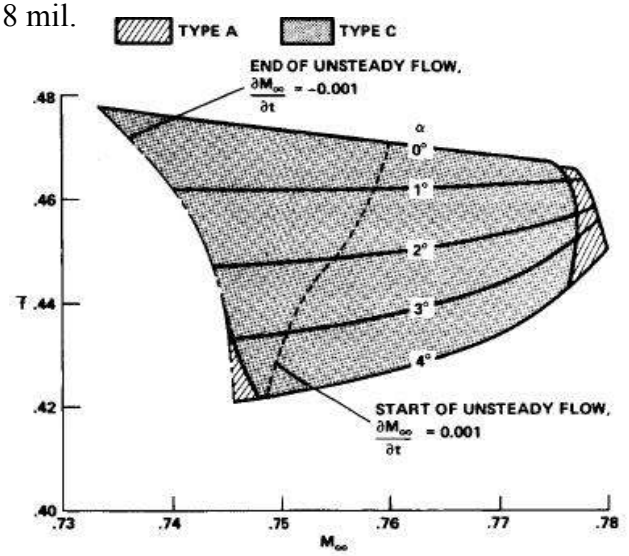
When do we get buffeting ? – exp.



Schlieren pictures for 18% biconvex, 1 deg., Mach 0.762, Reynolds 8 mil.



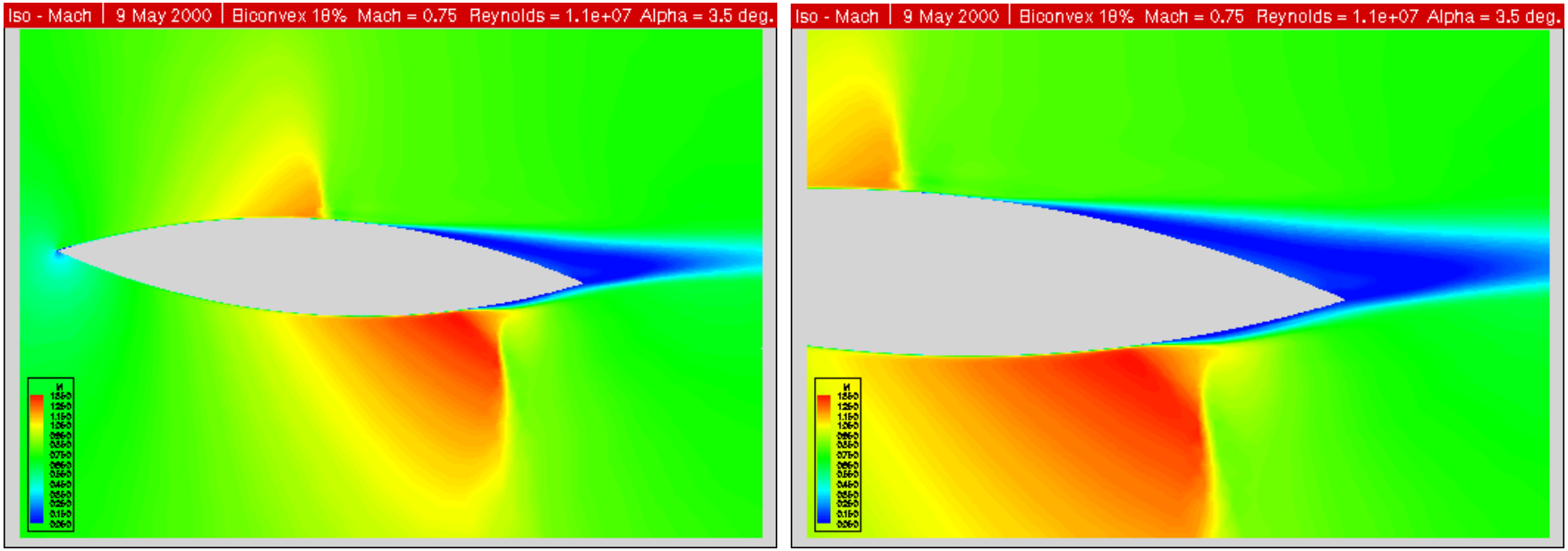
Regions of buffeting on biconvex 18% (McDevitt)



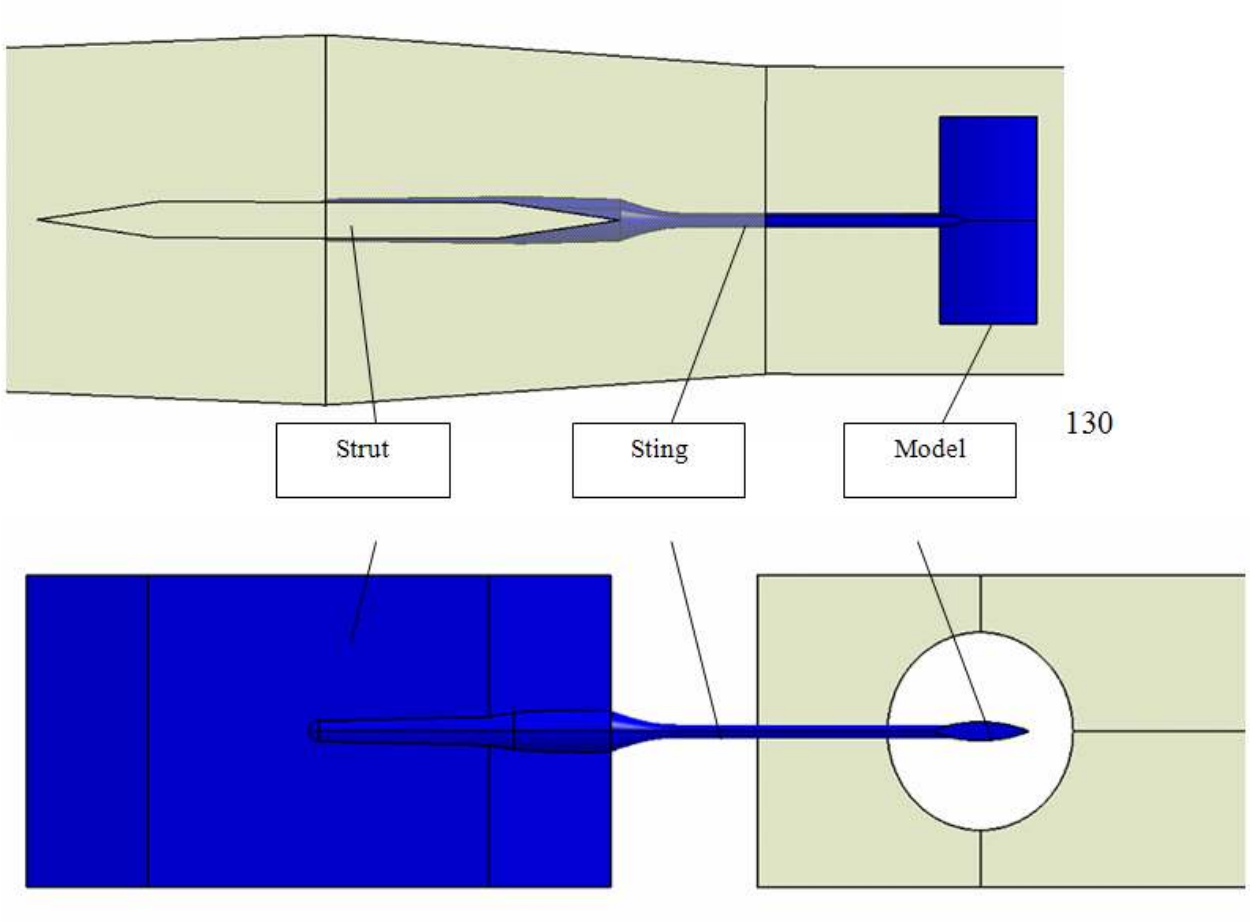
Buffeting frequency for biconvex 18% (Tijdeman)

When do we get buffeting ? – num.

Mach 0.75, Reynolds 11 mil., 3.5 deg



Design of buffeting experiment



$$c = 2 \cdot R \cdot \cos(\theta_0) = 400mm$$

$$b = \frac{h}{c} = 0.18$$

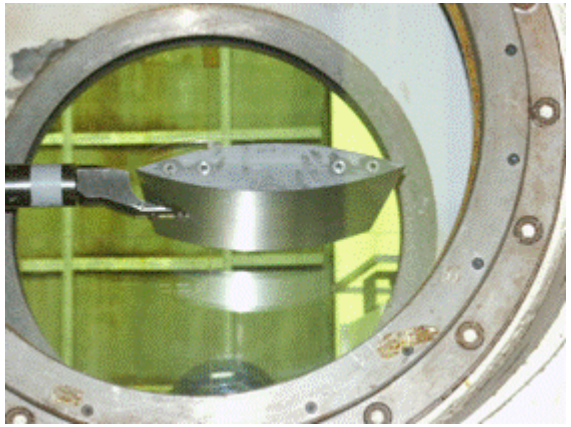
$$\theta_0 = 2 \cdot arctg\left(\frac{1-b}{1+b}\right) = 69.592^0$$

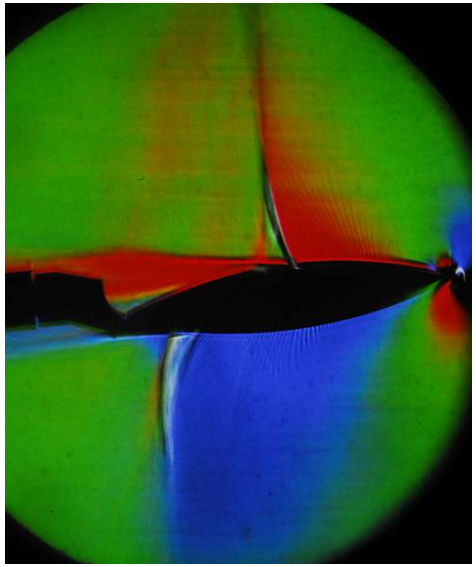
$$x = R \cdot \cos(\theta)$$

$$z = R \cdot (\sin(\theta) \pm \sin(\theta_0))$$

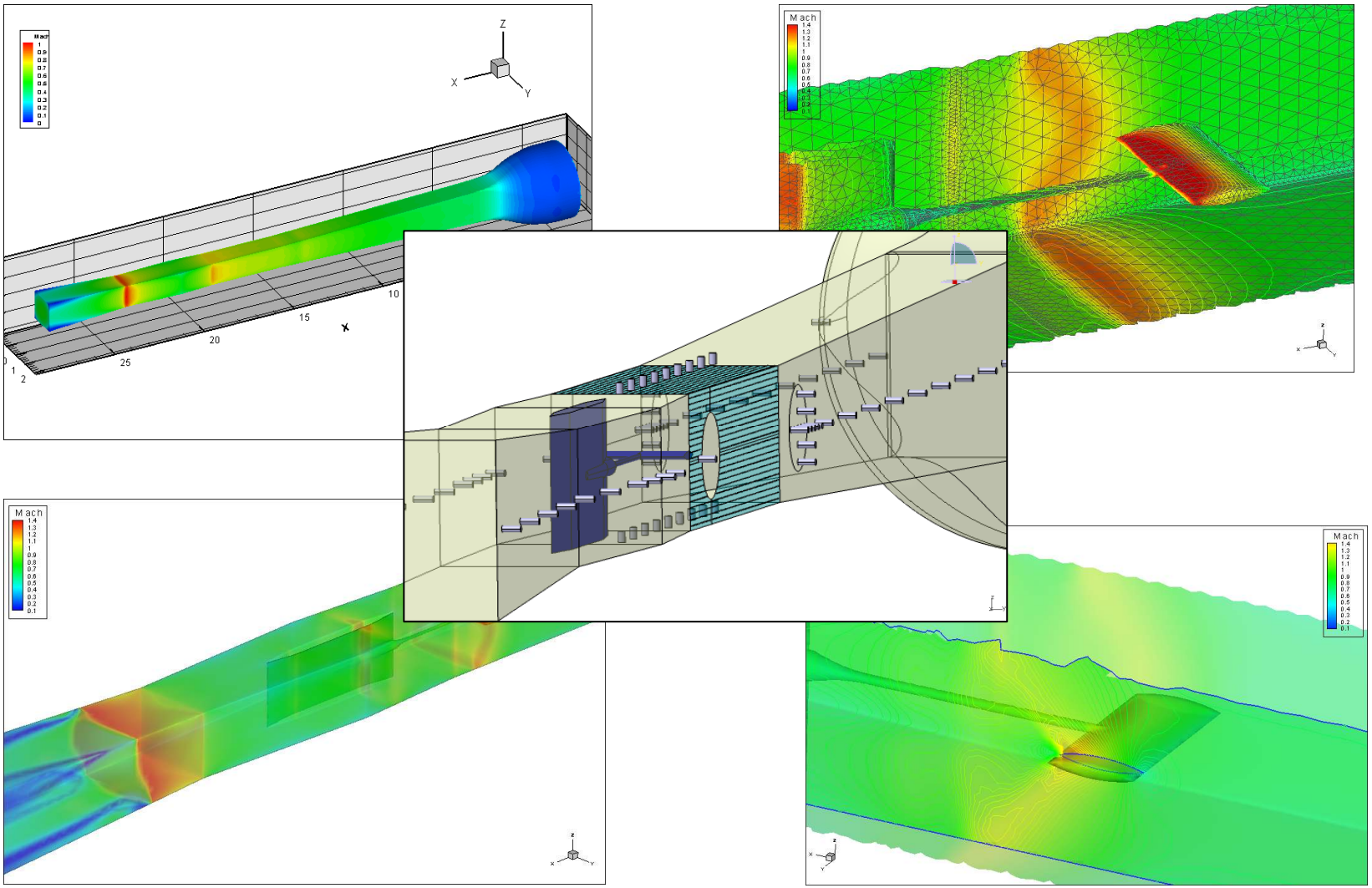
$$\theta \in [\theta_0, \pi - \theta_0]$$

The Buffeting Experiment

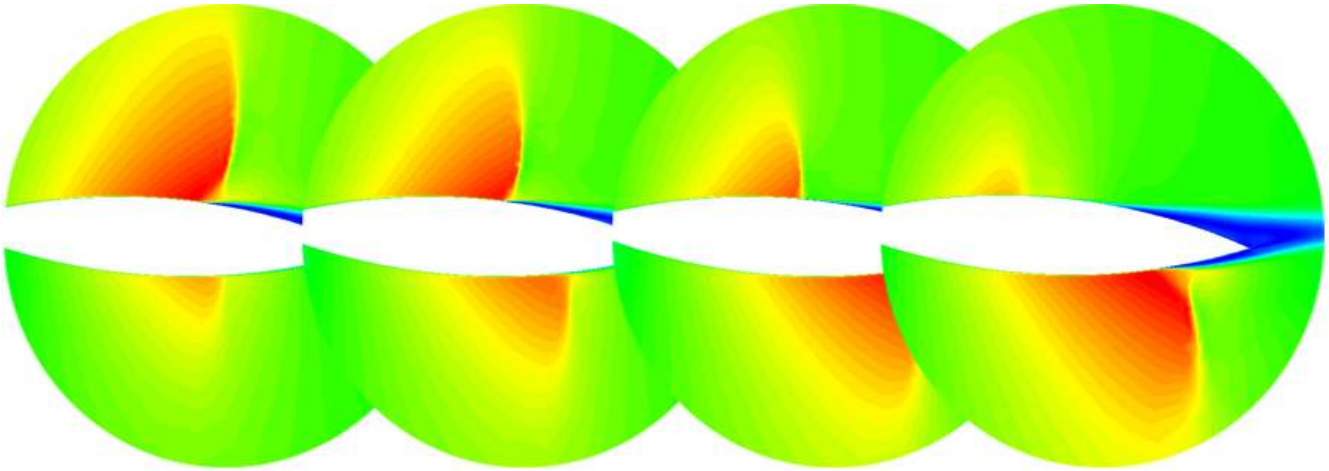




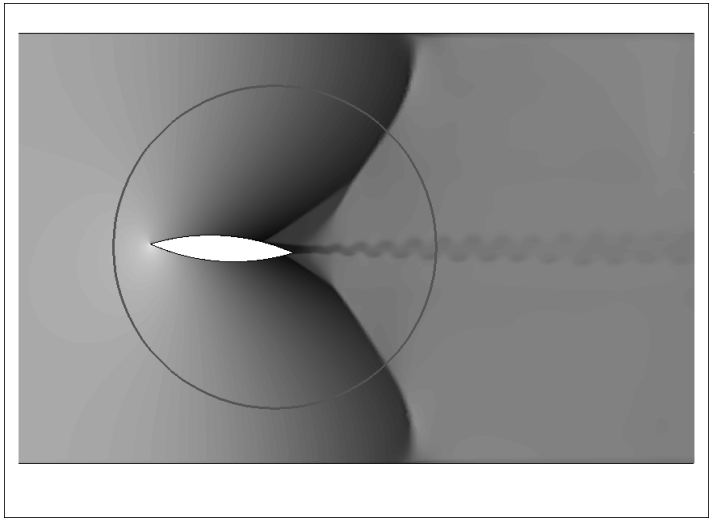
CFD Analysis – Global Flow Analysis



CFD Analysis …

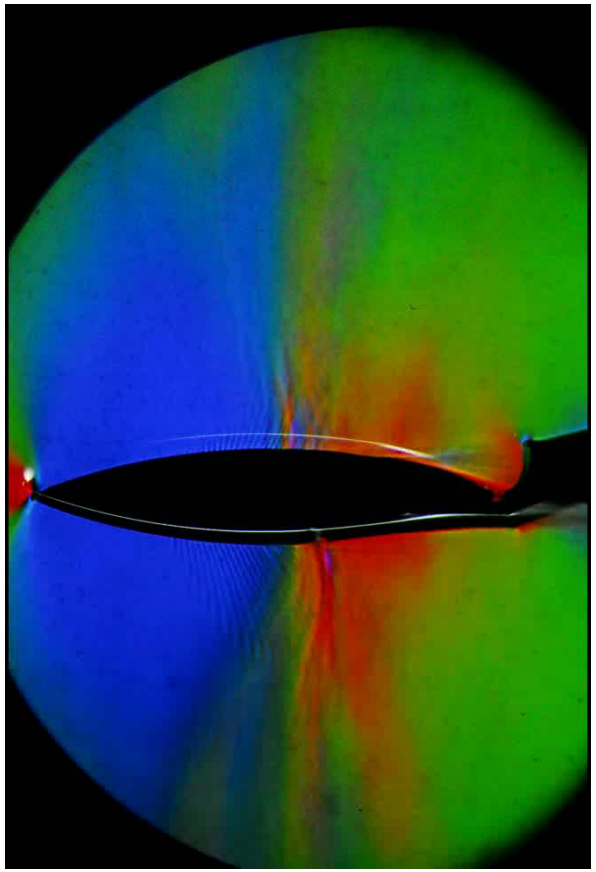


Mach = 0.76 Reynolds = 11 mil., 1 deg. (3D, 40%, URANS)



Mach = 0.79 Reynolds = 11 mil., 3.5 deg. (2D, URANS)

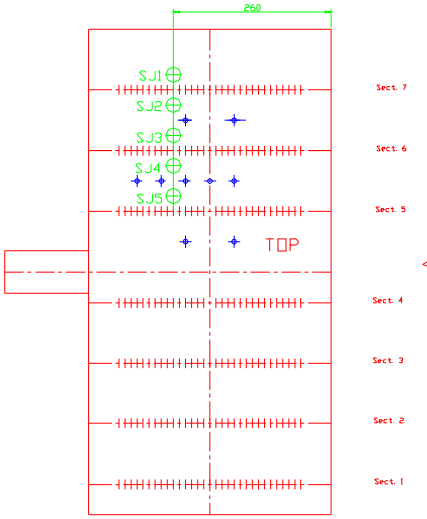
Experimental Activities - Overview



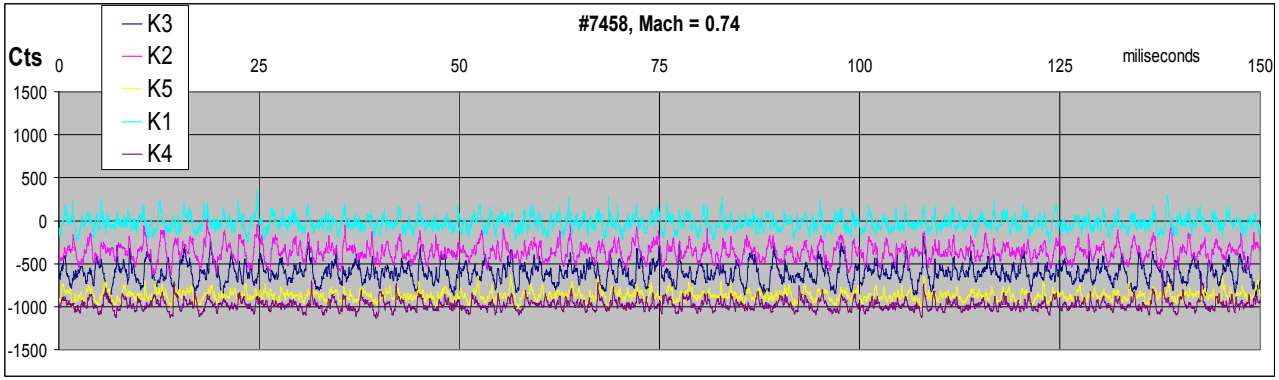
Mach 0.75 – step tests

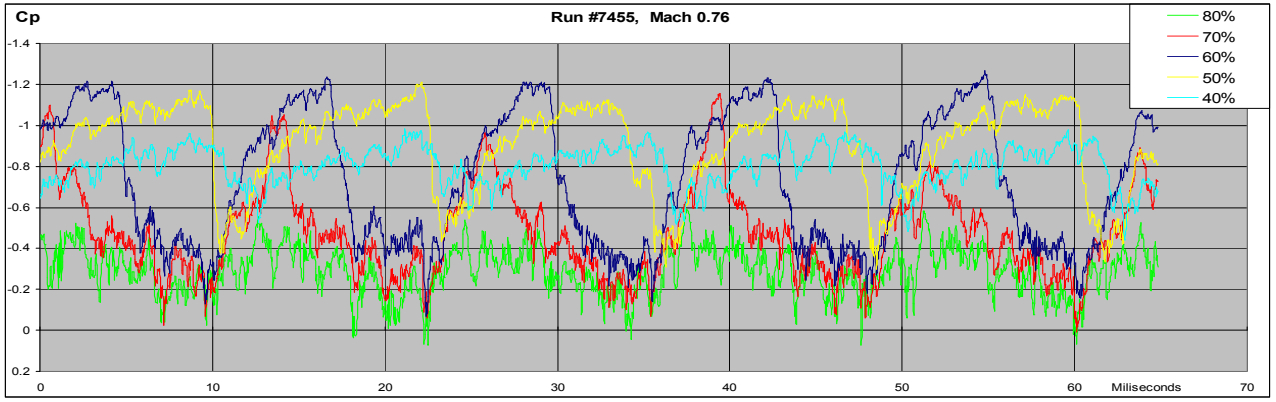
Mach 0.76, alpha = 2 deg.

Buffeting experiment w/o SJ control



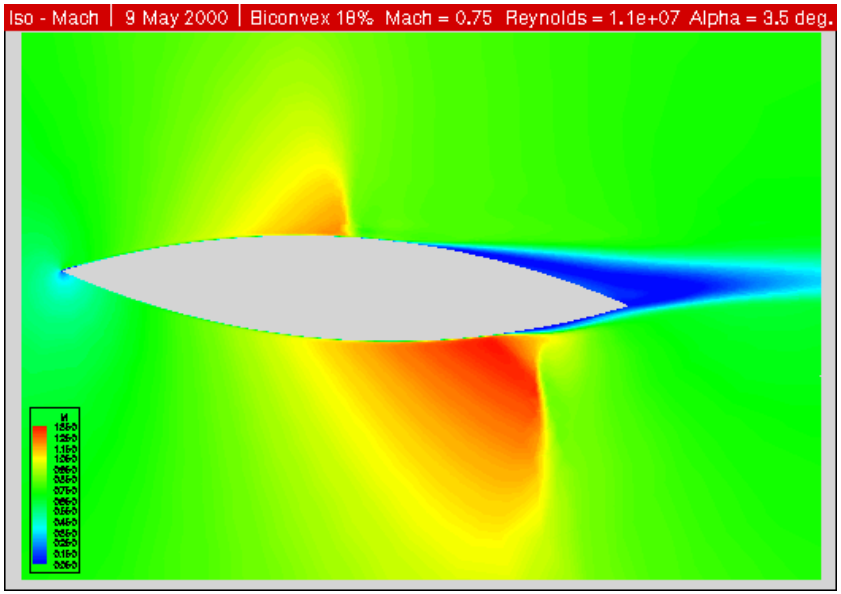
Model instrumentation

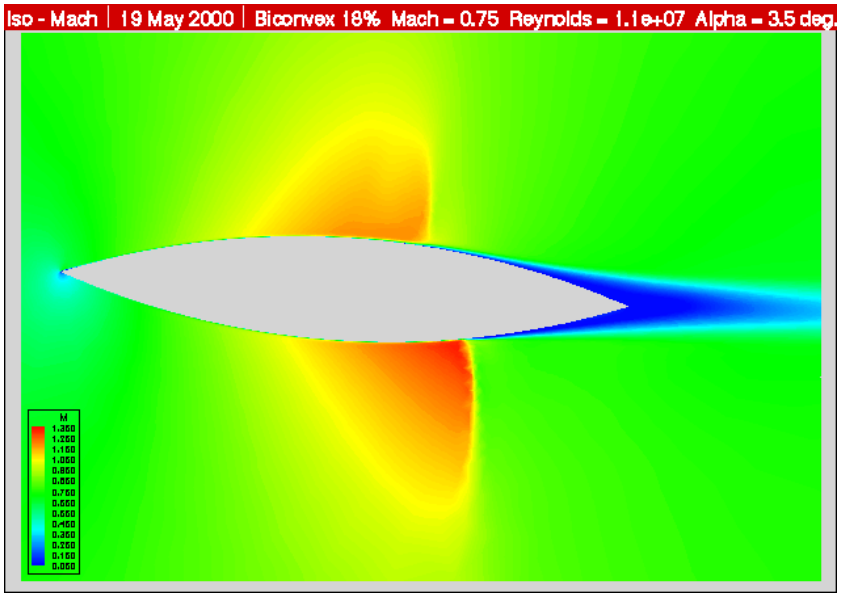




Basic experiment - Kulite readings

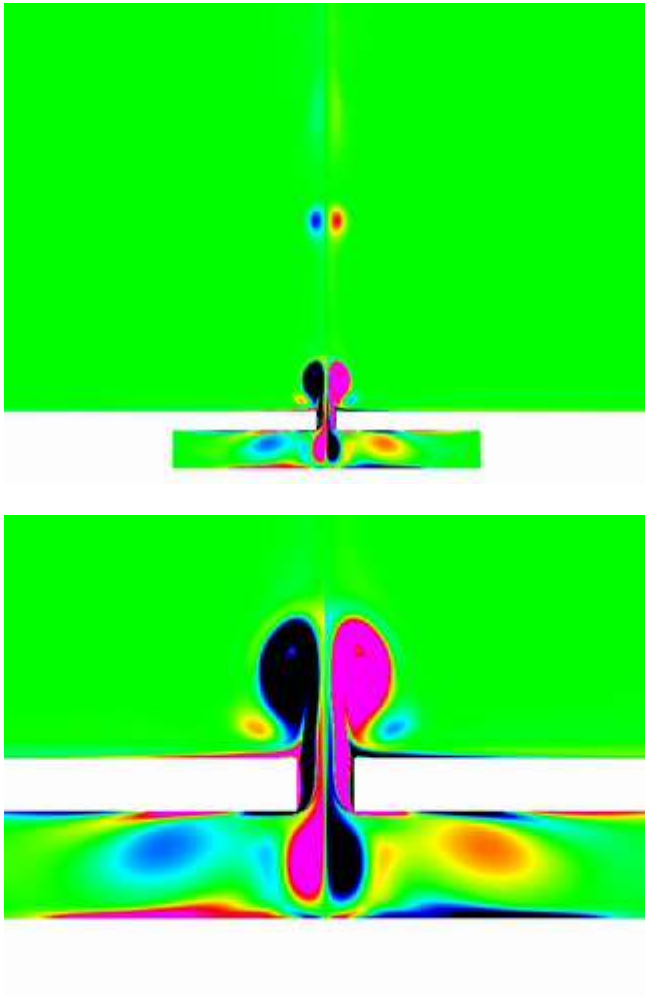
Active Flow Control using SJ

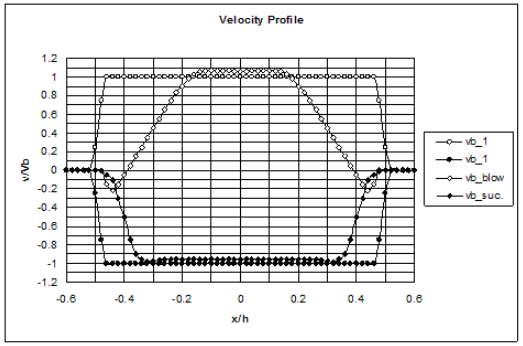


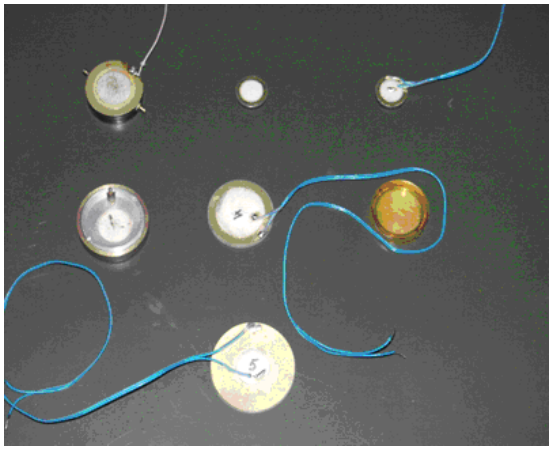


UFAST

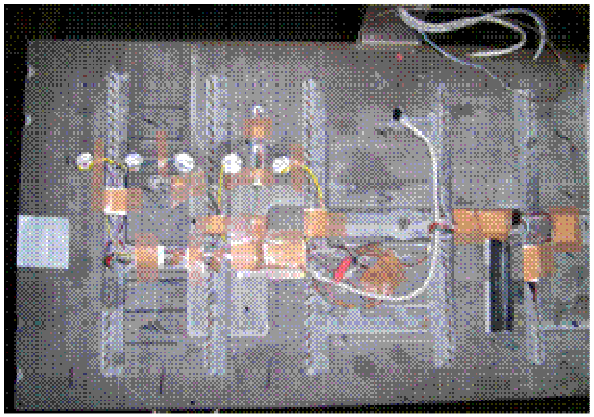
SJ actuator – design and CFD analysis

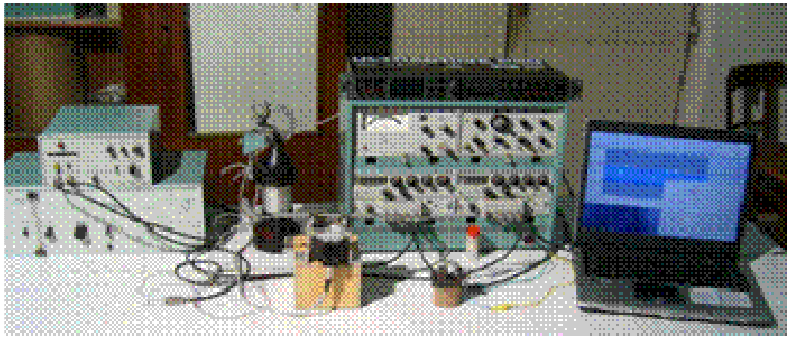


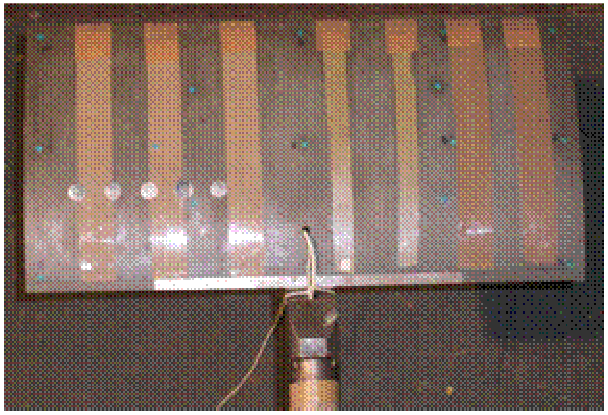


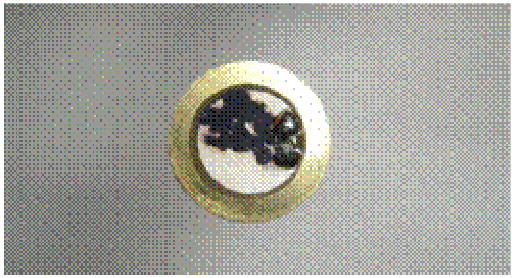


Model design & manufacturing – Phase 2









Damaged SJ diaphragm

Model with SJ controls

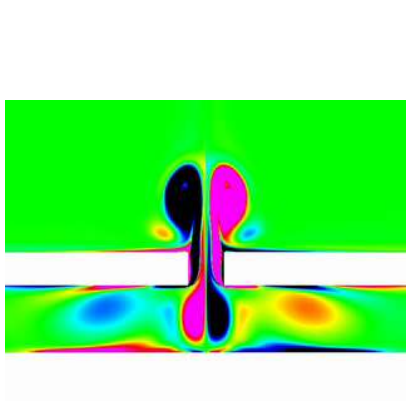
Testing the actuators – no flow

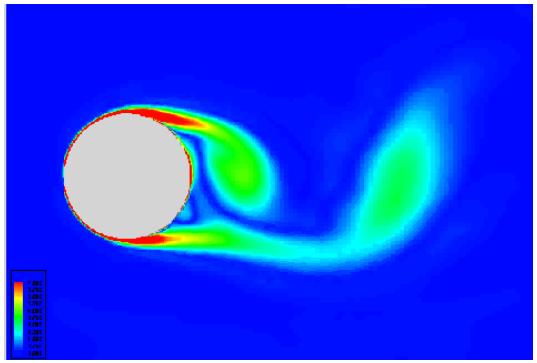
Buffeting alleviation using SJ

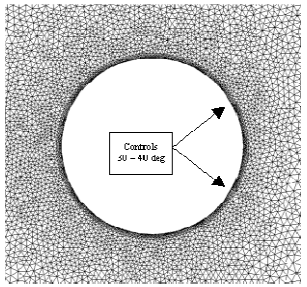
Basic motion, Mach 0.75

SJ control, Mach 0.75, $F^{+}= 8.5$

Active Flow Control using SJ







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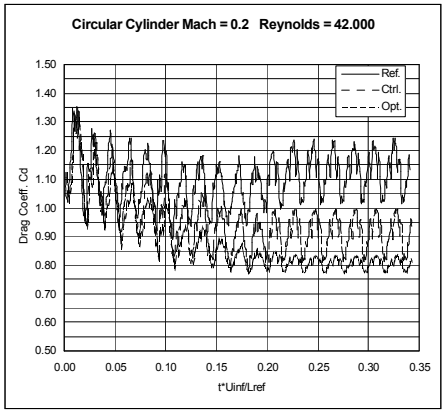
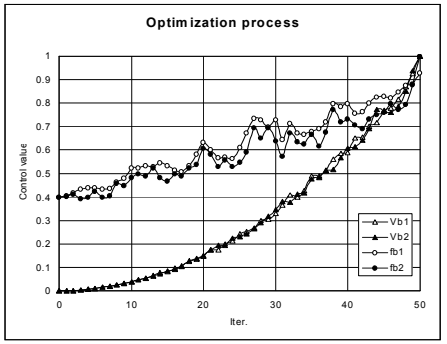
Cost Function
Control Laws
Optimization





$$C(\varphi,\zeta)=\min_{\varphi,\zeta} J(\varphi,\zeta)=\min_{\varphi,\zeta}\left(\frac{1}{n_T}\int_0^{n_T\cdot T} Cd\left(\varphi(t),\zeta(t)\right)\cdot dt\right)$$

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