

# InSiDE

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## Innovatives Supercomputing in Deutschland



# Editorial

Welcome to this new issue of inSiDE the journal on innovative Supercomputing in Germany published by the Gauss Centre for Supercomputing. Good news for High Performance Computing in Europe is ahead.

Two new systems from Germany are going to support PRACE in the coming years. The High Performance Computing Center at Stuttgart will install a 1 PFlop Cray XE6 called Hermit in summer. This will be followed by a 3 PFlop IBM cluster called SuperMUC installed by the Leibniz Rechenzentrum at Garching in 2012. Both systems are part of the German PetaGCS project and are funded by the Federal Ministry of Education and Research (BMBF) and the State Governments of Baden-Württemberg and Bavaria.

Both systems will become part of the European HPC landscape established by PRACE. They join the 1 PFlop IBM Blue Gene/P system called JUGENE, co-funded by the State Government of Nordrhein-Westfalen and being in operation since July 2009. We give a report on the status of PRACE in this issue. Furthermore we can report about the first regular PRACE HPC access grants for research projects. It is obvious that the concept of a European research landscape for simulation takes shape. Bundling its resources Europe again sets out to take a leading role in one of the key technologies of the 21st century.

The wide range of scientific fields that benefit from the newly available hardware is emphasized in this issue of inSiDE. 58 pages of application reports show the impact of new hardware and software on basic and applied research.

We start with three articles that were awarded the Golden Spike by the steering committee of the HLRS: Climate research from the Leibniz Institute for Ocean Research at Kiel/Germany, flow over an airplane wing and helicopter simulation from the University of Stuttgart. The two following articles describe the progress in turbulence simulation; both report on research performed by Gauss Large-Scale projects carried out on JUGENE in the previous granting period. Physics and chemistry research are represented by three outstanding and extensive articles. Finally two fascinating articles show what can be done in astrophysics using high end supercomputers.

The success of future applications originates from projects. This issue reports on four of them. LarkC is funded by the European Commission and focuses on high performance semantic web experience. Another European project plugIT works on the integration of business in High Performance Computing. Monitoring is a big issue for large scale systems. LRZ reports on a project to develop a software package called PerSyst. AstroGrid reports on a breakthrough in Grid Computing in a project funded by BMBF. Two short communications report on the starting of a new ITEA project called H4H on hybrid programming and on HOPSA, a new joint EU-Russian project for holistic performance analysis.

Among our many activities we highlight the 100 Gigabit Ethernet connection between Research Centre Jülich and Karlsruhe Institute of Technology. All in all inSiDE will again give you a comprehensive overview of HPC not only in Germany but also in Europe.

Enjoy reading!

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- Prof. Dr. H.-G. Hegering (LRZ)
- Prof. Dr. Dr. Th. Lippert (NIC)
- Prof. Dr.-Ing. Dr. h.c. Dr. h.c. M. M. Resch (HLRS)

# Laminar Flow Control in Vortex-deformed Swept-Wing Flows: Pinpoint Suction

Improving the fuel efficiency of aircraft has become an important task within the last decades. Not only do airlines benefit from saving increasingly expensive fuel but also the environmental aspect has gained growing interest and it will only be a matter of time until environmental laws limiting greenhouse gas emissions will be approved. Current commercials for newly designed aircrafts show the demand for more efficient airplanes: "The 787 Dreamliner is using 20% less fuel than any other airplane of its size" (Boeing) or "The A380 provides the lowest fuel burn per seat – which allows airlines to substantially reduce CO<sup>2</sup>-emissions while achieving profitable, sustainable growth for decades to come" (Airbus).

To date, realized optimizations for new airplanes are limited to enhanced shaping, avoiding too rough surfaces, and engine improvement, but little potential is thought to be left in these fields except surface quality on aerodynamic surfaces. New concepts have therefore to be envisaged that consider the underlying fluid dynamics phenomena

in detail. Inflight tests with a kind of shark-skin surface striving for turbulent boundary-layer drag reduction have shown improvements only in the range of very few percents. Laminar flow control (LFC) on the other hand provides a total drag reduction potential of e.g. 16% by realizing 40% laminar boundary-layer flow on wings and control surfaces of a current airliner [5]. Therefore it is the most promising candidate for expedient drag reduction.

Maintaining large regions of laminar boundary-layer flow has been proven for decades now in two-dimensional situations by applying boundary-layer suction which efficiently delays laminar-turbulent transition. A typical airliner wing, however, is swept back (cf. figure 1) to allow for higher cruise speed at acceptable pressure drag. The evolving crossflow component inside the boundary layer causes a new, dominant instability mechanism, and a straightforward implementation of the two-dimensional suction setups is not possible. For a three-dimensional boundary layer it turns out that - typically steady - longitudinal crossflow vortices evolve due to the new primary instability of the flow. While still being laminar these vortices - if grown to large amplitudes - are highly unstable to ubiquitous unsteady background disturbances. Due to the extremely large growth rates of this so-called secondary instability

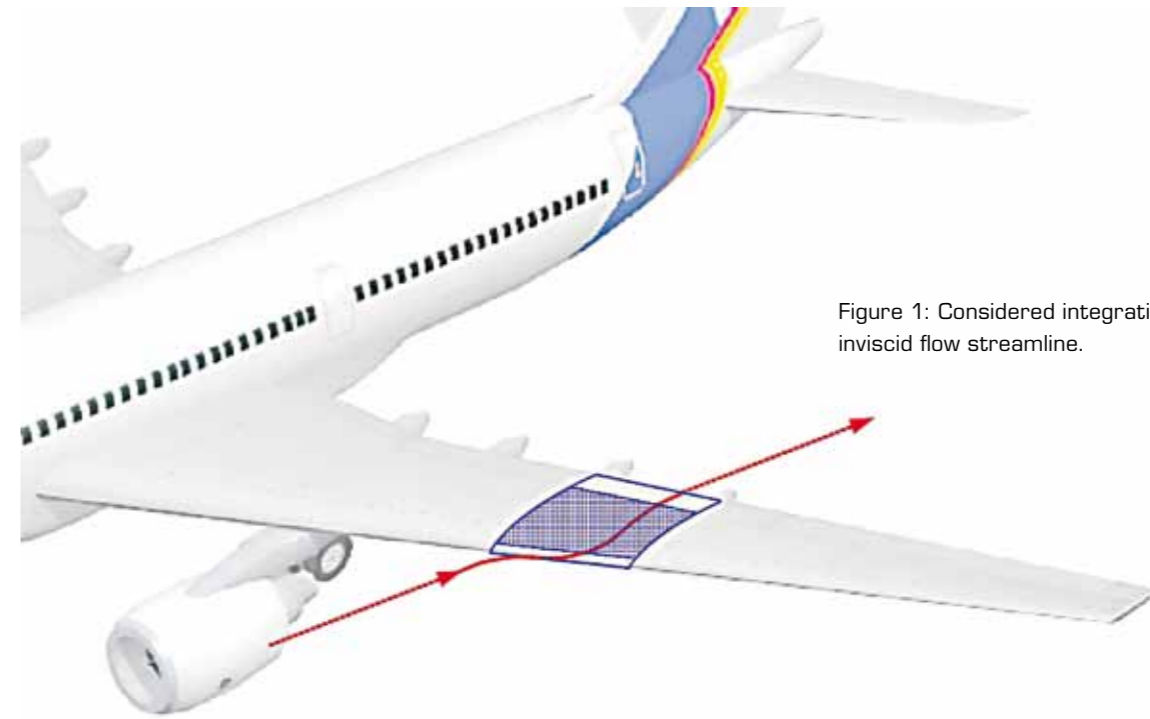
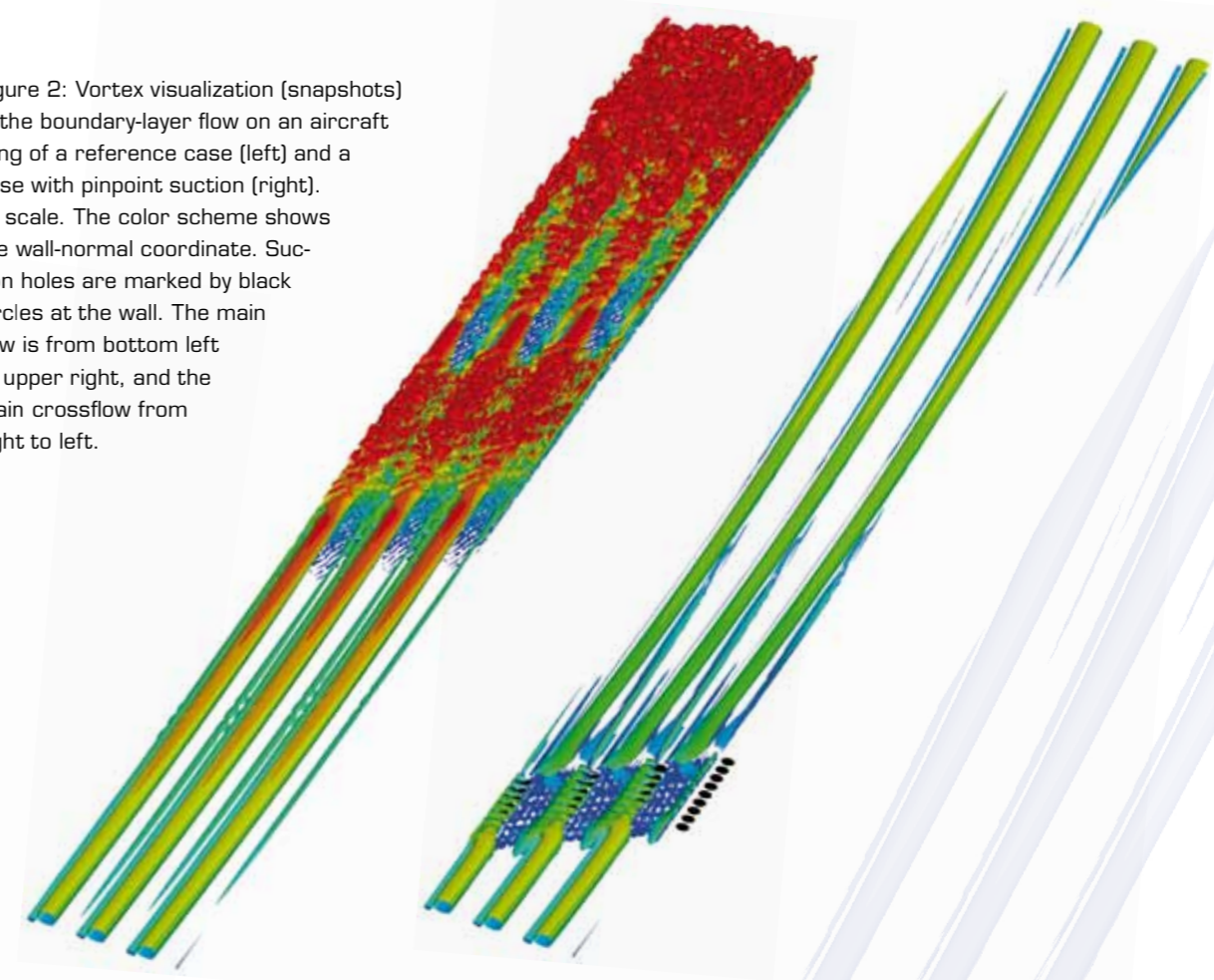


Figure 1: Considered integration domain with inviscid flow streamline.

laminar-turbulent transition sets in rapidly, typically after only few percents of the airfoil chord length. The crossflow vortices are generated by even minute surface non-uniformity.

Boundary-layer suction diminishes the crossflow by sucking high-momentum fluid to the wall, and thus also attenuates crossflow instability. However, the typically applied discrete suction

Figure 2: Vortex visualization (snapshots) in the boundary-layer flow on an aircraft wing of a reference case (left) and a case with pinpoint suction (right). To scale. The color scheme shows the wall-normal coordinate. Suction holes are marked by black circles at the wall. The main flow is from bottom left to upper right, and the main crossflow from right to left.



holes can generate, on the other hand, relatively large initial crossflow-vortex disturbances, jeopardizing the LFC.

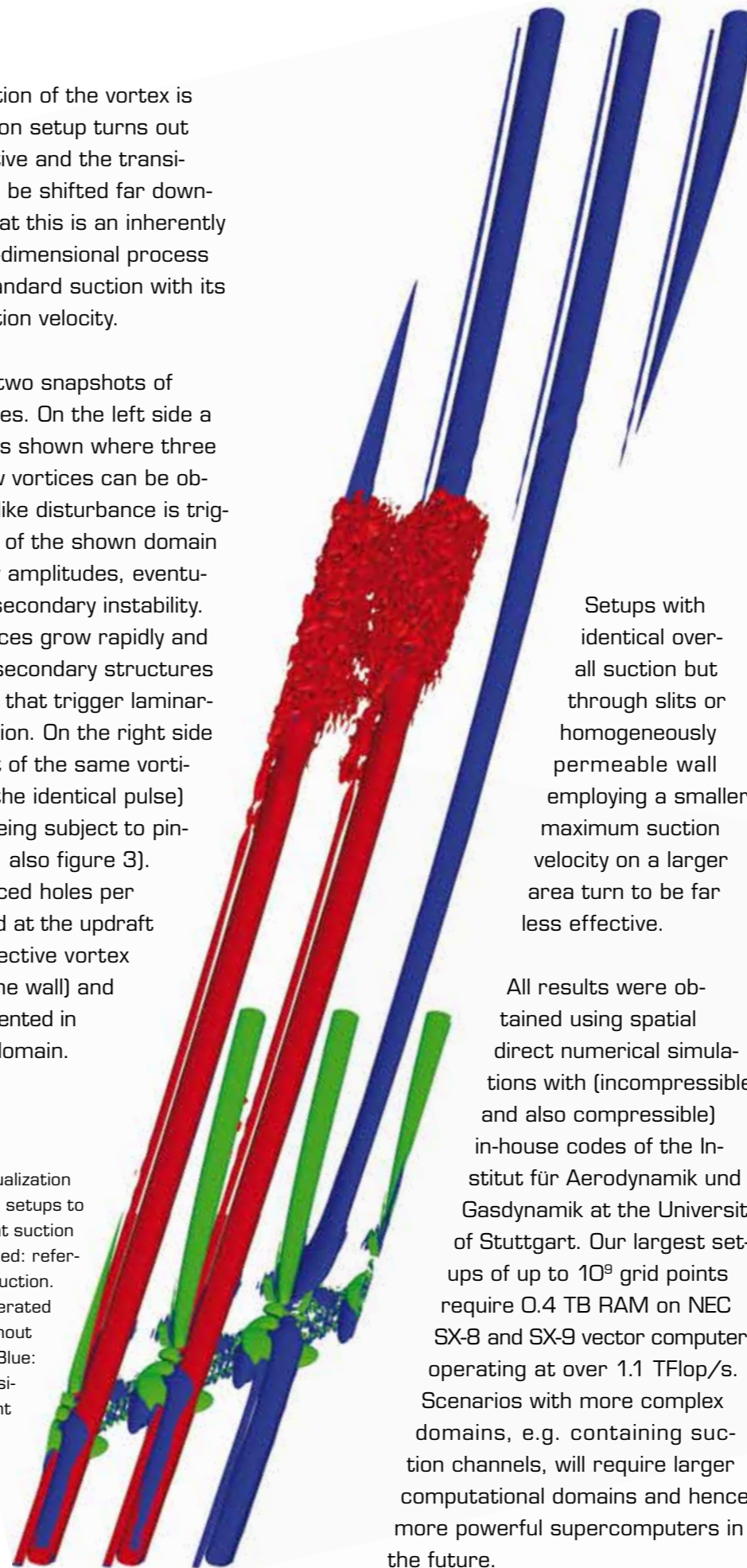
Improved suction concepts for this kind of three-dimensional wing flows had therefore to be developed. Messing & Kloker [4] proposed an idea called distributed flow deformation (DFD), in particular formative suction. By designing a suitable slot-suction panel useful vortices - with a much closer spanwise spacing than the turbulence-triggering ones - are continuously excited and maintained that are known to be stable with respect to secondary instability and suppress the nocent vortices. Laminar-turbulent transition could be delayed significantly.

A new idea of directly influencing large-amplitude crossflow vortices and secondary instabilities called pinpoint suction is currently developed [1,2,3]. The scenario considered contains the harmful, secondarily unstable crossflow vortices that develop naturally. Localized, strong suction through few holes only at the updraft side of each vortex, i.e. the locally most unstable region with high-shear layers, directly reduces the secondary growth while also reducing the vortex strength.

If the exact position of the vortex is known this suction setup turns out to be very effective and the transition location can be shifted far downstream. Note that this is an inherently non-linear three-dimensional process compared to standard suction with its much lower suction velocity.

Figure 2 shows two snapshots of vortical structures. On the left side a reference case is shown where three steady crossflow vortices can be observed. A pulse-like disturbance is triggered upstream of the shown domain at extremely low amplitudes, eventually undergoing secondary instability. These disturbances grow rapidly and soon finger-like secondary structures can be detected that trigger laminar-turbulent transition. On the right side the development of the same vortices (containing the identical pulse) is shown, now being subject to pinpoint suction (cf. also figure 3). Nine closely spaced holes per vortex are placed at the updraft side of the respective vortex (black holes at the wall) and transition is prevented in the considered domain.

Figure 3: Vortex visualization (snapshots) of three setups to illustrate the pinpoint suction concept. To scale. Red: reference case without suction. Green: vortices generated by suction holes without oncoming vortices. Blue: (non-linear) superposition - applied pinpoint suction.



Setups with identical overall suction but through slits or homogeneously permeable wall employing a smaller maximum suction velocity on a larger area turn to be far less effective.

All results were obtained using spatial direct numerical simulations with (incompressible and also compressible) in-house codes of the Institut für Aerodynamik und Gasdynamik at the University of Stuttgart. Our largest setups of up to  $10^9$  grid points require 0.4 TB RAM on NEC SX-8 and SX-9 vector computers operating at over 1.1 TFlop/s. Scenarios with more complex domains, e.g. containing suction channels, will require larger computational domains and hence more powerful supercomputers in the future.

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- Tillmann A. Friederich
- Markus J. Kloker

Institut für  
Aerodynamik und  
Gasdynamik,  
University of  
Stuttgart

## Publishers

Prof. Dr. H.-G. Hegering | Prof. Dr. Dr. T. Lippert | Prof. Dr. M. M. Resch

## Editor & Design

F. Rainer Klank, HLRS

klank@hlrs.de

Carina Möhlig, HLRS

moehlig@hlrs.de

## Authors

### Alexander Beck-Ratzka

alexander.beck-ratzka@aei.mpg.de

### Felix Bensing

bensing@iag.uni-stuttgart.de

### Arne Biastoch

abiastoch@ifm.geomar.de

### Thomas Boenisch

boenisch@hlrs.de

### Matthias Brehm

Matthias.Brehm@lrz.de

### Andreas Burkert

### Anton Daitche

a.daitche@googlemail.com

### Dietmar Erwin

d.erwin@fz-juelich.de

### Tillmann A. Friederich

friederich@iag.uni-stuttgart.de

### Rudolf Friedrich

fiddir@uni-muenster.de

### Stefan Frijters

s.c.j.frijters@tue.nl

### Markus Gampert

m.gampert@itv.rwth-aachen.de

### Michael Gauding

m.gauding@itv.rwth-aachen.de

### Shy Genel

Shy.Genel@campus.lmu.de

### Reinhard Genzel

### Pierre Gilet

gilet@hlrs.de

### Jens Henrik Göbbert

jh.goebbert@itv.rwth-aachen.de

### Florian Günther

f.s.guenther@tue.nl

### Carla Guillen

Carla.Guillen@lrz.de

### Jens Harting

jens@icp.uni-stuttgart.de

### Wolfram Hesse

Wolfram.Hesse@lrz.de

### Luigi Iapichino

luigi@ita.uni-heidelberg.de

### Florian Janoschek

florian@icp.uni-stuttgart.de

### Fabian Jansen

fabian@icp.uni-stuttgart.de

### Peter Johansson

### Oliver Kamps

okamp@uni-muenster.de

### Manuel Keßler

kessler@iag.uni-stuttgart.de

### Markus J. Kloker

kloker@iag.uni-stuttgart.de

### Bastian Koller

koller@hlrs.de

### Mariana Ležaić

m.lezaic@fz-juelich.de

### Olaf Mextorf

o.mextorf@fz-juelich.de

### Jörg Meyer

joerg.meyer@ch.tum.de

### Bernd Mohr

b.mohr@fz-juelich.de

### Thorsten Naab

joerg.meyer@ch.tum.de

### Walter Nadler

w.nadler@fz-juelich.de

### Eric Mc Nellis

erikmcnellis@gmail.com

### Ludwig Oser

### Ludger Palm

Ludger.Palm@lrz.de

### Norbert Peters

n.peters@itv.rwth-aachen.de

### Rolf Rabenseifner

rabenseifner@hlrs.de

### Michael M. Resch

resch@hlrs.de

### Karsten Reuter

karsten.reuter@ch.tum.de

### Helmut Satzger

Helmut.Satzger@lrz.de

### Philip Schäfer

p.schaefer@itv.rwth-aachen.de

### Godehard Sutmann

g.sutmann@fz-juelich.de

### Axel Tenschert

tenscher@hlrs.de

### Lipo Wang

lipo.wang@sjtu.edu.cn

### Michael Wilczek

mwilczek@uni-muenster.de

### Felix Wolf

f.wolf@grs-sim.de