IMP PAN

The Szewalski Institute of Fluid Flow Machinery

Polish Academy of Sciences

Department of Transonic Flows and Numerical Methods

Transonic Flows Dept. research tools

General research directions

Participation in European research projects

5FP
- **AITEB**

6FP
- **AITEB-2**
- **FLIRET**
- **TLC**
- **Coordination - UFAST**

7FP
- **ERICKA**
- **FACTOR**

Department of transonic flows and numerical methods

CFD tools:

In-house code **SPARC-** *parallel aerodynamic research code* , obtained from Karlsruhe University (dr. Magagnato)

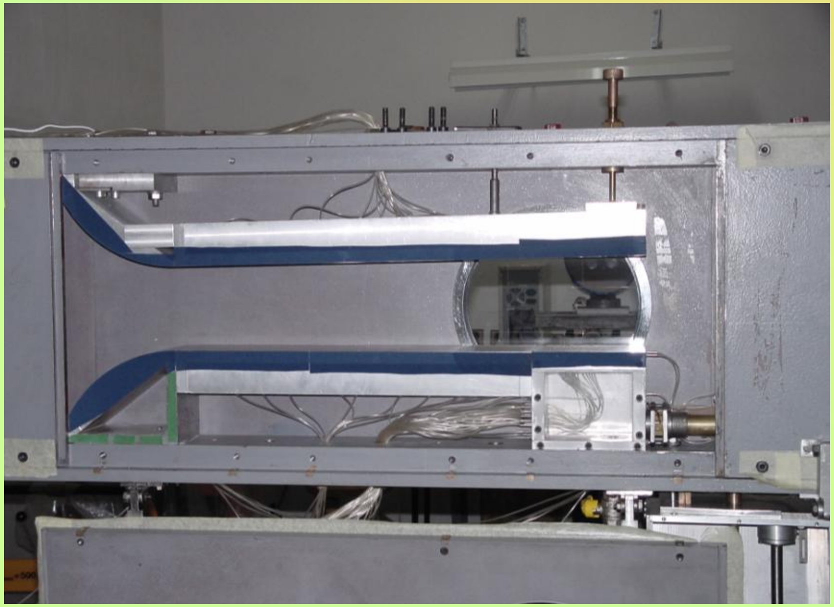
Fine-Turbo of Numeca from Brussels (prof. Ch. Hirsch)

FLUENT

FLOWer – aerodynamic code from DLR (German Aerospace Establishment) in Germany, Chimera meshing

Hardware:

Academic Computer Centre in Gdansk TASK,
INTEL tests HPC clusters in Swindon, UK



Experimental tools

Test Section: 1800mm × 350mm × 100mm
Vacuum Tanks: 120 m^3
Pump Unit: 2300 + 700 m^3/h
Evacuation time: 5, 20, 35 min
Blow down time (100mm × 100mm throat:)~20 sec.
Drying Unit: silica gel, layer of 1 m height 2.5 m diameter; 70 kW heating system (end temp. 150°C).

Measurement Equipment:

Pressure:
-digital barometer DRUCK,
-pressure transducers KULITE and DRUCK
-intelligent pressure scanners PSI System 9010, 4 × 16 channels,
-computer controlled pneumatic probe
- PSP Pressure Sensitive Paint

Optics:
-Schlieren system, SPECLE method
-Mach-Zehnder interferometer,
-CCD technology for picture registration
-PIV system of DANTEC.

Experimental tools

Methods under current implementation:

- Quantitative schlieren system – **SPECLE** method precise digital photography and post processing system – cooperation with prof. N. Fomin form Minsk

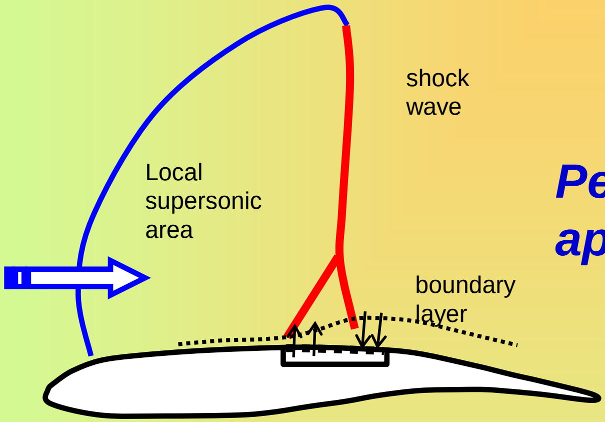
- Post-processing of the **interferograms** – elimination of optical errors in finite fringe mode– cooperation with prof. H. Babinsky in Cambridge University

- Pressure Sensitive Paint (**PSP**) – purchase of light source (ultra-violet) and CCD camera (16-bit light intensity), paint formula – cooperation with ONERA in Paris Yves Le'Sant and Marie-Claire Merienne

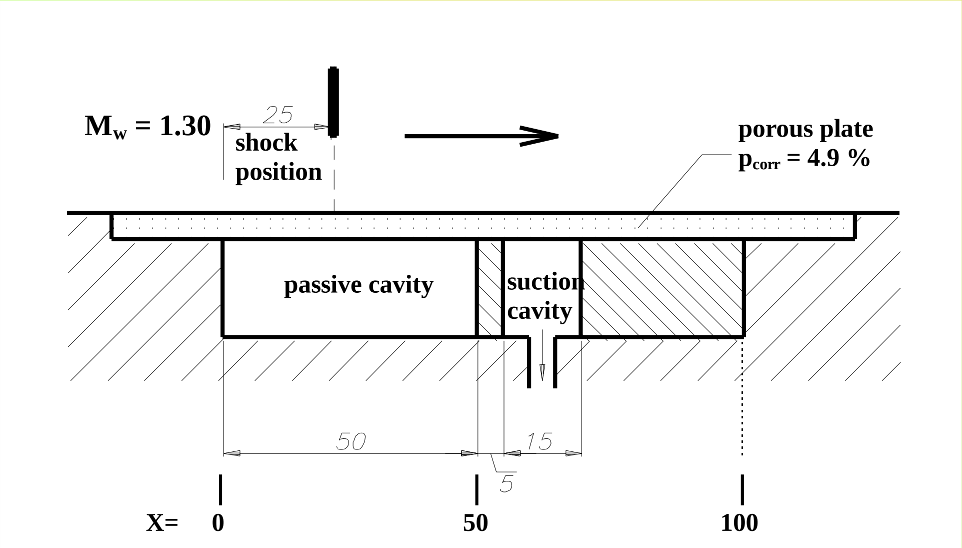
General research directions

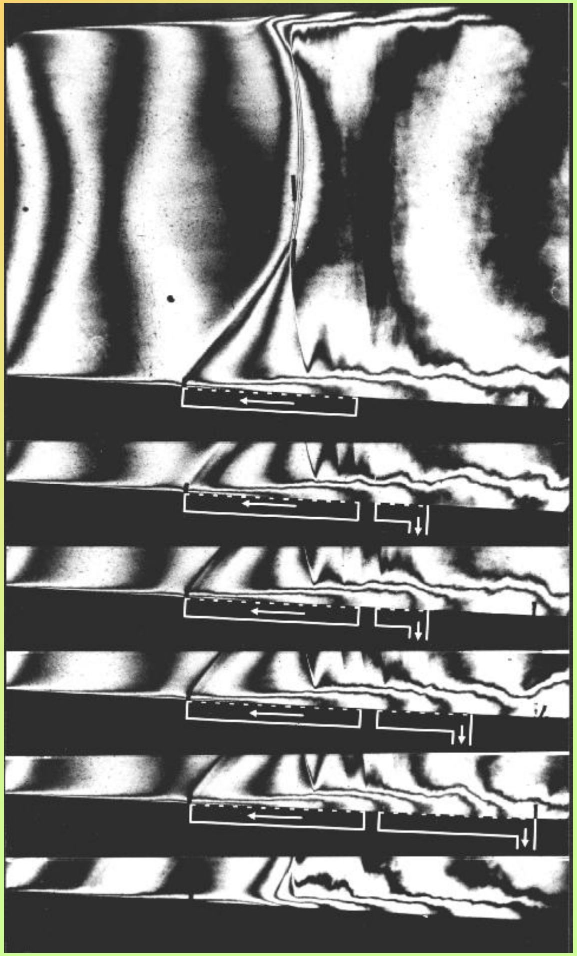
1) Shock wave – boundary layer interaction
2) Shock wave induced separation
3) Flow control methods counteracting separation **EUROSHOCK I / II**
4) Shock waves interaction (triple point)
5) Formation of asymmetric shock system in a nozzle
6) Secondary flows and vortical structures analysis
7) Air humidity effects on shock wave induced incipient separation
8) Condensation process – phenomenological models comparison with Molecular Dynamics, effect of inert gases presence
9) Lift enhancement methods **HELIX subcontractor**
10) Cooling of gas turbine blades and end walls **AITEB, AITEB-2**
11) Supports interference with model measurements in transonic wind tunnels **FLIRET**
12) Aerodynamic study of modern lean combustors **TLC**
13) Induction of asymmetric flow field by steam extraction in a turbine
14) Unsteady effects in shock wave induced separation **UFAST**
15) New projects in 7th FP **ERICKA** and **FACTOR**

4th FP 1994 – 1999 EUROSHOCK I and II (in Karlsruhe)



Perforated plate application

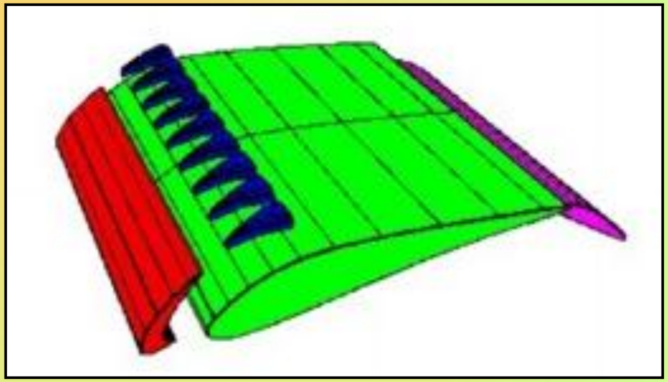




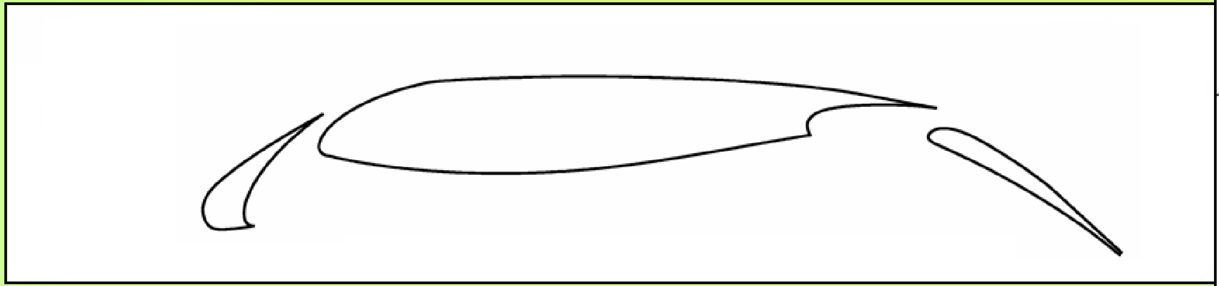
5th FP subcontract

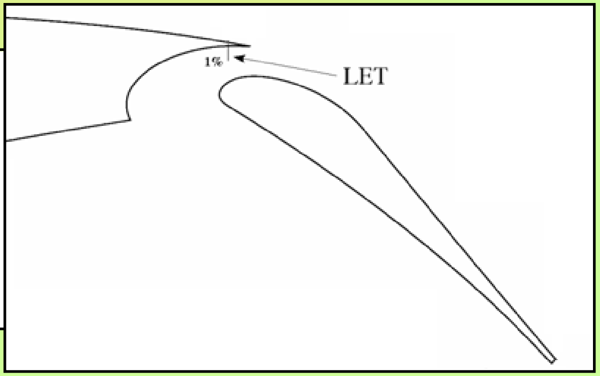
Lift enhancement methods

EU project **HELIX**

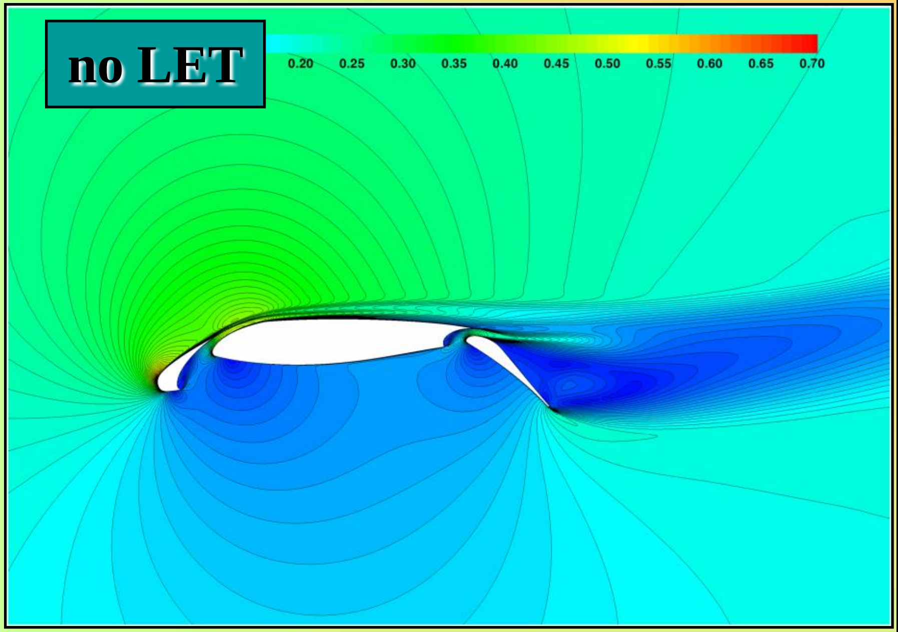


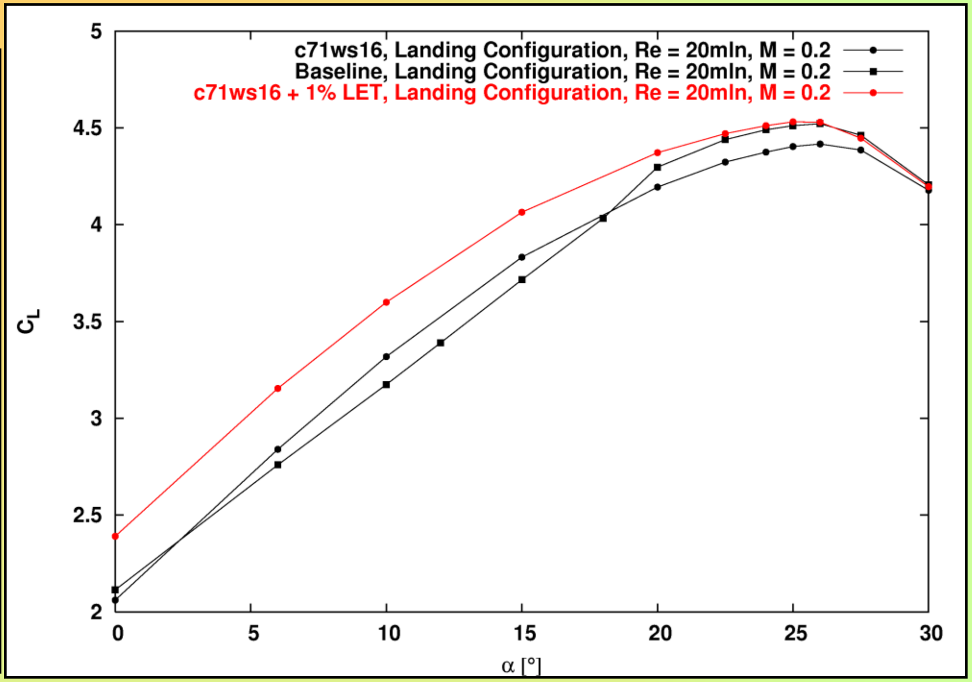
LET = Lift-Enhancing Tab

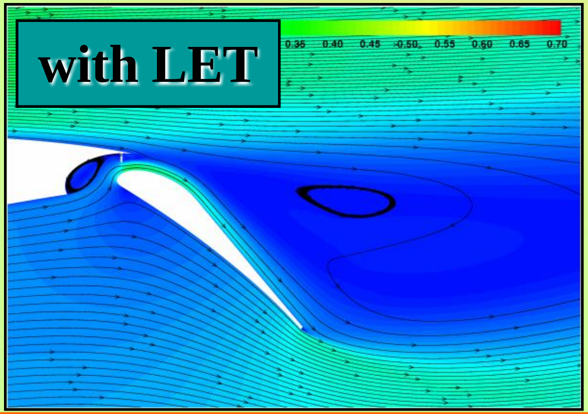


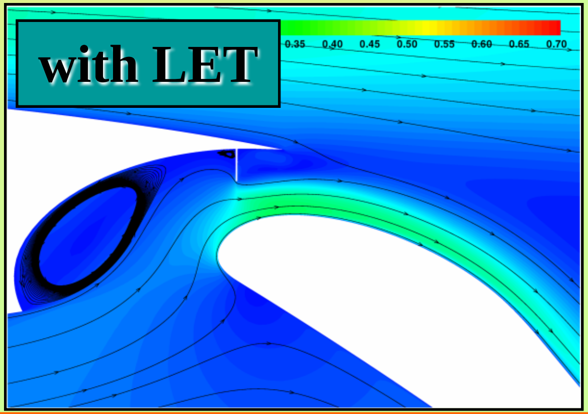


Lift enhancement methods









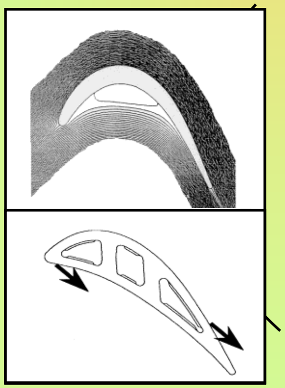
Cooling of gas turbines blades and end walls

Aerothermal **I**nvestigations on **T**urbine **E**ndwalls and **B**lades (**AITEB**)

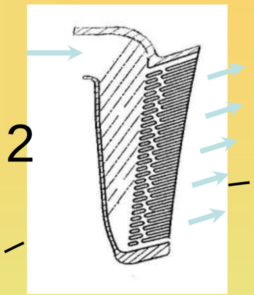
Co-ordinator: Frank Haselbach, Rolls-Royce-Deutschland

5th FP partner

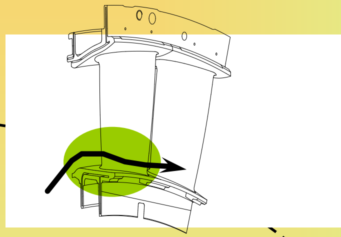
WP 1



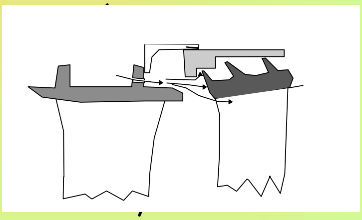
WP 2



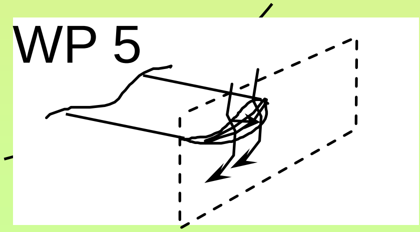
WP 3



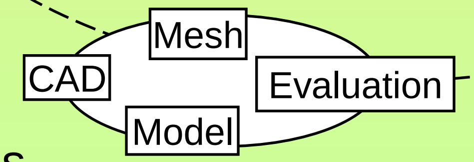
WP 4



WP 5



WP 6



CFD-Process

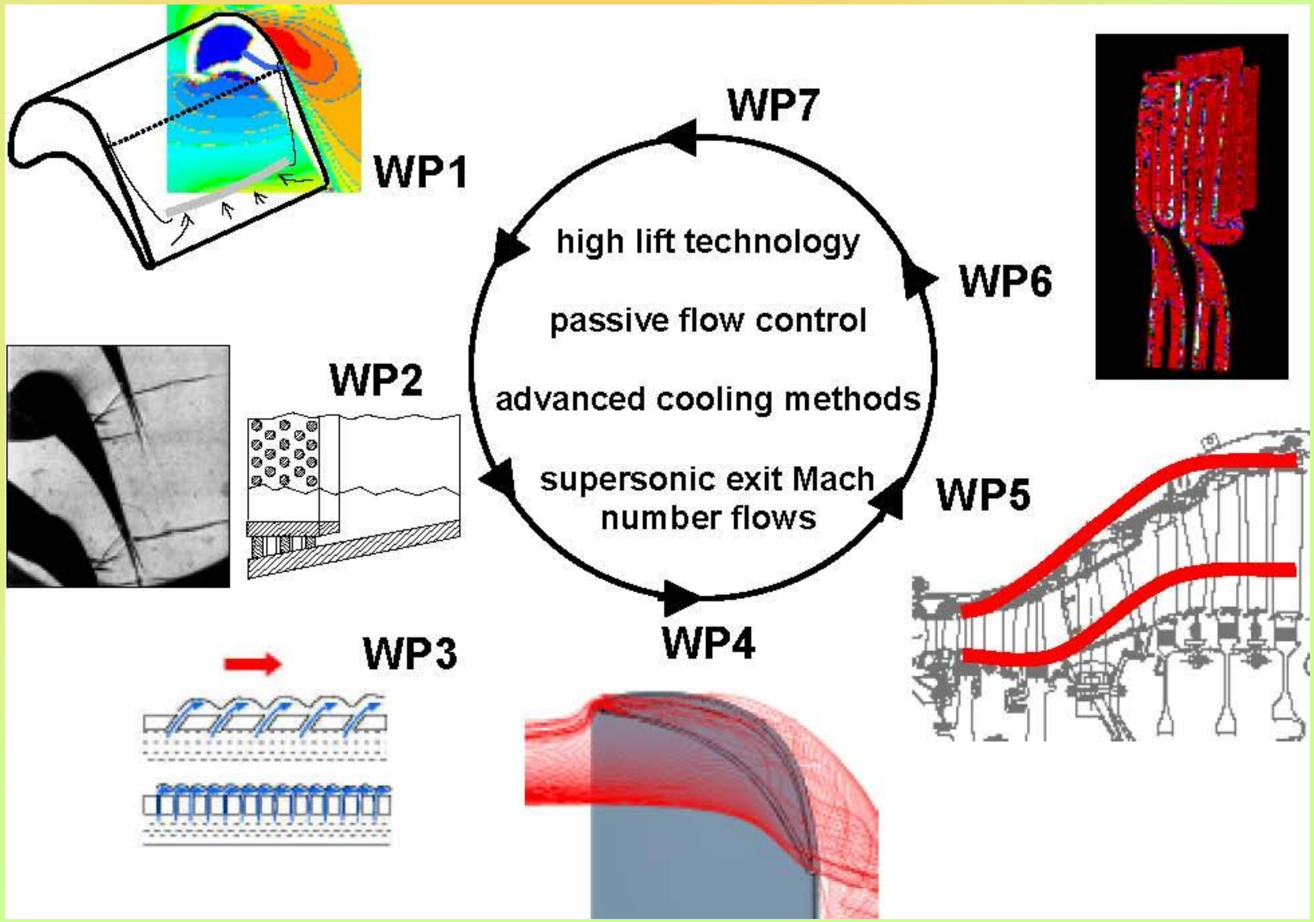
- improved cooling methods
- num. aerothermal design tools for 3D-Turbine Components

AITEB-2 Partners

1	Rolls-Royce Deutschland	RRD	D
2	Alstom Power	ALST	GB
3	Avio S.p.A.	AVIO	I
4	Siemens Ind. Turbomach.	SIEM	GB
5	MTU Aero Engines	MTU	D
6	Snecma Moteurs	SN	F
7	Turbomeca	TM	F
8	Volvo Aero	VAC	SE
9	German Aerospace Center	DLR	D
10	Von Karman Institute	VKI	BE
11	Cambridge Flow Solutions	CFS	GB
12	**Polish Academy of Science**	**IMP**	**PL**
13	University of Cambridge	UCAM	GB
14	University of Karlsruhe	ITS	D
15	University of Florence	DEF	I
16	Chalmers Univ. of Techn.	CHD	SE
17	University of German Armed Forces	UNIBW	D

Cooling of gas turbines blades and end walls

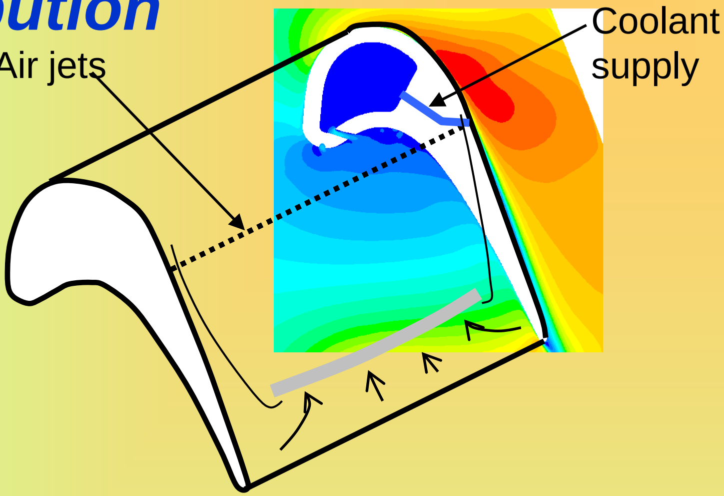
AITEB-2



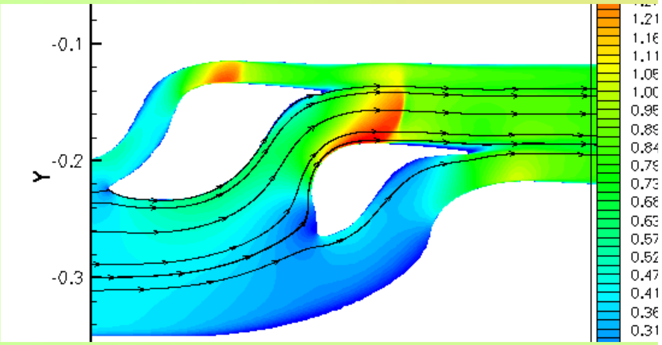
IMP contribution

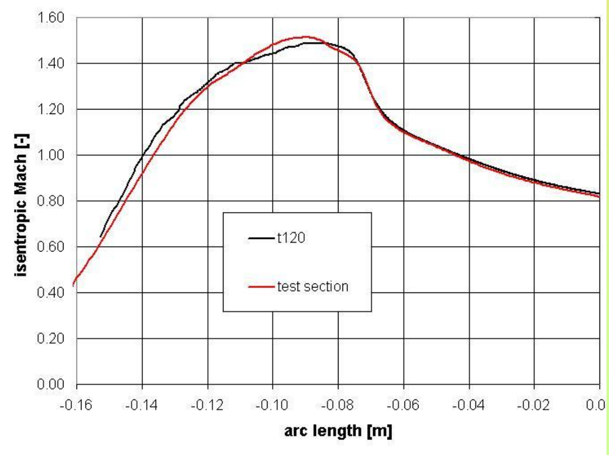
AITEB-2

WP-1



Test section proposed for the basic study



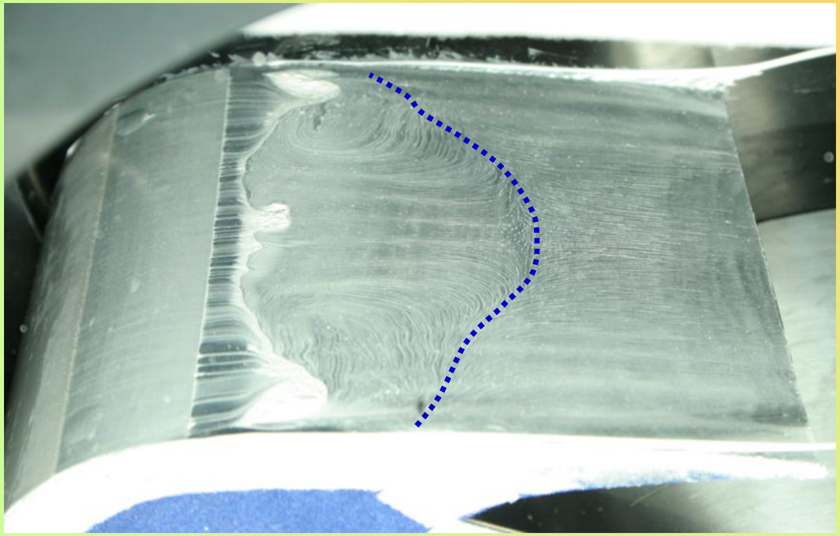


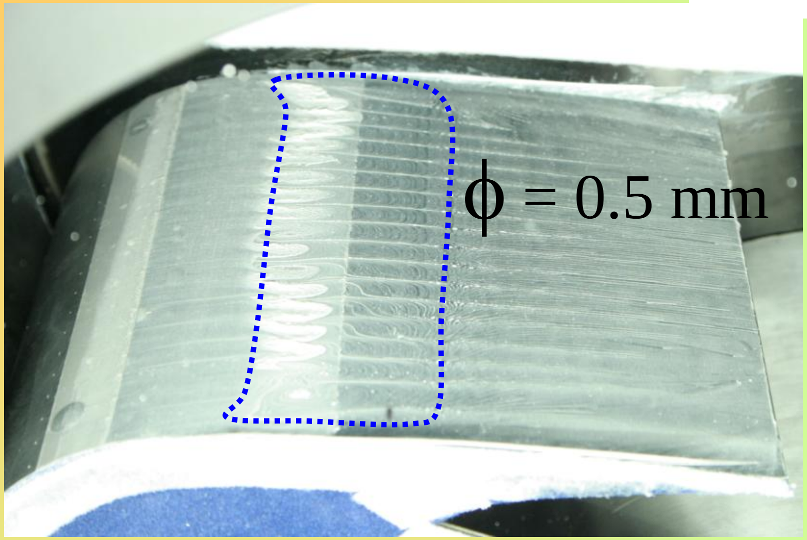
WP3 Effusive cooling

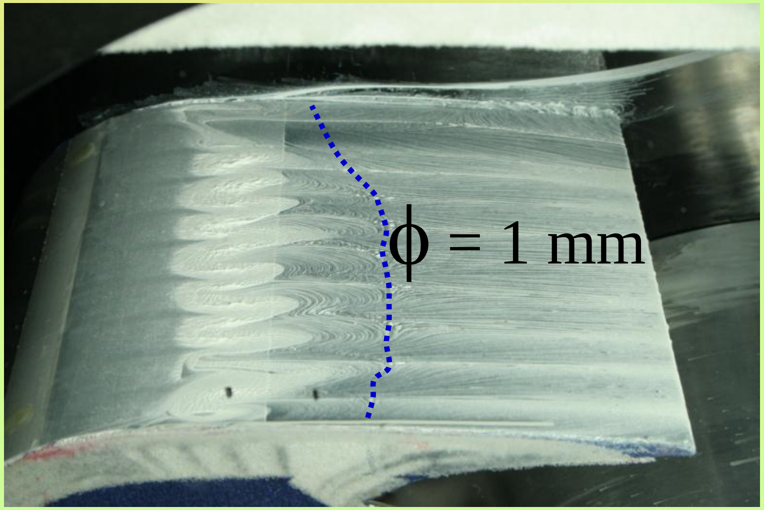
Micro-holes d=0.05 mm

- Is micro-flow modelling important?
- Transpiration flow model
- Holes stopping problem?
- Experiment

reference







FLIRET

Flight Reynolds Number Testing

1	Airbus Deutschland	A-D	D
2	Airbus France	A-F	F
3	Airbus United Kingdom	A-UK	UK
4	Airbus España	A-E	ES
5	ARA Ltd	ARA	UK
6	Dassault-Aviation	Dass	F
7	DEHARDE	DHD	D
8	DLR	DLR	D
9	ETW	ETW	D
10	Ing.büro Kretzschmar	IBK	D
11	ONERA	Onera	F
12	TsAGI	TsAGI	RU
13	Helsinki Univ. of Techn.	HUT	FIN
14	**IMP - PAN**	**IMP**	**PL**
15	TU Berlin	TUB	D
16	Univ. Stuttgart -IAG	IAG	D

Supports interference with model measurements in transonic wind tunnels

WP 1 is dedicated to supports for complete wind tunnel models (high speed).

WP 2 considers the main unsteady effects which play a major role in cryogenic testing: buffet onset and model vibrations (high speed).

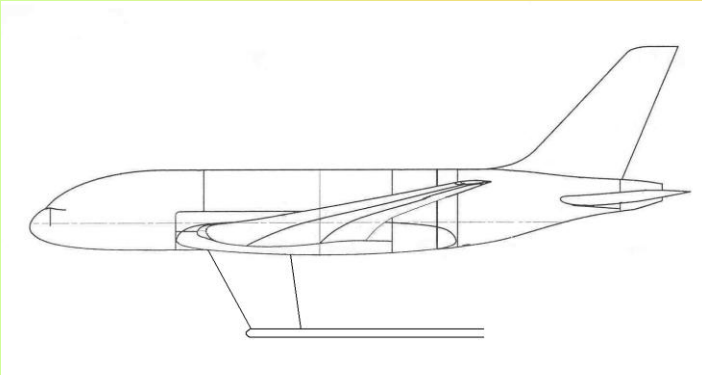
WP 3 deals with half models for high lift configurations (low speed).

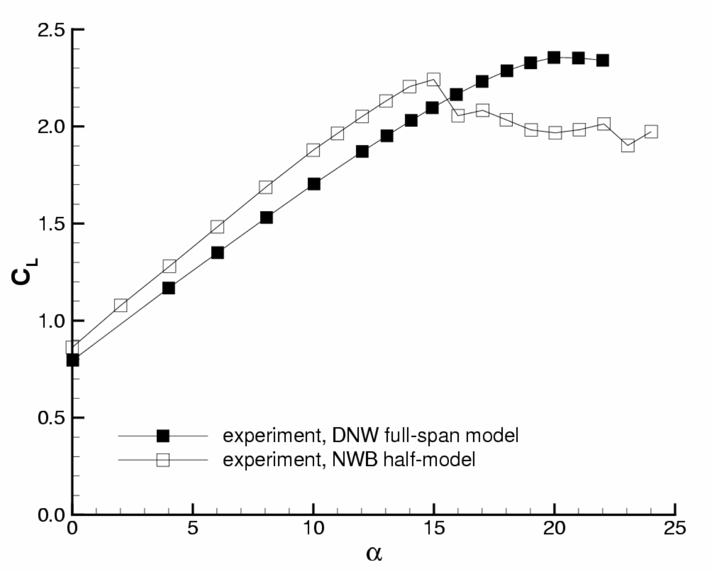
WP 4 provides the integration which is split into CFD, models, testing and recommendations for the future.

IMP PAN contribution

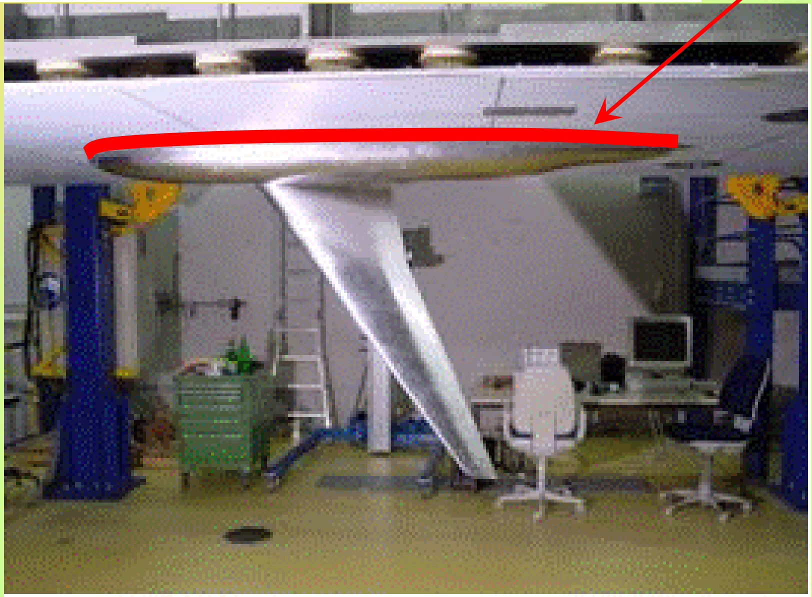
BLADE STING

Rear end measurements
MODEL I





penisch

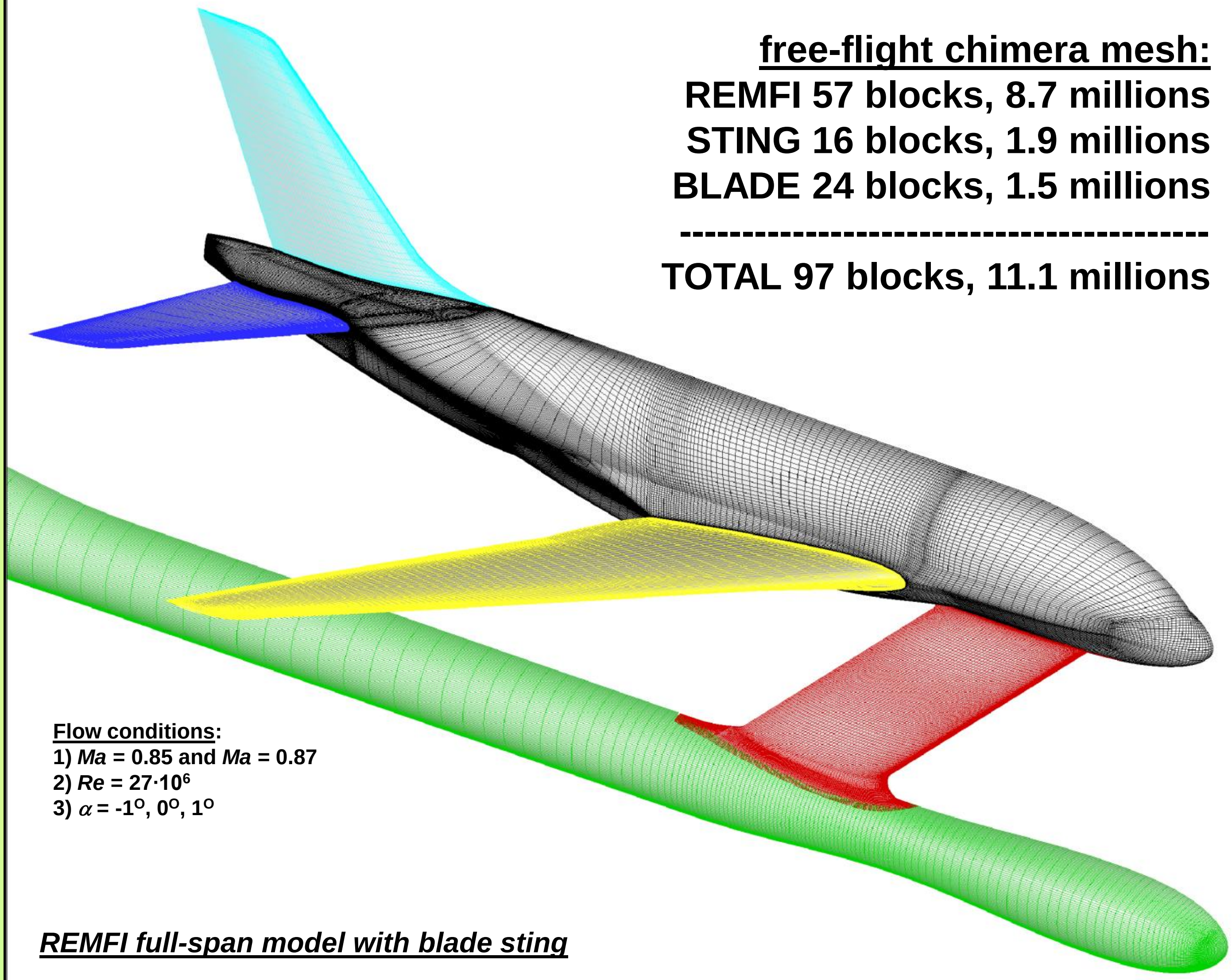


CFD analysis:

FLOWer code from DLR

Chimera mesh techniques

free-flight chimera mesh:
REMFI 57 blocks, 8.7 millions
STING 16 blocks, 1.9 millions
BLADE 24 blocks, 1.5 millions
--
TOTAL 97 blocks, 11.1 millions



Flow conditions:
1) *Ma* = 0.85 and *Ma* = 0.87
2) *Re* = $27 \cdot 10^6$
3) $\alpha = -1^{\circ}, 0^{\circ}, 1^{\circ}$

REMFI full-span model with blade sting

TLC - *Towards Lean Combustion*

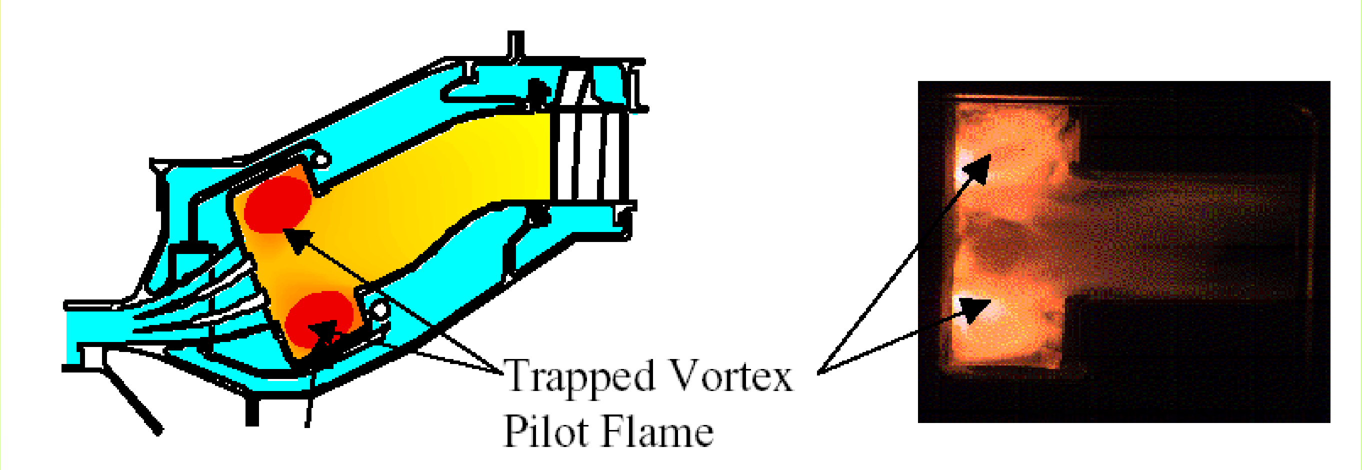
Coordination - SNECMA

The subject of TLC focuses on low-emission combustion of liquid fuel in aircraft engine combustors.

Many specific difficulties have to be solved from the physical point of view (auto-ignition, flashback, instabilities, lean extinction limit).

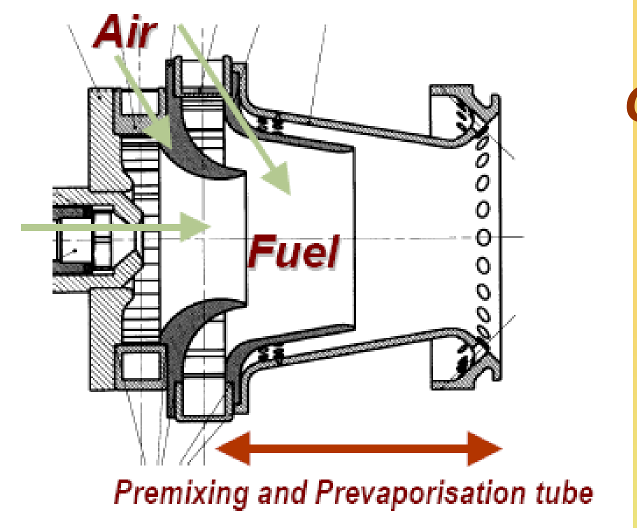
Trapped Vortex Combustor

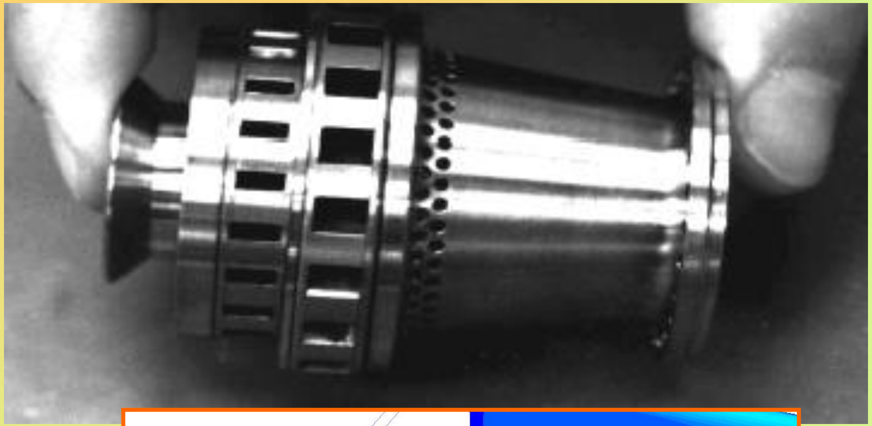
Contribution of IMP PAN:

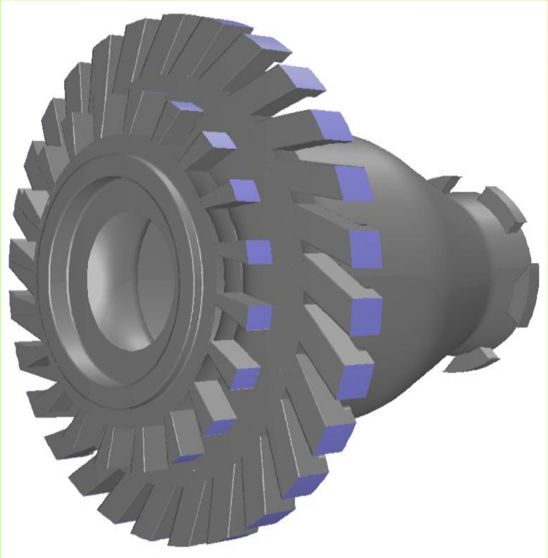


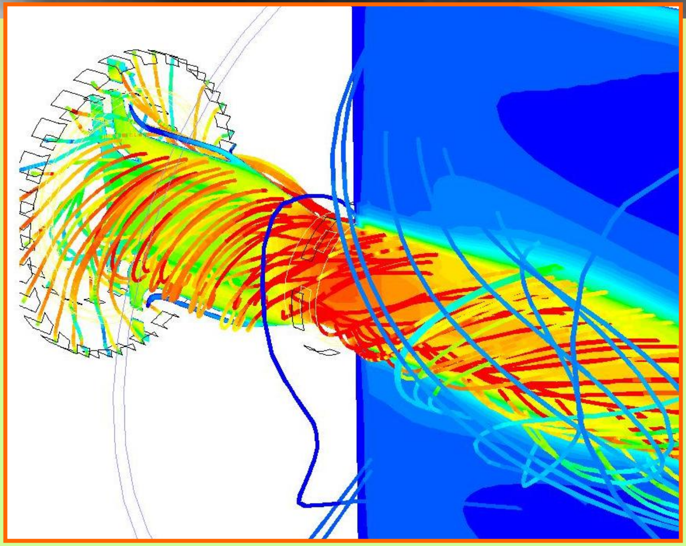
TVC concept (from the paper NASA/TM-2004-212507)

Contribution of IMP PAN
Geometry of LPP duct and combustion chamber



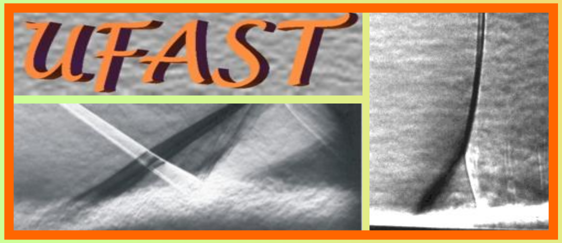






Unsteady effects in shock wave induced separation ***UFAST***

Coordination by IMP PAN



Industry Observer Group:

- RRD,
- Ansys Group
- Alenia
- Dassault aviation

No	Full name	Short name	Country
1	The Szewalski Institute of Fluid Flow Machinery Polish Academy of Sciences	IMP PAN	Poland
2	CNRS Lab. IUSTI, UMR 6595, Marseille	IUSTI	France
3	ONERA: (DAFE, DAAP)	ONERA	France
4	University of Cambridge, Dept. of Engineering	UCAM-DENG	Great Britain
5	Queens University Belfast, School of Aero. Eng.	QUB	Great Britain
6	Russian Academy of Science, Siberian Branch, Novosibirsk, Inst. of Theor. App. Mech.	ITAM	Russia
7	Delft University of Technology, Aerodyn. Lab.	TUD	Holland
8	Romanian Institute for Aeronautics	INCAS	Romania
9	University of Southampton, (SES)	SOTON	Great Britain
10	University of Rome "La Sapienza"	URMLS	Italy
11	University of Glasgow, Dept. of Aero. Engin.	UG	Great Britain
12	NUMECA, Belgium, SME	NUMECA	Belgium
13	de Toulouse	IMFT	France
14	FORTH/IACM, Found. for Res. and Techn.-Hellas	FORTH	Greece
15	Ecole Centrale de Lyon	LMFA	France
16	EADS-M, Deutschland GmbH Military Aircraft	EADS-M	Germany
17	Institute of Aviation, Warsaw	IoA	Poland

Objectives of UFAST:

The **first objective** of the UFAST project is to provide a comprehensive **experimental data base**

Experiments of "basic"interaction (WP-2)

and with flow "control devices" (WP-3) ***e.g. perforated walls, sublayer vortex generators, stream-wise vortex generators, synthetic jets, electro-hydrodynamic actuators EHD/MHD***

The **second objective** - application of recent developments in numerical simulations:

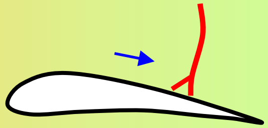
RANS/URANS (WP-4),

hybrid RANS-LES and LES (WP-5)**.**

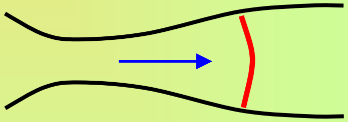
"best-practice guidelines"

The **third objective**, **improvement in physical understanding** of unsteady effects in shock induced separation

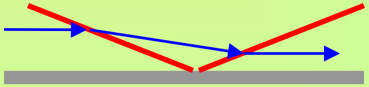
Interaction types considered in UFAST:



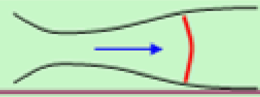
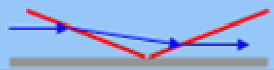
Transonic interaction



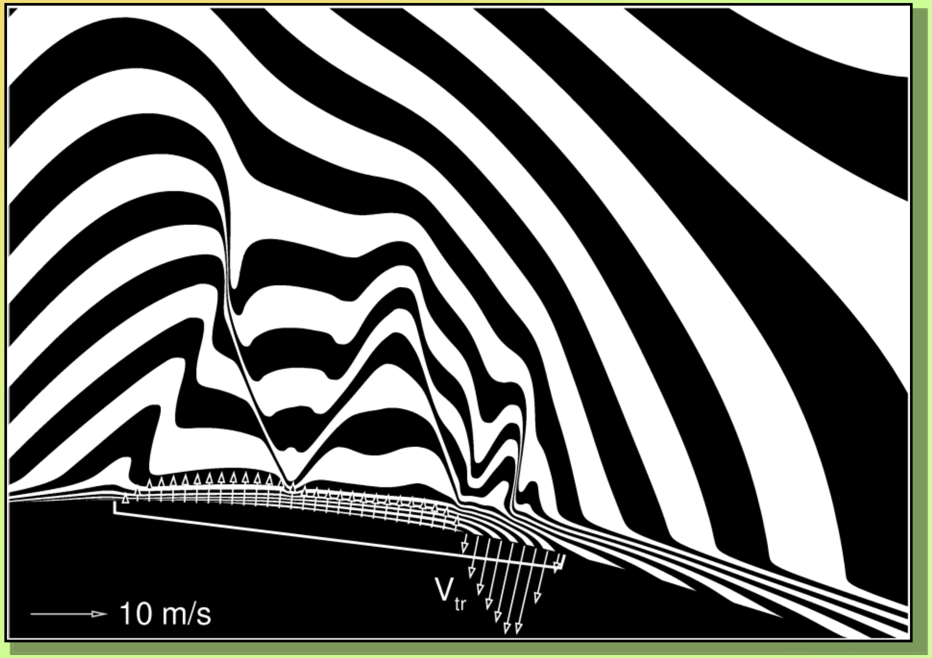
Nozzle flow



Oblique shock reflection

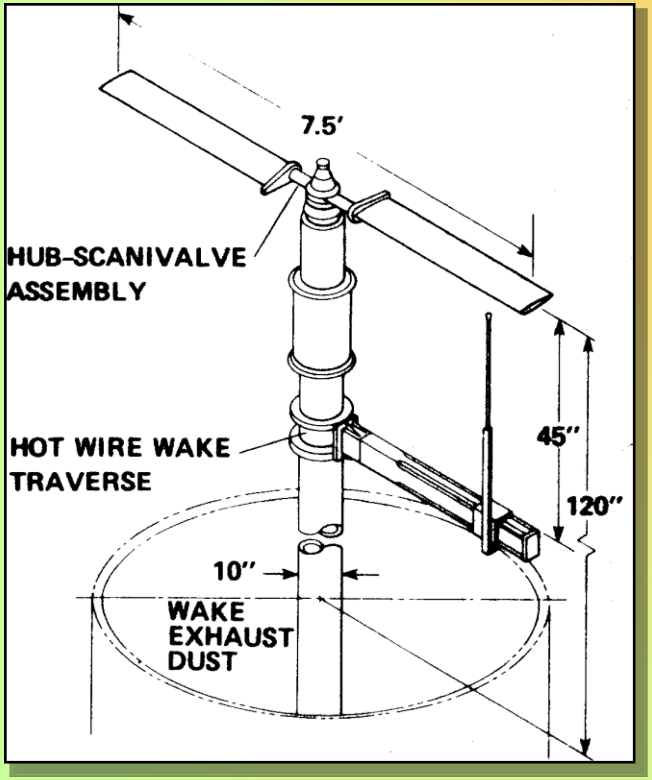
UFAST	Transonic interaction	Channel flow	Shock reflection
			
WP -2 Basic experiments ***Jean-Paul Dussauge***	**1** A) **QUB** – wall bump B) **INCAS** – biconvex aerofoil C) **ILOT** – NACA0012 with aileron	**2** A) **ONERA** (DAFE) –nozzle, forced shock oscillation B) **CUED** - nozzle, forced shock oscillation C) **IMP** - nozzle - curved channel	**3** A) **TUD** - M=1.6 B) **ITAM** - M=2.0 C) **IUSTI** - M=2.25
WP – 3 Interaction control experiments ***Holger Babinsky***	**1** 1) **QUB** - SJ 2) **QUB** - EHD 3) **INCAS** - SJ 4) **ILOT** - pitching aerofoil and aileron	**2** 1) **ONERA** – VG, AJVG 2) **CUED** - SVG 3) **IMP** - active suction, 4) **IMP** - AJVG	**3** 1) **ITAM** - EHD 2) **IUSTI** - AJVG
WP -4 RANS, URANS ***Charles Hirsch***	**1** **LIV** – A-1 **INCAS** – B-3 **IMFT** – A-1, B-3, C-4	**2** **LIV** - A-1, C-4 **FORTH** - A-1, B **IMP** - C-3, C-4 **NUMECA** – B **LMFA** – C3	**3** **URLMS** – A **NUMECA** – C **IMFT** - C **LMFA** – A, B **UAN** – B, C2
WP -5 Hybrid, RANS/LES, LES ***George Barakos***	**1** **LIV** - A-1, C-4 **INCAS** – B-3 **IMFT** – A-1, B-3, C-4 **EADS-M** - B	**2** **LIV** - A-1, C-4 **FORTH** – A-1, B **IMP** – C-4 **NUMECA** – B, C-4	**3** **SOTON** – A, B, C **NUMECA**- C **IMFT** - C **URLMS** – A **ONERA** (DAAP) – C-2

Application of the Passive Control of Shock Wave to the Reduction of High-Speed Impulsive Noise

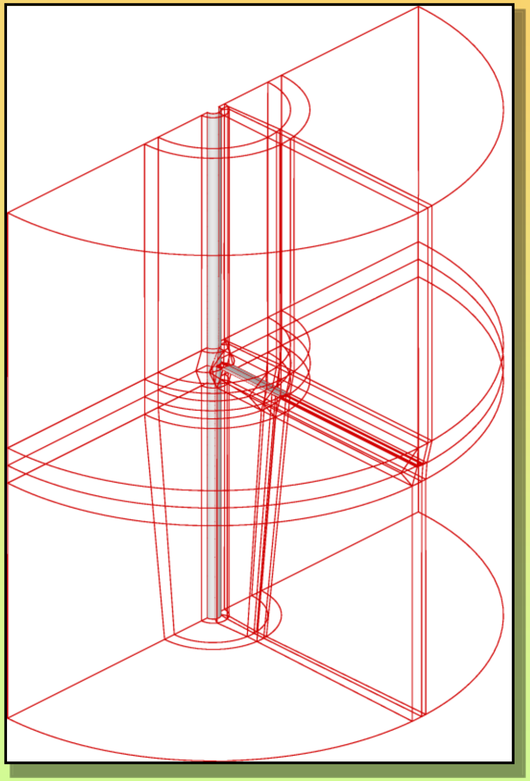


Model helicopter rotor in hover (F. X. Caradonna and C. Tung, NASA 1981)

2-bladed NACA0012 rotor in high-speed hover (AR=6)

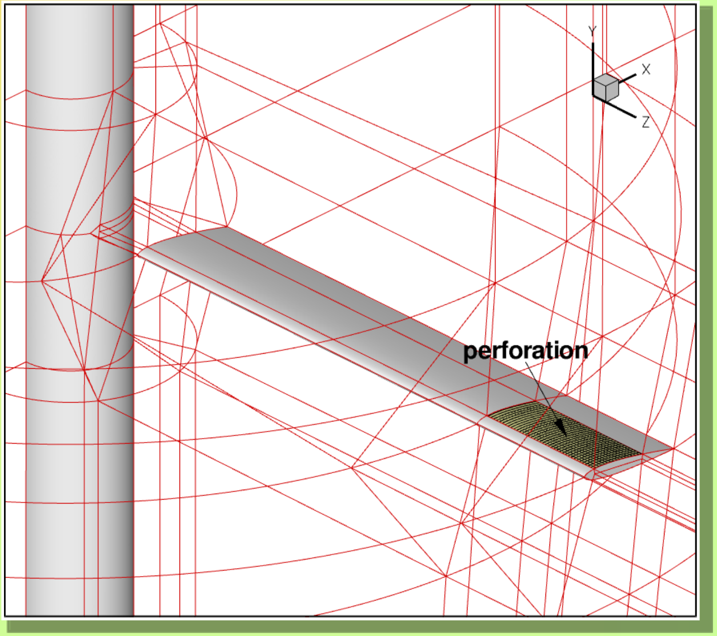


experimental set-up



single blade grid topology (80 blocks)

Perforation charact.:
outer 20% of the span,
10%c - 65%c, porosity 5%



perforation location

tip Ma: 0.88, Re: $4 \cdot 10^6$

AoA α: 8^o

High velocity flight – M = 0.22

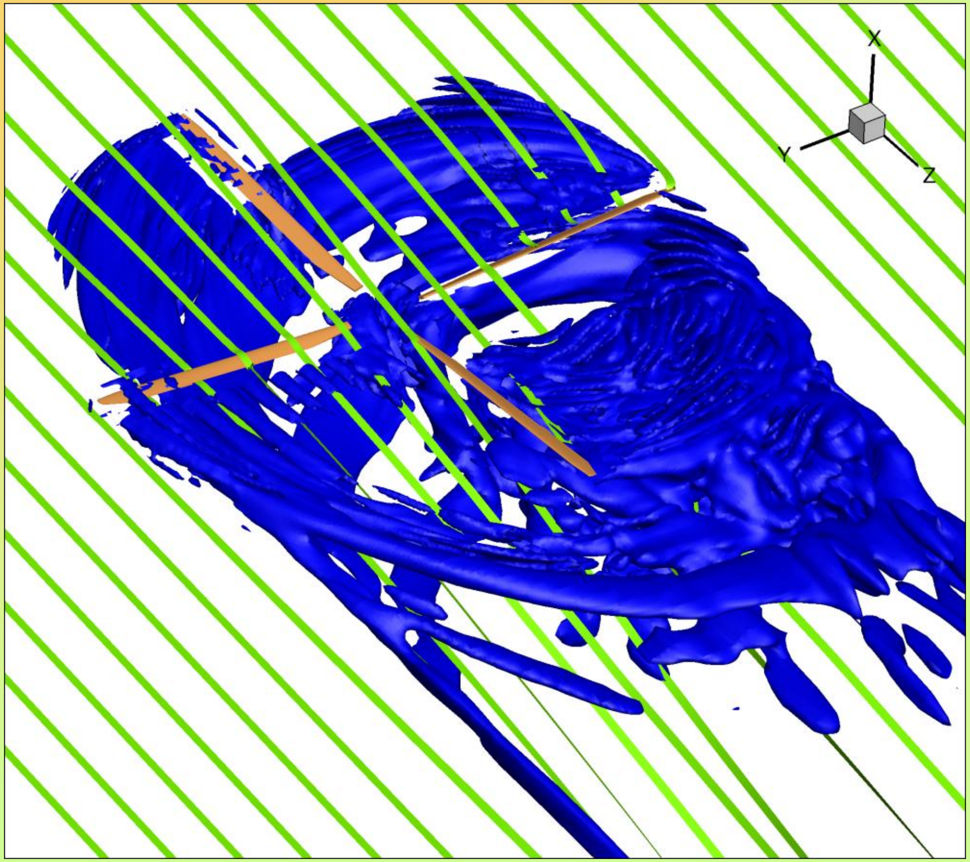
Blade tip velocity M = 0.66

FLOWER (DLR)

k-ω (Linear Expicit Algebr. stress mod.)

No blade elastic deformation

but full articulation included



ERICKA - **E**ngine **R**epresentative **I**nternal **C**ooling **K**nowledge and **A**pplications

FACTOR - Full Aero-thermal Combustor – Turbine interactiOn Research

Follow-up project of UFAST – Effect of transition location on the shock wave induced separation – external and internal aerodynamics

THE PEOPLE PROGRAMME – Marie-Curie
Industry-Academia Partnerships and Pathways
STA-DY-WI-CO (LMS Belgium - IMP PAN Poland)
STAtic and DYnamic piezo-driven StreamWIse vortex generators for active flow Control

Initial Training Networks
IMESCON
Innovative MEthods of Separated Flow CONtrol in Aeronautics

Thank you for your attention