

## TFAST project - Potential impact and the main dissemination activities

The research topic of TFAST project finds the application in the Flight Physics as well as in the Propulsion. Therefore the impact of TFAST on Air Transport Greening will be manifold. Regarding the strategic development in drag reduction the laminarisation of boundary layers on lifting parts of the airplane has a potential to reduce fuel consumption by 10%. In propulsion systems enhanced laminarity of boundary layers may reduce fuel consumption by 1 or 2 % but it affects also the maximum mass flow rate output of compressor and reduces the heat flux to turbine blades, improving durability of equipment and improving safety. These aspects can not be expressed in terms of fuel consumption.

It is foreseen that the TFAST project very well complies with the structure of the AAT Thematic Priority concerning research for strengthening the competitiveness of the European aircraft industry in the global market but also by providing a new fundamental knowledge base for shock wave/boundary layer interaction. This scope of work may be realised only on the wide international platform, - a European level.

Different groups in TFAST, ensuring a sound critical mass, are working together on a particular set of flows (unsteady transonic and supersonic) and are fostering work by cross-fertilisation and close knowledge dissemination.

The TFAST project plays a major role in providing reliable methods that are applicable to unsteady and highly compressible flows, with the clear goal of becoming recommended for industrially relevant application challenges. It is the technical achievement of the TFAST project which is – supported by the new data base – serve as the basis for a European knowledge of all aspects in the area of transition location effect on unsteady shock wave/boundary layer interaction.

Moreover, it is the formation of trans-national teams - meeting the challenging goals of TFAST - which contribute to the establishment of a more common (at least in the aeronautics sector) environment in Europe that is favourable to innovation. The latter is even more supported by the number of universities in the TFAST project, that will – on the basis of the knowledge gained – educate students by using knowledge base provided by TFAST.

From the Strategic Research Agenda published by the European Commission, two major ideas can be extracted.

The first one is the notion of sustainable growth, with its corollary of more affordable air travel in terms of technical, societal/environmental and financial preoccupations. The TFAST project is focussing on a particular scientific and technological point, namely closing the knowledge and technology gap in the area of laminarity and shock wave interaction. Thus increasing knowledge in this domain of interest is an activity clearly related to innovation and it has a larger strategic impact because it widens the physical understanding with consequences on energy saving, reduction of noise and of the emission of pollution. No doubts, by this the TFAST project matches the recommendations of the Strategic Research Agenda and is an important building block in Europe's effort to become the dominant region for the design and manufacturing of advanced civil aircraft.

The latter is already the second strategic element, namely TFAST's contribution to a global leadership for European Aeronautics. It was mentioned above that this can be achieved by a better knowledge of the involved phenomena, and by the provision of new measurements as well as the corresponding theoretical methods. And it is obvious that it can only be achieved by an upstream research project that at the same time tackles real-world situations as they are present nowadays in industry. Of course, strategic impact is achieved to a great deal by joint work of different institutions, research centres, universities, and industry and by their co-operation on the common topic of SWBLI. Surely, by enabling work in a group of sufficient size, and taking advantage of cross-fertilisation between the different teams, it is expected to increase the potential, expertise and the efficiency of each partner at a high level of excellence.

More precisely, the TFAST project includes participants from seven EC member countries and one participant from Russia and one from Ukraine. This group, together with the Advisory Board,

offers the right potential for collaborative work and the coherence in the activity for the sake of research in the European Union. In other words, TFAST could not be run at a national level, but in contrast it fosters European synergy and forms a European Research Area.

It must be underlined that among the objectives of strategic importance, education retains a central place. Many of the partners of TFAST are university laboratories. This implies that students participation in the research granted by this project and contribution to advanced work and novel problems with innovative approaches and learning from partners of rather different sites. Their acquaintance with industrially relevant topics contribute to their education at an international and multi-cultural framework.

The TFAST project conducted – as a project objective - a relevant set of well focused experiments, relevant to the above mentioned flow-physics phenomena, and the data base, both of experimental and numerical results provide a sound basis for work to be carried out, which can easily be exploited by other interested groups in Europe, but primarily of course to the aeronautics industry. Experiments are designed by pro-active CFD work in order to link experiment and CFD as closely together as possible and to allow for cross-fertilisation, rather than on competition between them.

## Dissemination activities

Publication Type	Number
Number of peer reviewed publications	7
Number of papers in Proceedings of a Conference/Workshop	24
Article/Section in an edited book or book series	1
Thesis/Dissertation	4
University Publication/Scientific Monograph	1

Dissemination of the information and results of TFAST project is closely related to a former project UFAST. This is a very advantageous situation helping a lot in the wide reach of the dissemination activities.

ECCOMAS 2012 in Vienna - A Special Technical Session was offered to the UFAST/TFAST research presentation:



STS04

Turbulent and transitional boundary layer interaction with a shock wave - UFAST and TFAST projects  
(P. Doerffer)

STS04

Mon, 16:30 - 18:30, M-HS07

This session included presentations from the following partners: George Barakos LIV, Marianna Braza IMFT, Sergio Pirozzoli URML, Benoit Tartinville NUMECA.

The consortium was offered by Prof. Wolfgang Rodi to participate in the data basis Qnet-CFD organised by ERCOFTAC. This is possibility for world-wide dissemination of work related to UFAST project, which is delivered by the members of TFAST consortium. Our contribution paves the way for future dissemination of TFAST results. The following topics were selected for Qnet-CFD:

- ♦ oblique shock reflection with experiments of Jean-Paul Dussauge from Marseille and CFD from Eric Garnier from ONERA and from Neil Sandham from Southampton. Leading person will be Jean-Paul Dussauge. (Test case 2-dimensional SWBLI is now in the Qnet data base as UFR3-32)
- ♦ normal shock following a bump with experiments of Reynald Bur from ONERA and CFD from George Barakos from Liverpool
- ♦ normal shock at a convex wall (local supersonic area) with experiments from IMP PAN group and CFD carried out with NUMECA software

The coordinator of TFAST was invited to the ERCOFTAC Workshop on unsteady interaction to present lessons learned from UFAST and TFAST projects.



The key-note lecture was entitled “Unsteady effects and boundary layer type influence on the shock wave and boundary layer interaction.

11:10 – 12:00      Key Note Lecture: P. Doerffer, IMP PAN, Poland

*Unsteady Effects and Boundary Layer Type Influence on the Shock Wave  
Boundary Layer Interaction  
Results of UFAST and TFAST European Projects*

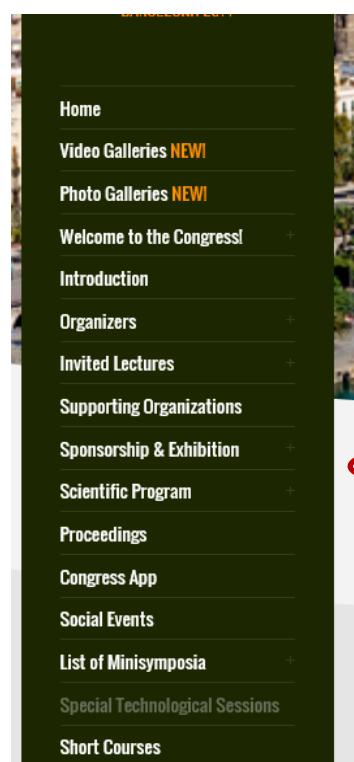
As one can see above the supporting partners and the ERCOFTEC itself secures a wide dissemination platform for project work and results.

Participation of one of the members of the consortium SOTON, presenting results from the Task-1.1, at the 43rd AIAA Fluid Dynamics Conference 24-27 June 2013, San Diego, California.

127-FD-30		
Chaired by: M. BORG, Booz Allen Hamilton and M. CHOUDHARI, NASA Langley Research Center		
0900 hrs	0930 hrs	000 hrs
AIAA-2013-2981	AIAA-2013-2982	AIAA-2013-2983
Real Gas and Surface Ablation Effects on Hypersonic Boundary Layer Instability over a Blunt Cone	Stability and Unsteadiness in a 2D Laminar Shock-Induced Separation Bubble	High-Order Simulation of Induced Disturbance in a Mach Boundary Layer
C. Mortensen, X. Zhong, University of California, Los Angeles, Los Angeles, CA	A. Sansico, N. Sandham, Z. Hu, University of Southampton, Southampton, United Kingdom	J. Atkins, NASA Langley Research Center, Hampton, VA

## ECCOMAS 2014 in Barcelona – special session for TFAST project





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### Special Technological Sessions

STS 01	<a href="#">Multi-Physics Green Challenges in Aeronautics: The EC Grain2 EU-China Networking Project</a> <i>Organized by Jacques Periaux, Gabriel Bugeada and Sun Jian</i>
STS 02	<a href="#">Turbomachinery Challenge</a> <i>Organized by Francesco Martelli, M. Manna and S. Salvadori</i>
STS 03	<a href="#">Aero-acoustics in Aeronautics: Advanced Methods and Industrial Challenges</a> <i>Organized by Hermann Deconinck and Dominique Collin</i>
STS 04	<a href="#">Optimization</a> <a href="#">VKI Lecture Series Reporting on "Introduction to Optimization Methods and Tools for Multi-disciplinary Design in Aeronautics and Turbomachinery"</a> <i>Organized by Jacques Periaux and Tom Verstraete</i>
STS 05	<a href="#">Transition Location Effect on Shock Wave Boundary Layer Interaction</a> <i>Organized by Piotr Doerffer</i>
STS 06	<a href="#">Flow Control and Drag Reduction</a> <i>Organized by Dietrich Knoerzer and Geza Schrauf</i>
STS 07	<a href="#">Application of Hybrid RANS/LES Approaches to Attached and Mildly Separated Flows</a> <i>Organized by Dieter Schwamborn, Mikhail Strelets and Charles Mockett</i>
STS 08	<a href="#">Higher-Order Methods for Aerospace Applications</a> <i>Organized by Norbert Kroll and Koen Hillewaert</i>

### List of presentations:

1. Computational Investigations on Correlation between Laminar-Turbulent-Transition Location and Buffet Onset, Katarzyna Surmacz, Janusz Sznajder, Wiesław Stalewski, Institute of Aviation (IoA), Poland
2. Effect of the transition location on a shock-boundary layer interaction, Lionel Larchevêque, Aix Marseille Université, CNRS, IUSTI UMR 7343, France
3. Implicit CFD Method For Transitional Shock Wave – Boundary Layer Interaction, G. Zografakis, G.N. Barakos, University of Liverpool, United Kingdom
4. DNS and Stability Analysis of a Transitional Shock-Wave/Boundary-Layer Interaction at  $M = 1.5$  A. Sansica, N. D. Sandham, Z. Hu, University of Southampton, United Kingdom
5. Application of EARSM Turbulence Model to Shock Boundary Layer Interaction with Laminar to Turbulent Transition, B. Tartinville, G. Carabin, Ch. Hirsch, NUMECA Int. S.A., Belgium

**4<sup>th</sup> EASN Association International Workshop on Flight Physics and Aircraft Design – 27-29.10.2014**  
Aachen

**List of presentations:**

P. Doerffer -Transition Location Effect On Shock Wave Boundary Layer Interaction  
 G. Barakos -Numerical Simulations of Transitional Shock Boundary Layer Interaction and Buffeting Control  
 J.P. Dussauge - The TFAST Project: physical and experimental challenges.

Time		Tuesday 28.10.2014 (afternoon)		
Room:	Session	Ford	General	Junkers
	#11 Transition & #12 Advanced CFD		#13 Aerodynamic Wing Concepts & Design	#14 Innovative Cockpit Design & #15 Personal Air Vehicle
	Session Chair(s)	P. Doerffer / D. Drikakis	A. Rizzi / A. Seifert	R. Habig / F. Nieuwenhuizen
16:30	16:55	<b>TFAST Project:</b> Transition Location Effect on Shock Wave Boundary Layer Interaction- Project overview, P. Doerffer	Multifunctional Moveables – from A350 into the future, D. Reckzeh	<b>i-VISION Project:</b> i-VISION (Immersive Semantics-based Virtual Environments for the Design and Validation of Human-centred Aircraft Cockpits) – Overall Presentation L. Rentzos
16:55	17:20	<b>TFAST Project:</b> Numerical Simulations of Transitional Shock Boundary Layer Interaction and Buffeting Control, G. Barakos	<b>DESIREH Project:</b> Low Speed Design of Laminar Wings, TBC	<b>i-VISION Project:</b> i-VISION – the Future of Human-centric Cockpit Design, R. Habig, L. Rentzos
17:20	17:45	<b>TFAST Project:</b> Physical and Experimental Challenges, J.P. Dussauge	Hybrid Laminar Flow Implementation, K. Risse	<b>MYCOPTER Project:</b> myCopter – Enabling Technologies for Personal Aerial Transportation Systems, F. Nieuwenhuizen, H. Böllhoff
17:45	18:10	Azure: High-Order CFD Software for Aerospace Applications, D. Drikakis, A. Antoniadis, P. Tsoutsanis	<b>AFLONEXT Project:</b> 2nd Generation Active Wing Active Flow- Loads & Noise control on Next Generation Wing - Overall Presentation, A. Seifert	<b>MYCOPTER Project:</b> Vision Based Control And Navigation For Personal Aerial Vehicles, M. Achfeld, S. Lyner, S. Weiss, M. Chif, R. Siegwart
18:10	18:35	Ground Testing: Driving Forward Innovation in Fluid Dynamics, K. Konki	<b>UMRIDA Project:</b> Uncertainty Management for Robust Industrial Design in Aeronautics - Overall Presentation TBC	<b>MYCOPTER Project:</b> Handling Qualities and Training Requirements for Personal Aerial Vehicles, M. Jupp, P. Perfect, L. Lu, M. White
END OF DAY 2				
20:00	22:00	Facultative Dinner *		

\* *Facultative Dinner Description & Details.*

Aerodays 2015 - 20-23 October 2015 at the QEII Centre, London



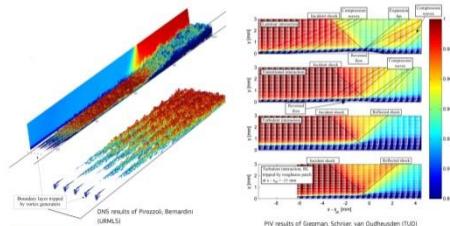
Test stand shared with Project: Go4Hybrid, GRAIN2, MARS. Posters and movie showing selected results were presented.



## TFAST

### Transition Location Effect on Shock Wave Boundary Layer Interaction

Coordinator: IMP PAN (PL) 2012/02/01-2016/01/31 Total budget: 5.1M €  
 Partners: Rolls-Royce Deutschland (DE), Dassault Aviation (FR), Institut Universitaire des Systèmes Thermiques Industriels (FR), ONERA (FR), DLR (DE), Numerica (BE), University of Rome "La Sapienza" (IT), University of Liverpool (UK), Russian Academy of Science Siberian Branch (RU), University of Cambridge (UK), University of Delft (NL), University of Southampton (UK), Institut de Mecanique des Fluides de Toulouse (FR), Institute of Aviation (PL), Academy of Science of Ukraine (UA)



The main objective of the TFAST project is to study the effect of transition location on the structure of interaction. The main question is how close the induced transition may be to the shock wave while still maintaining a typical turbulent character of interaction.

The main study cases - shock waves on windtunnels, turn and corner flows, supersonic intake flow, will help to answer open questions posed by the aeronautics industry and enable more complex applications. In addition to basic flow configurations, transition control methods stream-wise vortex generators and electro-hydrodynamic actuators will be investigated for controlling transition location, interaction induced separation and inherent flow unsteadiness. TFAST for the first time will provide a characterization and selection of appropriate flow control methods for transition induction as well as physical models of these devices.



Seventh Framework Programme  
European Union funding  
for research, technological development and demonstration

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WP1 - Reference cases of laminar and turbulent interactions  
 Leader: IUSTI

There are two basic configurations of shock wave boundary layer interaction and these are a part of the TFAST project: normal shock wave and oblique shock wave reflection.

WP2 - Transition control devices in the UCAW

Boundary layer tripping by wire or roughness and flow control devices (Vortex Generators and cold plasma) are used for boundary layer transition induction. It is intended to determine in what way the application of these techniques induces transition and how the transition location is affected.

WP3 - Internal flow - Control of laminar separation

In the case of an airfoil at high Reynolds operating, at particularly high altitudes the Reynolds number can drop by a factor of 4, when compared to the sea level values. The laminar boundary layer on the transonic compressor rotor blades interact with shock waves. As a result a strong separation zone separation will form. It can seriously affect the aero-engine performance and operation. One way to avoid strong separation is to ensure that boundary layer upstream of the shock wave is turbulent.

WP4 - External flows - Turning the flow around

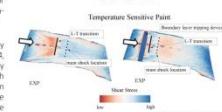
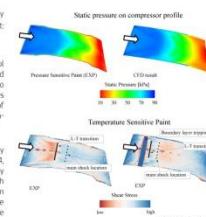
Modern HP turbine stages consist of highly loaded aerofoils, including transonic and even supersonic flow regions. The strong acceleration along the early suction side leads to a reseparisation of the flow, which in turn has a strong impact on the size of the shock induced separation bubble. As heat transfer and film cooling effectiveness are of crucial importance in high pressure regions, a better understanding of separation mechanisms is needed for a competitive design.

WP5 - External flows - Wing leading DAW

Study of transition location effect (from laminar transition to fully turbulent) on separation size, shock structure and unsteadiness. Boundary layer tripping by wire or roughness and flow control devices (Vig) will be used for boundary layer transition induction. A 2D laminar airfoil is especially designed by DAAV for the transonic tests in the UCAW and the Jok wind tunnels.



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During the conference presentation was given by Prof. Piotr Doerffer "Transition Location Effect on Shock Wave Boundary Layer Interaction".

**ECCOMAS Congress 2016, 5 - 10 JUNE 2016 Crete Island, Greece**

Special Technical Session during European Congress on Computational Methods in Applied Sciences and Engineering will be organised

### TFAST STS05: Transition Location Effect on Shock Wave Boundary Layer Interaction

#### Organisers and chairpersons:

Piotr Doerffer, Paweł Flaszynski, IMPAN;

#### Presentations:

P. Doerffer - *Transition location effect on shock wave boundary layer interaction*

M Braza, D. Szubert, Y. Hoarau, F. Billard - *An experimental and numerical study of shock boundary layer interaction in external aerodynamics configurations*

Anna Petersen - *Application of Air Jet Vortex Generators in a highly loaded Turbine Stator*

W. Stalewski, J. Sznajder - *Load Control of Natural-Laminar-Flow Wing via Boundary Layer Control*

P. Flaszynski, P. Doerffer, R. Szwaba - *Laminar-turbulent transition effect on shock wave boundary layer interaction on compressor profile*

G. Barakos - *CFD Methods for Transitional Shock Wave – Boundary Layer Interaction*

**TFAST project results will be published SPRINGER Book**

#### Series Title:

Notes on Numerical Fluid Mechanics and Multidisciplinary Design

Provisionally entitled: Transition Location Effect on Shock Wave Boundary Layer Interaction – Experimental and Numerical Findings from TFAST project