EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 1: Management

Summary

The management of the EuHIT project is designed to ensure a flexible and efficient coordination of all activities in and between all work packages of the whole project and administrative support of the Coordinator at consortium level. In this respect, TNA has been coordinated, decisions of the General Assembly have been coordinated, achievements have been assessed according to agreements on deliverables and milestones, reports have been collected, coordination between the partners and the EU has been coordinated, tranches have been distributed among the partners, meetings have been organized. Costs savings have been reallocated by decisions of the General Assembly following an application procedure, which agrees on budgets for new deliverables.

List of Deliveries and Milestones

There are no deliverables and milestones in this WP.

Dissemination Activities

1. Title: AGU Ocean Science meeting
   Type of activity: Advertisement
   Main leader: UNIBO
   Date: February 21-26, 2016
   Place: New Orleans, USA
   Type of audience: International Scientists on Ocean Research
   Countries addressed: international
2. Title: Ninth International Symposium on Turbulence and Shear Flow Phenomena (TSFP-9)

	Type of activity:	Advertisement
	Main leader:	TUIL
	Date:	June 30 – July 3, 2015
	Place:	Melbourne, Australia
	Type of audience:	International Scientists on Shear Flows
	Countries addressed:	international
3.	Title:	21. Fachtagung Lasermethoden in der Strömungsmesstechnik
	Type of activity:	Short Presentation and Flyers
	Main leader:	MPIDS
	Date:	September 3 – 5, 2013
	Place:	München, Germany
	Type of audience:	Fluid Mechanics Scientists
	Countries addressed:	Germany
4.	Title:	22. Fachtagung Lasermethoden in der Strömungsmesstechnik
	Type of activity:	Short Presentation and Flyers
	Main leader:	MPIDS
	Date:	September 9 – 11, 2014
	Place:	Karlsruhe, Germany
	Type of audience:	Fluid Mechanics Scientists
	Countries addressed:	Germany
5.	Title:	23. Fachtagung Lasermethoden in der Strömungsmesstechnik
	Type of activity:	Short Presentation and Flyers
	Main leader:	MPIDS
	Date:	September 8 – 10, 2015
	Place:	Dresden, Germany
	Type of audience:	Fluid Mechanics Scientists
	Countries addressed:	Germany
6.	Title:	24. Fachtagung Experimentelle Strömungsmechanik
	Type of activity:	Short Presentation and Flyers
	Main leader:	MPIDS
	Date:	September 6 – 8, 2015
	Place:	Cottbus, Germany
	Type of audience:	Fluid Mechanics Scientists
	Countries addressed:	Germany

7. Title: 17th International Symposium on Applications of Laser Techniques to Fluid Mechanic
   Type of activity: Short Presentation and Flyers
   Main leader: MPIDS
   Date: July 7 – 10, 2014
   Place: Lisbon, Portugal
   Type of audience: Fluid Mechanics Scientists
   Countries addressed: international

8. Title: 18th International Symposium on Applications of Laser Techniques to Fluid Mechanic
   Type of activity: Short Presentation and Flyers
   Main leader: MPIDS
   Date: July 4 – 7, 2016
   Place: Lisbon, Portugal
   Type of audience: Fluid Mechanics Scientists
   Countries addressed: international

9. Title: 68th Annual Meeting of the APS Division of Fluid Dynamics
   Type of activity: Advertisement
   Main leader: MPIDS
   Date: November 22 – 24, 2015
   Place: Boston, USA
   Type of audience: Fluid Mechanics Scientists
   Countries addressed: international

10. Title: 15th European Turbulence Conference
    Type of activity: Advertisement
    Main leader: MPIDS
    Date: August 25 – 28, 2015
    Place: Delft, The Netherlands
    Type of audience: Fluid Mechanics Scientists
    Countries addressed: international

11. For each infrastructure EuHIT-movies have been created to showcase the strength of each facility. These are available on the EuHIT website.

12. Flyers and posters have been printed and have been distributed/shown at the aforementioned conferences.

Project meetings

Here only the decision-making meetings of the General Assembly are given. Details about decisions are given in the following section about task 1.4.

- General Assembly Meeting, Brussels, January 27-29, 2015
- General Assembly Meeting, Grenoble, May 11-12, 2015
- General Assembly Meeting, online, July 22, 2015
- General Assembly Meeting, online, February 3, 2016
- EuHIT Conference and GA Meeting, Göttingen, May 2-4, 2016
- EuHIT Workshop Göttingen Turbulence Facility and ICTR rebirth Meeting, Göttingen, February 14, 2017

Publications

There are no publications in this WP.

Personnel Statistics:

1. Name: Eberhard Bodenschatz
   Task: Work Package Leader
   Gender: male
   PM: 0

2. Name: Holger Noabch
   Task: Project Manager
   Gender: male
   PM: 48

Task 1.1: Contract and IP management

Responsible partner: MPI-DS

Collaborators: none

Objectives:

• Ensure compliance of the consortium with the provisions of the EU grant agreement and its annexes.
• Maintenance of consortium agreement, including compliance with the rules on decision-making.
• Management of intellectual property right issues in accordance with provisions of the grant agreement and consortium agreement.

Concise overview:

The Consortium Agreement has been completed, signed by all partners. Advices have been given according to arising any questions of the partners. The management took care of a close contact to the EU.

Use of resources:

Human resources have been used according to the list above.

Problems and corrective actions: none

Task 1.2: Financial management

Responsible partner: MPI-DS

Collaborators: none

Objectives:

• Monitoring of budget and expenditures.
• Distribution of the EU payments to the partners
• Providing advices to all partners regarding financial issues (e.g. eligibility of costs).

Concise overview:

The tranches from the EU have been distributed among the EuHIT consortium partners. Cost savings have been reallocated two times to new deliverables after decision by the General Assembly. Advices have been given according to arising questions of the partners. The usage of the budgets has been monitored according to the progress of the work packages. Therefore, also the provision of the milestones and deliverables has been monitored.

Use of resources:

Human resources have been used according to the list above.

Problems and corrective actions:

Most of the milestones and deliverables have been reached or delivered in time. Therefore, the progress of the work is obvious. The following exceptions have been identified.

MS46 (Adaptation of SPT to GTF3) and D25.1 have not been reached or delivered. The reason is that the bubble generator the partner developed did not work properly. The partner rebuilt it, but it still did not function and the partner concluded that it would be best to purchase a bubble generator from LaVision, who the partner heard were developing a commercial version. Jakob Mann visited LaVision (in Göttingen) and saw a prototype that worked much better than that of the partner, but they were still working on it, and it was unclear when (and if) they would start producing and selling the device. At that point the partner had spent the (very limited) resources from EuHIT, but were hoping that a bubble generator could be financed as part of the instrumentation of the wind tunnel, which is going to be built on Risø. So there is a small chance that the partner may be able to develop a shadow PTV system one day, but it will not be within EuHIT.

Partner 1 (MPI-DS) has postponed the equipment of the wind tunnel with the particle tracking system because of scientific needs to perform a longer measurement campaign in the wind tunnel without the particle tracking system. All hardware parts are ready to be built into the wind tunnel (delivered and tested). Only the mounting has been postponed. The consequence is a delay in milestones MS19 and MS21. The illumination subsystem will be completed with the installation of the LPT into GTF 1. The installation will start in early 2018 and be complete by mid to late 2018. MS44 (WP24 Workshop) has not taken place. It was delayed to allow more time for Lagrangian measurements to be taken in the experiments involved in WP24. Since this process is still not finished, such a workshop is reasonable only after the end of the EuHIT project.

Partner 10 (FAU) has had significant problems finishing the installation of the active grid in the index-matched flow channel. However, there was significant progress during the last reporting period and the partner has finished all expected work according to the installation of the grid and the characterization of the flow field. Only deliverable D20.5 could not be finished in time as it needs extended experimental effort.

Task 1.3: Preparing the periodic reports to the EU

Responsible partner: MPI-DS

Collaborators: none

Objectives:

The project office collects the results and deliverables reports as well as the financial Form Cs and Audit Certificates from the partners. Periodic reports will be compiled and submitted to Brussels, ensuring compliance with the reporting guidelines and the reporting deadlines

Concise overview:

All contributions from the partners have been collected and uploaded to Brussels.

Use of resources:

Human resources have been used according to the list above.

Problems and corrective actions: none

Task 1.4: Communication management and meeting coordination

Responsible partner: MPI-DS

Collaborators: none

Objectives:

• On behalf of the coordinator, the project office communicates with the EU concerning administrative matters (e.g. financial issues, grant agreement amendments, reporting).
• The project office makes available all relevant documents of the project (e.g. grant agreement and its annexes, consortium agreement, reporting guidelines and templates, meeting minutes, etc.) via the project website.
• Coordination and promotion of publications and other dissemination activities,
• Organisation of the four consortium meetings to occur in regular intervals during the duration of the grant.
• Coordination of all meetings of the Steering Committee and the Scientific Advisory board.
• Help for coordination of all scientific meetings of EuHIT.

Concise overview:

The management is accepted and heavily used by all partners as an information desk to obtain advice in all questions of the administrative treatments of the whole project and individual work packages. Meetings are scheduled and arranged according to the requirements.

During the EuHIT project the Consortium has met (meetings with making decisions only) for the following meetings

General Assembly Meeting, Brussels, January 27-29, 2015

At this meeting the EuHIT consortium reported activities to the EC. Besides the mid-term review, the meeting has been used by the members of the consortium to discuss the status of the work packages in presentations by the work package leaders.

General Assembly Meeting, Grenoble, May 11-12, 2015

At this meeting the two partners LEGI and CEA have been visited. The work package leaders have presented the status of the work packages. Besides the presentation, the General Assembly has made the following the decisions.

1. Redistribution of money that cannot be claimed against the EC as running costs (about 700000):

    - Workpackage Leaders should go through the first application (10Mio) and make suggestion for redistributions to the Steering Committee and Coordinator. The SC makes a recommendation to the Management. Management will execute the decision based on available funds.

2. TNAs must deliver reliable new Access Cost Tables to estimate the remaining

budget and the amount to be redistributed.

3. Deliverables and Milestones should be reported and upload continuously.

4. Recommendations about improving the visibility of the EuHIT:
   - Sommer School in Trieste (ask Joe Niemela)
   - Website: News lists
   - Video and Walk-Through-Tool for every Facility, present it on the Webpage
   - Booth at conferences with flyers, poster, gadgets and a special flyer about Turbase. It was suggested to upload the movies on a memory stick.
   - Flyer update with QR-Code
   - Factsheet
   - use DFG (and similar in other countries) networks to distribute the information about EuHIT

5. Workshops at some of the Facilities
   - LML May 18-19, 2015
   - CEA, CCTF, ICTP and CERN in Oct. 2015

6. Additional Workshops and Conference, which should also represent EuHIT there:
   - BTU on Taylor-Couette Flows, Sept. 2015

7. TNAs should have their workshops as soon as possible, but at least end of 2015. The geophysical facilities could also have a joint workshop. Could be a satellite meeting to a big conference. BOI and GTF could have this as a satellite to the RBC-Conference in Goettingen. Same is true for Low Temp He.

8. Data Processing should be provided by the TNA to the User. The User retains the ownership of the data. The facilities will make a contract (example by Ronald du Puits) with the User about the possibility to publish the data without the User after an embargo time of e.g. one year. This includes, if necessary, another round of travel.

9. Costs for data processing either as part of User Access (include the time as provided access time) or apply for extra funds, e.g. to upload data produced at the facility. All facilities can go up to 20% of their running costs independent of what they have applied for.

10. Next meeting (EuHIT Conference): When: end of May or beginning of June 2016, RTD WP Leaders will work as Scientific Adv. Board, Where: Cottbus, Predappio, check whereelse, may be Goettingen?

11. Users, who have problems to upload data to Turbase can also send a harddisk by normal mail. EuHIT will pay the costs for the courier service.

12. Is it possible to allow industrial users an embargo of data and knowledge that is long enough (after EuHIT ended)? To be clarified.

13. What happens to Turbase data after EuHIT?

14. The Lille data base should go to Turbase. Financial support will go to Lille (about 50kEUR, no disagreement from participants).

15. Turbase will be opened for the entire community to upload their turbulence data sets. The size of one dataset will be limited to ...?

General Assembly Meeting, online, July 22, 2015

Topics of discussion:
- Explanation of details on the second tranche to TNA members, GA agreed to the suggested procedure
- Explanations of savings (estimate 558463.04EUR — 1815764.44EUR, based on the current numbers, depending on the user access in the remaining time of EuHIT)
- Assembly of applications for extra funds
  1. Schools (50000EUR)
  2. UNOL, Cantiliver (40000EUR)
  3. Neel, low temp. probe (150000EUR)
  4. UTOV, 120000 additional pers. months (120000EUR)
  5. CINECA, data infra structure (60000EUR)
  6. Lille, data transfer (50000EUR)
  7. CEA Sacley, Goettingen, fractal propeller (85000 — 115000EUR)
  8. UNIBO, DNS simulation of NSTAB (25000EUR)
  9. Goettingen, data quality (60000EUR)
  10. DTU, spent in the first period (about 20000EUR)
- Procedure to apply for extra funds out of savings (except the two decisions made right away, see decisions below)
  Ask all WP leaders for the proposals for extra funds for a period of 9 months and until the end of the grant. In the first 9 months we have 490000EUR for that. Please send in a 2-page proposal with deliverables and cost calculations according to EU rules. For the second period the amount of funds available is still unclear. Deadline for proposals: Aug. 9, 2015. Vote on Aug. 12 by the GA with rank order 0 — 10 (best). Mail vote on acceptance on Aug. 13 by the GA with 2/3 majority.
- Decisions/votes (see below)

Decisions (with votes):
1. Move money for CINECA from WP18 to WP4 (approved by the GA with 16 from 16 votes)
2. 50000EUR for schools (approved by the GA with 16 from 16 votes)
3. Amount to spend with extra funds out from the savings
- 560000EUR? (approved by the GA with 13 from 16 votes)
4. about 20000EUR for DTU (approved by the GA with 16 from 16 votes)
5. Agreement on the voting rules for the extra funds? (approved by the GA with 16 from 16 votes)

General Assembly Meeting, online, February 3, 2016

The General Assembly has agreed to spend cost savings for new developments.

EuHIT Conference and GA Meeting, Göttingen, May 2-4, 2016

The EuHIT Conference was a suitable platform for all TNA users to demonstrate their experiments and their respective results. The users performing experiments at the facilities have been invited to give presentations at the conference. At the same time this was the appropriate audience to initiate future collaborations and additional experiments at the facilities. The last day of the meeting was restricted to the members of the EuHIT consortium. Here, arrangements of the EuHIT tasks during the last year have been discussed and decisded, e.g. the date of the last call for user access. Furthermore, final redistributions of budgets from savings due to facilities with too few user access or too low eligible running costs have been decisded.

EuHIT Workshop Göttingen Turbulence Facility and ICTR Rebirth Meeting, Göttingen, February 14, 2017

Besides the demonstration of the Göttingen Turbulence Facility (GTF) the workshop at the MPI-DS has been used to initiate collaborations between the partners of the EuHIT program after the direct financial support of the EC. The partners have emphasized their interests for further collaborations similar to the EuHIT project. Especially the TNA activities have found great popularity. Therefore, the consortium has decided to re-establish the International Collaboration in Turbulence Research (ICTR). This will be a platform for international researchers allowing the further access to the turbulence facilities from the EuHIT program. An appropriate web design for automated handling of applications has been agreed to be available soon. Furthermore, the collaboration and the infrastructure should be extended providing a wide range of information from the insiders to potential users. Below is a list of decisions and impulses from this meeting.

- interests in further collaborations in turbulence research
- possible questions to be solved in turbulence
- future networking
- exchanging experiences in providing access to facilities for external user groups
- providing names of scientists and experts for the various topics identified and sharing data, also past the EuHIT program
- organization of future access to the GTF and also to other facilities
- continuing the procedure of calls to apply and to review user applications to turbulence facilities
- sharing data bases with quality management
- teaching parts for young scientists, collection of lectures
- broaden the number of facilities involved to worldwide
- providing video introductions and presenting online
- re-use of the web interface of EuHIT
- tutorial for best-practice data analysis

Use of resources:

Human resources have been used according to the list above.

Problems and corrective actions: none

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Work Package 2: Synergy and communication

Summary

In this Work Package the EuHIT web-portal has been designed, developed and maintained. EuHIT.org serves as an entry point for EuHIT for the broad audience. It is also reliable and comprehensive platform for managing TNAs and for exchanging information and for dissemination of progress of project. EuHIT.org is a visible, searchable and mature website with large community of users - at the end of the project there were more than 500 registered users. Besides that EuHIT consortium members have organized a set of dedicated events, from consortium meetings to large EuHIT Conference.

Transparent online selection procedure for users of the transnational access has been designed and implemented as a part of the EuHIT web portal.

List of Deliveries and Milestones

Deliverable D2.1 ,Initial setup of the EuHIT Web Portal and networking tools' has been delivered on time (delivery date M3)
Deliverable D2.2 ,Full Release of the EuHIT Web Portal and networking tools' has been delivered on time (delivery date M12)

Dissemination Activities

Please list appropriate activities. In the meantime workshops and poster presentations at conferences have been held.

Type: Short presentation and flayers at XXI Fluid Mechanics Conference
Title: EuHIT Programme
Date: 15-18 June 2014
Place: Kraków
Type of audience: Scientific community
Size of audience: 200
Countries addressed: International

Type: Short presentation and flayers at 7th OpenFOAM Workshop
Main Leader: Kamil Kwiatkowski
Title: EuHIT Programme
Date: 23-26 June 2014
Place: Zagreb, Croatia
Type of audience: Scientific community
Size of audience: 250
Countries addressed: International

Type: Short presentation and flayers at XXI Fluid Mechanics Conference
Main Leader: Kamil Kwiatkowski, Konrad Bajer
Title: EuHIT Programme
Date: 15-18 June 2014
Place: Kraków, Poland
Type of audience: Scientific community
Size of audience: 200
Countries addressed: Poland and others

Type: Posters and flyers at ETC14 European Turbulence Conference
Main Leader: Konrad Bajer
Title: EuHIT Programme
Date: 1-4 September 2013
Place: Lyon, France
Type of audience: Scientific community
Size of audience: 500
Countries addressed: International

Type: Presentation at Polish Fluid Mechanics Committee Meeting
Main Leader: Konrad Bajer
Title: European High-Performance Infrastructures in Turbulence (EuHIT) - an opportunity for experimental work in European laboratories
Date: 15 October 2014
Place: Warsaw, Poland
Type of audience: Scientific community
Size of audience: 50
Countries addressed: Poland

Title: European Geosciences Union General Assembly 2016

Type of activity: personal communication, flyers

Main leader: Kamil Kwiatkowski, Jacek Kopeć

Date: 17-22.04.2016
Place: Vienna, Austria
Type of audience: Scientific community, 13500 persons
Countries addressed: International

Project meetings

EuHIT meeting with Coordinator, 23-25.03.2017

EuHIT meeting with Coordinator, 23-27.04.2017 Gottingen,

EuHIT School on Turbulence, Warsaw 3-6.07.2016

EuHIT Turbulence Conference, 2-4.05.2016 Gottingen,

Consortium meeting and Mid-term review, Brussels, Belgium, 26.01-29.01.2015

EuHIT General Assembly, Grenoble, France, 10.05-13.05.2015

EuHIT General Assembly, (via Webex service), 22.07.2015

Extraordinary EuHIT General Assembly, (via Webex service), 03.02.2015

Second EuHIT Meeting in Twente, 11-14 May 2014

EuHIT Kick-Off Metting in Gottingen, 12-13 May 2013,

Publications

Personnel Statistics:

Konrad Bajer (m), 3.5 PM, Scientific Coordinator (till 29.08.2014)
Kamil Kwiatkowski (m), 8.65 PM, Scientific Coordinator (since 01.11.2014)
Wojciech Bedyński (m), 1.05 PM, assistant
Jacek Kopeć (m), assistant, 7.5 PM, assistant
Mateusz Turcza (m), webmaster, 14.5 PM

Task 2.1: Establishment and maintenance of the EuHIT Web Portal, networking tools and internal project communication

Responsible partner: UWAR

Collaborators: MPI-DS

Objectives:

Develop and create the EuHIT web-portal, an entry point to the EuHIT resources and a reliable platform for exchanging information that is available worldwide. Maintenance of the portal, networking tools and internal project communication

Concise overview:

During four years of life-span of the EuHIT.org is has been evolved from static webpage to powerful, comprehensive content-manager system customized to serve the unique needs of large and vivid scientific community.
The portal implemented functionalities according to the „Description of Work" - including advertising the EuHIT facilities and their capabilities to potential users, implementation of online TNAs management, integration with multi-users video-conference system (webex), implementation of so-called EuHIT Drive supporting internal communication and information exchange.
After this first stage the EuHIT.org was revised according to feedback from the community: independent pages for projects, infrastructures or organized events (workshops and conferences). This way portal informs the researchers not directly participating in the project about its activities, broadcast timely recent developments and scientific achievements. Additionally, the news service was implemented.
EuHIT.org presents a dataset of all TNA projects, Joint Research Activities, and publications.

Use of resources:

Konrad Bajer (m), Scientific Coordinator, 1.5 PM

Kamil Kwiatkowski (m), Scientific Coordinator, 1.15 PM

Wojciech Bedyński (m), assisant, 1.05 PM

Jacek Kopeć (m), assistant, 7.5 PM

Mateusz Turcza (m), technician, 7.5 PM

Problems and corrective actions:

Task T2.1 is performed as planned.

Task 2.2: Management of access provision

Responsible partner: UWAR

Collaborators: MPI-DS

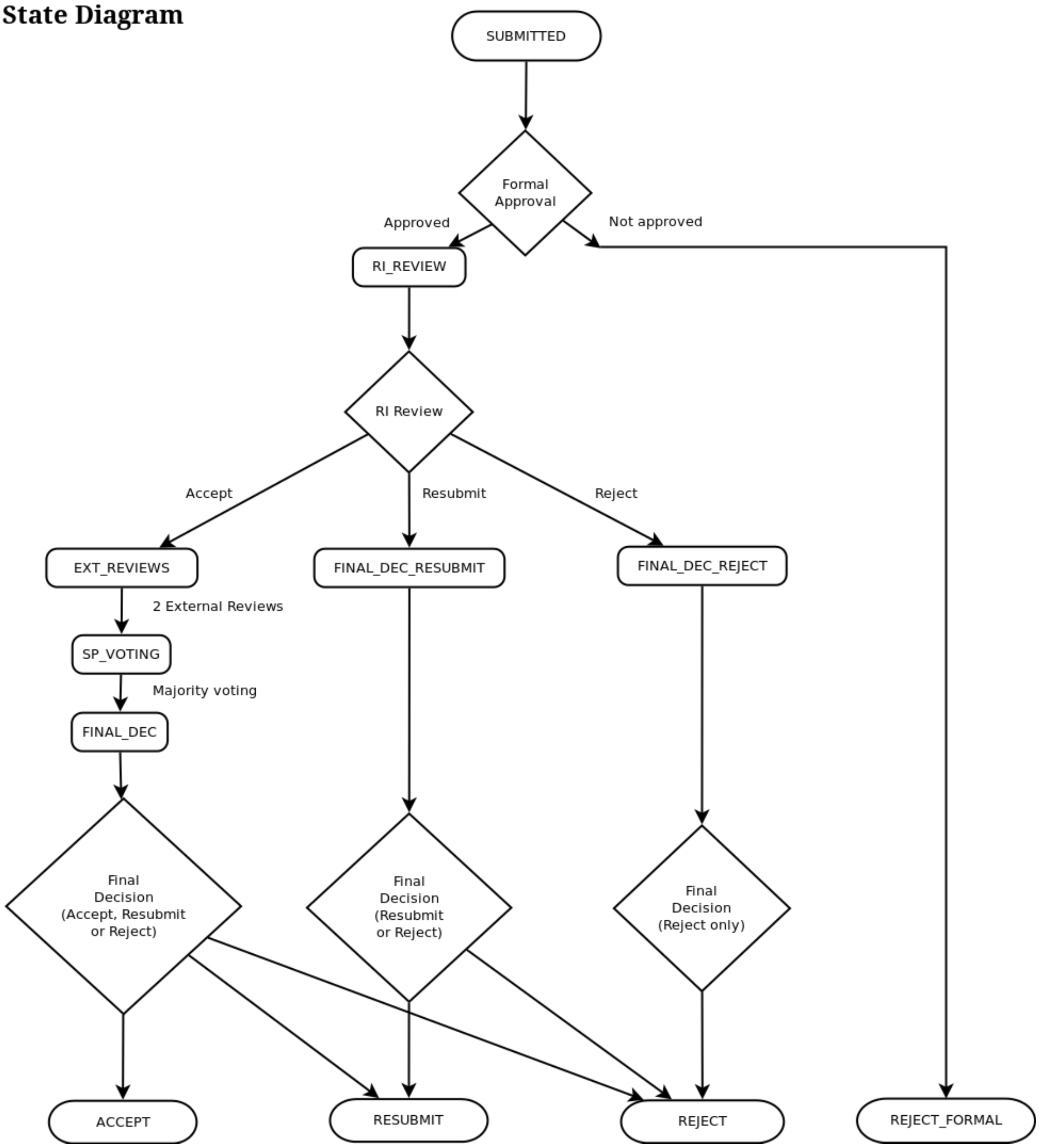
Objectives:

Managing of the submission, evaluation and management of TNA proposals. Fine-tuning of the selection procedure for users of the TNAs, maintenance online system.

Concise overview:

Transparent online system for submission and evaluation of TNAs proposals was implemented. It follows the procedure:

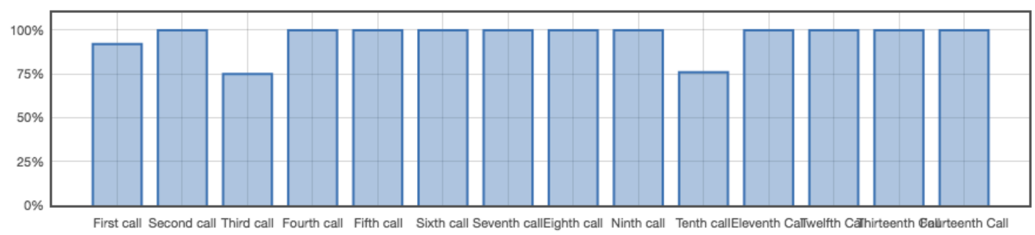
EuHIT Proposal Evaluation State Diagram



In total fourteen calls for TNAs proposals were open (https://www.euhit.org/transnational-access/call-schedule)

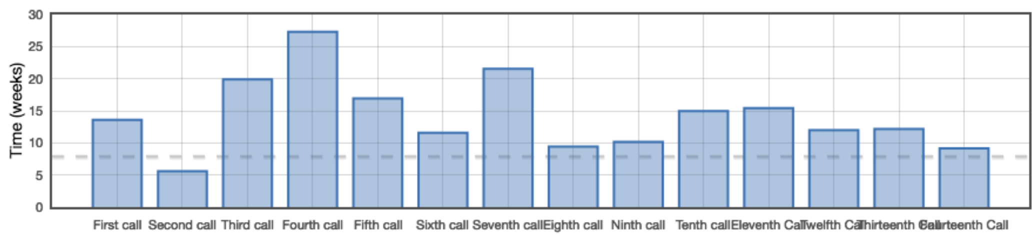
Fourteenth Call	1 October 2016 – 1 November 2016,	7 proposals
Thirteenth Call	27 June 2016 – 30 August 2016,	4 proposals
Twelfth Call	2 May 2016 – 1 June 2016,	5 proposals
Eleventh Call	1 February 2016 – 6 March 2016,	7 proposals
Tenth call	4 October 2015 – 2 November 2015,	13 proposals
Ninth call	5 July 2015 – 3 August 2015,	4 proposals
Eighth call	5 April 2015 – 11 May 2015,	2 proposals
Seventh call	4 January 2015 – 9 February 2015,	3 proposals
Sixth call	5 October 2014 – 3 November 2014,	3 proposals
Fifth call	6 July 2014 – 6 August 2014,	2 proposals
Fourth call	6 April 2014 – 10 May 2014,	6 proposals
Third call	5 January 2014 – 4 February 2014,	4 proposals,
Second call	6 October 2013 – 11 November 2013,	1 proposal
First call	9 July 2013 – 16 September 2013,	13 proposals

Percentage of accepted proposals in each call



Calls marked with asterisk (*) are not yet completed.

Average proposal evaluation time



8 weeks (dashed line) is the advertised length of the evaluation process. Proposal evaluation time is measured from the closing of the respective call to the submission of the final decision. Calls marked with asterisk (*) are not yet completed.

Use of resources:

Konrad Bajer (m), Scientific Coordinator, 2 PM

Kamil Kwiatkowski (m), Scientific Coordinator, 7.5 PM

Problems and corrective actions:

Task T2.2 is performed as planned.

Task 2.3: Periodic Meetings and the EuHIT Conference

Responsible partner: MPI-DS

Collaborators: UTWENTE, CEA, CNRS

Objectives:

The kick-off meeting and the two periodic meetings gathering about 50 participants and focused on the interaction of different research groups and on the cross-flow of ideas between theoretical, experimental and numerical turbulence research communities shall be organised. EuHIT Partners and groups of researchers active in related science communities, on one hand, and representatives of the institutions and funding agencies involved in the research infrastructures, on the other hand, are to be invited. One of the aims is to give a chance to funding agency representatives to appreciate directly the added value and the beneficial effects of the innovative approach to the experimental research resulting from the joint exploitation of the integrated Research Infrastructures. For each periodic meeting a committee shall be appointed, subject to the approval
of the EuHIT Steering Committee. The committee prepares the programme of the Meeting. Participation is by invitation only, but the events are well publicised to ensure good representation of expertise covering the entire field of turbulence research, Efforts shall be made to ensure broad representation of the public bodies funding and operating the Research Infrastructures.

At the end of the EuHIT project, a EuHIT CONFERENCE and the final consortium meeting shall be organised. EuHIT is expected to yield a large number of significant scientific results, which will motivate an international conference of broad interest. The Conference shall be broadly advertised using all EuHIT networking tools, so as to maximize its impact on the European turbulence research community, and to attract a wide participation beyond the EuHIT Partner institutions. The participation of young researchers, especially from the peripheral and outermost regions, shall be at least partially sponsored. Representatives of the industrial R&D groups involved in turbulence research and officials from the research infrastructure operating institutions shall be invited to participate. The conference aims to document the strength and importance of turbulence research and to demonstrate the advantages of innovation through integration of research communities and infrastructures. Three main effects are expected from periodic meetings and EuHIT Conference:

- Broad advertisement of the EuHIT Trans-National Access programme to all external scientific communities as an unprecedented opportunity to programme ad-hoc experiments, access a large and controlled collection of data, verify ideas and hypothesis on the highest performance turbulence facilities available in Europe;

- Promotion of the idea of „innovation through integration" in fundamental as well as applied research;

- Maximum dissemination of the scientific results obtained in the context of the EuHIT project towards related science communities.

Concise overview:

All periodic meetings of the GA as well as the EuHIT Conference have been organized and have been delivered as planned. Additionally, the mid-term review and the workshop of the GTF facility have been used for an aside meeting and two virtual meetings of the GA have been organized via a video conference system.

- Kick-off Meeting: May 13, 2013, Göttingen
- 2nd Periodic Meeting: May 12 – 13, 2014, Twente
- Mid-Term Review Meeting: January 28 - 29, 2015, Bussels
- 3nd Periodic Meeting: May 11 - 12, 2015, Grenoble
- GA Meeting: July 22, 2015 (web conference)
- GA Meeting: February 3, 2016 (web conference)
- EuHIT Conference and GA Meeting: May 2 – 4, 2016, Göttingen
- EuHIT Workshop Göttingen Turbulence Facility and ICTR Rebirth Meeting: February 14, 2017, Göttingen

The Conference was a suitable platform for all TNA users to demonstrate their experiments and their respective results. The users performing experiments at the facilities have been invited to give presentations at the conference. A separate deliverable report has been handed in.

The GA meetings have been used to coordinate the work between partners for each WP as well as for the EuHIT consortium as a whole. Important aspects e.g. of finance redistributions have been discussed there.

Use of resources:

Holger Nobach (m), Scientific Secretary, 5 PM

Sabrina Volkmar (f), Administrative Assistant, 5 PM

Problems and corrective actions:

Task T2.3 is performed as planned.

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

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Work Package 3: Innovation through integration

Summary

The aim of WP3 is to increase the potential of the EuHIT research infrastructures for innovation by stimulating and supporting partnership and transfer of knowledge with industry, and by fostering the use of the EuHIT research infrastructures by industrial researchers.

List of Deliveries and Milestones

Deliverable D3.1 Final Report on Outreach and Industry Relationships (month 48)
Deliverable D3.2 Final Report on Dissemination Activities (month 48)
Deliverable D3.3 Final Report on Scientific Workshops (month 48)
Deliverable D3.4 EuHIT School on Turbulence (month 48)

Dissemination Activities

Please list appropriate activities. In the meantime workshops and poster presentations at conferences have been held.

1. Title: **EuHIT website**
   Type of activity: website
   Main leader: UWAR
   Date: permanent
   Place: http://www.euhit.org
   Type of audience: potential users, research community
   Countries addressed: international

2. Title: **EuHIT TNA videos**

	Type of activity:	video
	Main leader:	MPI-DS
	Date:	permanent
	Place: (compilation)	https://www.euhit.org/about/what-is-euhit from https://www.euhit.org/infrastructures for each individual infrastructure
	Type of audience:	potential users, research community
	Countries addressed:	international
3.	Title:	**EuHIT workshops**
	Type of activity:	website (announcements and organization)
	Main leader:	UWAR
	Date:	permanent
	Place:	through http://www.euhit.org - Community
	Type of audience:	potential users
	Countries addressed:	Europe
4.	Title:	EGU General Assembly 2016
	Type of activity:	Advertisement
	Main leader:	UWAR
	Date:	April 17–22, 2016
	Place:	Vienna, Austria
	Type of audience:	International Scientists working on Geosciences
	Countries addressed:	international
5.	Title:	Workshop on the Atmospheric Stable Boundary Layer
	Type of activity:	Advertisement
	Main leader:	UWAR
	Date:	March 26–31, 2017
	Place:	Delft, The Netherlands
	Type of audience:	International Scientists on Atmospheric Turbulence
	Countries addressed:	international
6.	Title:	EuHIT School on Turbulence
	Type of activity:	Advertisement, Training, Dissemination
	Main leader:	UWAR
	Date:	July 3–6, 2016
	Place:	Warsaw, Poland
	Type of audience:	International Young Researcher
	Countries addressed:	international

7. Title: Warsaw Fluid Dynamics Week
   Type of activity: Advertisement, Training, Dissemination
   Main leader: UWAR
   Date: July 3–9, 2016
   Place: Warsaw, Poland
   Type of audience: International Young Researcher
   Countries addressed: international

Project meetings

Besides the meetings of the General Assembly, there are no regular meetings among or between the groups. The groups stay in an intensive contact according to the tasks, which are related to all travel (meetings, announcements, TNA travel) and to the coordination of the EuHIT online presence.

Publications

There are no publications in this WP.

Personnel Statistics (MPI-DS):

1. Name: Eberhard Bodenschatz
   Task: Work Package Leader
   Gender: male
   PM: 0
2. Name: Holger Noabch
   Task: Project Manager
   Gender: male
   PM: 0
3. Name: Sabrina Volkmar
   Task: Assistant
   Gender: female
   PM: 1.5

Personnel Statistics (UWAR):

1. Name: Kamil Kwiatkowski
   Task: Scientific Coordinator
   Gender: male

PM: 9

2. Name: Jacek Kopeć
   Task: Scientific Assistant
   Gender: male
   PM: 8

3. Name: Mateusz Turcza
   Task: Technician
   Gender: male
   PM: 4

Task 3.1 Outreach to industry

Responsible partner: MPI-DS

Collaborators: none

Objectives:

The Management is responsible for establishing and maintaining partnership of the EuHIT RIs with the industry. MPI-DS creates and maintains a database of the industrial R&D representatives and researchers in the companies involved in turbulence-related activity. Those representatives are to be regularly informed about the developments in the EuHIT project and are to be invited to participate in the EuHIT events. Industrial R&D community shall be encouraged to use the EuHIT web-portal. Every effort shall be made to foster the use of the research infrastructures by industrial researchers, with the aim of increasing the potential for innovation of both the RIs and of the companies.

Concise overview:

Collaborations with industry have been initiated and continuously intensified. Various contacts and cooperations exist with e.g. Dantec Dynamics (Skovlunde, Denmark), German Aerospace Center (Götingen, Germany), LaVision (Göttingen, Germany), Vision Research (Wayne, USA).

Use of resources:

Human resources have been used according to the list above.

Problems and corrective actions: none

Task 3.2 Dissemination and exploitation of project results

Responsible partner: UWAR

Collaborators: MPI-DS

Objectives:

Implementation and maintaining of the online database for sharing and disseminating EuHIT results. Providing tools for EuHIT community and partners to disseminate scientific outcomes and results.

Organization of international summer school gathering young researchers and providing the comprehensive training on turbulence flows, with special interest on the experimental research conducting within EuHIT.

Concise overview:

The main outcome of this task - the publicly available dataset of project results - is integrated with EuHIT.org. The dataset is available via the EuHIT Drive Tool - a comprehensive on-line tool for sharing and disseminating publications and other materials. EuHIT Drive was adjusted for the purpose of disseminating all kind of results produced by the EuHIT Consortium and EuHIT partners. The database is optimized to contain:

- Articles and publications (preferred PDF format, other possible)
- Images and diagrams (preferred JPG and PNG, other possible)
- Photos (preferred JPG and PNG, other possible)
- Presentations (preferred PDF, other possible)
- Videos (embedded link to external video services)
- Other (archives, spreadsheets, etc.)

The outcome of the EuHIT scientific Work Packages is presented via the WP public profiles, implemented individually for TNA WPs, JRA WPs and separately for Turbase (Turbase profile eg. including datasets synchronization, cryogenic WPs organised joint workshop, thus the workshop page common in their profiles). Every profile contain a publication database - easily imported from bibTex or RIS files, based on this individual databases the joint dataset of EuHIT-related publications is developed (https://www.euhit.org/publications).

Part of dissemination activity is preparing package of promotional materials available for EuHIT community - the materials have been revised. Such package include currently: high quality logo, EuHIT flyer, EuHIT poster, short presentation and set of high-quality professional movies dedicated to each RI and longer movie (click ‚play video' at the EuHIT front page) summarizing EuHIT.

Important task that UWAR has undertaken is the organization of the training of young researchers, the EuHIT School on Turbulence (EST).
The four lectures were selected based on their scientific excellence and educational performance:

- prof. Gregory Falkovich - who perfectly introduce to the turbulence science as a ‚meeting point'
- dr Michael Wilczek - who provides excellent theoretical background
- dr Greg Voth - who introduced fundamental experimental technics
- prof. Hrvoje Jasak - was invited to introduce general concept of numerical modeling of turbulent flow and the OpenFOAM code as a tool.

Important contributions to the School were presentations and consultancy given by the representatives of almost every EuHIT facilities and Turbase developers.

With over 100 participants from EuHIT eligible countries we consider this event a major dissemination effort. The EST was paired with another event – 8th European Postgraduate Fluid Dynamics Conference to create Warsaw Fluid Dynamics Week 2016 – a unique event dedicated to fluid dynamics where EuHIT plays a key role.

Importantly, around 20 travel grants, awarded by the best young researchers who were not able to cover travel costs themselves, significantly increased the visibility and popularity of the events.

Use of resources:

Kamil Kwiatkowski (m), scientific coordinator, 9.0 PM,

Jacek Kopeć (m), assistant, 8.0 PM,

Mateusz Turcza (m), technician, 4.0 PM

Problems and corrective actions:

Task T3.2 is performed as planned.

Task 3.3 Workshops at the facilities

Responsible partner: MPI-DS, CEA, TUIL, UTWENTE, UNIBO, ICTP, CERN, CNRS, CUNI, FAU, UNITO, CINECA

Collaborators: none

Objectives of the third reporting period (month 37 - 48):

Each of the RIs locations should perform a workshop to reach potential users of the installations. No specifications have been made on the schedule.

Concise overview:

There have been performed five Scientific Workshops by the TNA facilities of EuHIT. Instead of having individual workshops at each facility, facilities with common orientations have joint to perform workshops together to maximize the impact on the scientific community and to better reach potential users. This way the respective facilities could better announce their special features in comparison to the other competitive facilities.

The performed workshops are

- Wall Turbulence and Advanced Measurement Techniques at Lille (beneficiary CNRS), May 18-19, 2015
- EuHIT Cryogenic Turbulence Workshop (beneficiaries CERN, CUNI, CEA, ICTP), 26-29 Oct. 2015
- High-Reynolds Number Turbulent Flows (beneficiary UNIBO, UNITO), Sep. 5-6, 2016
- Göttingen (beneficiary MPIDS), Feb. 14, 2017
- Ilmenau (beneficiary TUIL), 15-16 Feb. 2017

Use of resources:

The various partners are responsible for the realization of the workshops.

Problems and corrective actions: none

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 4: TurBase: Establishing a virtual turbulence research community

Summary

The following description of TurBase is taken from the WP4 description:

"WP4: TurBase: Establishing a virtual turbulence research community.
The development of a culture of cooperation between research infrastructures in the turbulence research community is further fostered through the creation of ***TurBase****, an easily accessible knowledge-base infrastructure for high quality turbulence data. TurBase requires a considerable collaborative and networking activity in order to pool and highlight the needs of the scientific communities, to establish common standards and metadata structures, to develop a suitable library of Application Programming Interface and to disseminate the acquired knowledge also outside EuHIT. TurBase is the backbone of the EuHIT integrated activity, which greatly facilitates the scientific objectives of the research infrastructures, as well as their mutual interactions. The activity produces the fundamental specifications necessary for the development of the library components and the access tools, improving dissemination and exploitation of scientific results obtained at research infrastructure nodes. The activity contributes to foster collaboration within the research community allowing benchmarks and validations of different data sets within the same data formats, and improving the accessibility of data from all end-users. Definition of 'best practices' and deployment of standardized data promotes clustering of new research initiatives helping the growth of a wider community in the European area. The impact of TurBase extends well beyond the lifetime of EuHIT."*

The activities carried out in WP4 are aimed at the development of the TurBase infrastructure and consist in the following tasks:

TASK 4.1: Networking activity aimed at identifying fundamental classes of turbulent data.
TASK 4.2: Specification of the data model for identification, indexing and search in the TurBase database.
TASK 4.2.1: Help Desk and API.
TASK 4.3: Articulation with other activities.

All tasks have been completed (i.e. the corresponding deliverable were delivered). Importantly, TurBase is currently functional and used by the EuHIT community and the world.

List of Deliverables

D4.1) Formalization of the basic and extensible TurBase metadata model, consistent with the requirements of being capable to represent data content/structure/quality. [month 12 - completed]
D4.2) Beta version of TurBase operational. TurBase is made available to TNAs for indexing their data and to allow tagging them for content/structure/quality. [month 30 - completed]
D4.2.1) Help Desk and API. [month 36 - completed]
D4.3) TurBase fully operational.

Dissemination Activities

Title:	TurBase (and TurBase Service)
Type of activity:	web site
Main leader:	CINECA
Date:	deployed in March 2014, updates in progress
Type of audience:	scientific community
Countries addressed:	worldwide accessible

Project meetings

Aside from the general project meetings, the main partners that are mainly involved in the activities of the WP4 had regular bilateral meetings as well as regular (roughly bi-monthly) online meetings.

Publications

Not applicable.

Personnel Statistics:

TU/e

Scientific Coordinator

- F. Toschi (m), 2.8 PM

Experienced Researcher

- S. Tympel (f), 14 PM

Technician

- A.P.C. Holten (m), 3 PM

Senior Researcher

- H.J.H. Clerx (m), 1.1 PM
- R.P.J. Kunnen (m), 3 PM

UTOV

Senior Researcher

- L. Biferale (m), 2.5 PM
- R. Benzi (m), 2.8 PM

Experienced Researcher

- F. Bonaccorso (m), 12.5 PM

CINECA

Data manager

- C. Cacciari (m), 1.89 PM

Experienced developer

- F. Salvadore (m), 10.69 PM

Liason between WP4 and WP18 and management

- G. Erbacci (m), 2.15 PM
- P. Alberigo (f), 0.17 PM

Storage Infrastructure management, Support and Operations

- G. Chillemi (m), 7.52 PM
- N. Sanna (m), 0.88 PM
- G. Amati (m), 3.89 PM

CNRS

Senior researchers

- Alain Pumir (m), 0.15PM
- Mickaël Bourgoin (m), 0.02PM
- Jennifer Jucha (f), 1.83PM

NB: In regards to the personnel statistics it is important to underline that, as agreed at the review meeting with EC, in WP4 Cineca claims more effort than the one initially planned in the DoW, due to the management and the service of the Storage infrastructure that Cineca puts at disposal of the EuHIT programme in WP18 (at no cost). In WP4 CINECA provides the management and the technical support for the Europe's largest digital library service for data coming from numerical simulations and experiments in the field of turbulence, hosted on the CINECA HPC and Data Facility. This activity contributes to maintain the digital library service robust, open, and extensible, and to support the development of advanced services fostering data analysis and integration.

Task 4.1 Networking activity aimed at identifying fundamental classes of turbulent data

This activity aims at identifying the fundamental classes of turbulent data that require individual characterization (scouting for the possible raw data that may enter the TurBase). This task allows defining the “data alphabet” out of which to build the TurBase language and syntax (i.e. the suggested standardized data formats and metadata descriptors both for data and database). The EuHIT Consortium shall prompt the community to select a wide set of heterogeneous data sets, available and future, which needs to be classified and disseminated among the community. The metadata model for the scientific data shall be characterized by a restricted and extensible set of physical parameters (physical metadata) facilitating the integration, identification and reuse of data from different communities for specific problems (e.g. Lagrangian turbulence, thermal convection, cryogenic turbulence, boundary layer, etc.) and of different type (numerical, experimental, etc.) This also allows to include specifications on the used instrumentation and the data quality (spatial and temporal resolution, accuracy, boundary conditions, etc. which are as important as the data for the end user). D4.1

Responsible partner: 17

Collaborators: 8, 13, 16

Concise overview: the project was completed by month 12.

Use of resources: not applicable

Problems and corrective actions: not applicable

Task 4.2 Specification of the data model for identification, indexing and search in the TurBase database.

The data in the TurBase shall be characterized by the physical metadata (Task 4.1) and by additional metadata necessary to uniquely characterize, index, search, and the data sets. In order to make the tool flexible and user-friendly, the easiest and the most efficient standards to simplify the use of the data need to be identified. Standards evolve throughout the networking activity, through interaction between TurBase, TNAs and the users. A standard shall be disseminated and updated during the duration of the project. Moreover, the project develops basic software adapters that allow the end users to easily interface with the TurBase. Additional API, programs and tools developed by TNAs or TNA users to access, manipulate or analyse the different data (encoded either in the recommended formats as well as in proprietary raw format) shall be hosted on the TurBase. The collection of these additional tools will further improve the accessibility and usability of the data in the knowledge base. D4.2

Responsible partner: 13

Collaborators: 8, 16, 17

Concise overview: This activity was already started during the first reporting period. During this reporting period the activity was completed and the corresponding deliverable delivered. The infrastructure of TurBase and its usability were considerably improved in this period also based upon the feedback from users and the help desk activity.

Use of resources: The use of resources appears in line with what was originally expected.

Problems and corrective actions: In the beginning the alpha version of TurBase was implemented on CKAN (Comprehensive Knowledge Archive Network), which is an open-source content delivery portal. For a number of reasons, detailed in the deliverable D4.2, this choice was not considered flexible enough for our purposes. During this period the TurBase portal was thus completely rewritten using as basic building block the following software stack: **Web2py** ◦ A robust framework for creating web servers in Python; **AngularJS** ◦ Used as front-end framework, it offers intuitive interaction for the users; **Elasticsearch** - A search-engine library, which is powerful and highly customizable. It can address all the requirements of Turbase Portal regarding searching the data in all the metadata previously added to the datasets, with almost no overhead when editing the database to add/edit/remove tags or files. **During this transition** The beta version of Turbase still maintain the alpha version concept of datasets (fundamental in CKAN) and all datasets were re-imported, to make sure not to have any impact on the users of Turbase. Both **editors**, which create and maintain datasets, and **users**, which search/browse/download data from datasets, are offered the familiar structure they were used to, even though the new version guarantees some new features not previously present.

Task 4.2.1 Help Desk and API:
Correctly describing datasets is the key for having a high quality repository of turbulence data. Helping the uploaders at better annotating experimental data with finer metadata will lead to reach a higher overall quality of the TurBase knowledge base. Suggestions from early users, will be used to decide how to improve the usability. A dedicated service to inspect datasets without downloading them, using a few IPython based interactive infrastructure can be further developed. Supporting the dataset authors in converting or creating IPython codes might significantly improve the quality of the service, depending on the feedback from the users. Moreover, a good and well documented API (or IPython library) for typical statistical analysis of the turbulence data can further improve the user friendliness of TurBase.

Responsible partner: 13

Collaborators: 8, 16, 17

Concise overview: The goal of this task was two-fold. First, we aimed to establish and continuously provide support for users aiming to upload their data (Help Desk). Second, we aimed for developing a tool which allows researchers to access and investigate data without the need to download them. The following summary for the help desk is taken from the report of Deliverable D4.2.1: "In particular, we have offered a **day-by-day help-desk** to guide the dataset editors to better describe and to better organize their data. The activity of the WP4 has focused on: **(i)** helping selecting alternative **file formats** to achieve an offer to the end-user as uniform as possible; **(ii)** to optimize the **number of files** in each dataset (in some cases splitting the experimental result in more than one dataset was a way to improve the usability of the data); **(iii)** to optimize some aspects related to the **web-based** nature of the TurBase service (downloading a big number of small files is not a comfortable web experience)." In addition, we monitored the classification of datasets, the number of datasets uploaded, and dataset quality. In addition, a tool was developed, currently called "TurBase Service" and accessibly from within TurBase, which allows users to use the data without the need to download them first, aiming at lowering the barrier for reanalyzing data acquired by (other) members of EuHIT. Currently, there exist a number of example notebooks which allow the user to access data on TurBase.

Use of resources: The use of resources appears in line with what was originally expected.

Problems and corrective actions: -

Task 4.3 Articulation with other activities.

Facilitating the exchange of data among the various facilities is of utmost importance to provide a deeper understanding of the data obtained in the various TNAs, which is ultimately the scientific objective of the project. A final goal of the WP is to make TurBase easily accessible, provide manuals, and recommendation for users and administrators. D4.3

Responsible partner: 13

Collaborators: 8, 16, 17

Concise overview: The DLTD has been considerably improved and is hosting datasets from TNAs accesses performed. The TurBase portal is functional and allows users to browse and download data.

Use of resources: The use of resources appears in line with what was originally expected.

Problems and corrective actions: -

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 5: Access to Göttingen High-Turbulence Facilities (GTF)

Summary

Three installations were accessible under this WP, the Göttingen Turbulence Wind Tunnel (GTF1), the Göttingen U-Boot (GTF2) and the Göttingen von Kármán mixer (GTF3). A total of four user groups accessed GTF1, four accessed GTF2 and three accessed GTF3.

1. Acoustic Lagrangian Measurements (AcLag)
This project aimed to characterize the Lagrangian and vorticity statistics in high Reynolds number flows, using ultrasonic scattering allowing for a spectral measurement of turbulent velocities in the GTF1. Being able to use such acoustic diagnosis in highly pressured SF_6 opens new possibilities of metrology measurements. This successfully finished project covered 35 user days. It was supervised by Mickael Burgoin (LEGI, Grenoble at that time, now ENS Lyon, France) with significant contributions by Christophe Baudet (LEGI, Grenoble), Nicolas Mordant (LEGI, Grenoble) and Mathieu Gibert (Institut Neel, Grenoble).

2. Stirring and decay of turbulence (tdecay)
9 user days covered the study of influence of active-grid stirring protocols on the correlation properties of the generated turbulence. Results show that there was a large influence of the stirring protocol on the correlation properties of the flow as well as subtle effects on the downstream decay of turbulence were observed. The project is supervised by Willem van de Water with main contributions by Kevin Griffin and Nathan Wei. To finalize and validate the results, 51 more user days of GTF1 access were necessary for the users.

3. Array of anemometers in Grid Turbulence (AiRTiGhT)
An array of anemometers of various operating principles was mounted in GTF1 and operated up to very large Reynolds numbers. The majority of these probes had been developed for other fluids (air, cryogenic helium) and had never been operated before

in SF6. The measurement campaign benefited from a unique two-dimensional active grid, recently commissioned in this facility. This grid was used to generate randomly distributed eddies. The resulting turbulent flow was probed with the anemometer array nine metres downstream of the grid. The experiment has demonstrated the relevance of cryogenic probes in SF6 experiments. Indeed, cryogenic probes are designed with two constraints also found in the present facility: very intense turbulence and limited access to the flow. In cryogenic helium flows, probes should have high spatial and time resolution (to resolve all turbulent fluctuations), a robust design (because replacing a broken probe takes can be time consuming) and compatible with in-place calibration procedure. These three characteristics are also relevant to GTF1 tunnel.

4. Turbulence Generated by Sparse 3D Multi-Scale Grid (M3DSG)

The main goal of this project was to build a 3D sparse grid and to understand how such a grid introduces and influences the turbulences in a wind tunnel. Using hot wire anemometry, the flow was measured behind the grid at different grid configurations and flow speeds. This project was led by Jose M. Redondo (Barcelona, Spain). Other team members involved were Jacek Kopec and Kamil Kwiatkowski (both Warsaw, Poland) as well as Nadeem Malik (Dhahran, Saudi Arabia) and Jackson Teller Alvarez (Barcelona, Spain). At the time of this report, results from this work have been presented at the EGU General Assembly conference (2017) in Vienna, Austria. Another abstract has been submitted for the 12th Ercoftac Workshop on Synthetic Turbulence in Paris, France (will be held in July 2017).

5. Plume visualization by Light Induced Fluorescence in a rotating Rayleigh-Bénard convection (VisPlumes)

The goal of this project was to investigate rising (hot) and sinking (cold) plumes in Rayleigh-Bénard convection using two color Laser Induced Fluorescence. How do the plumes interact with the large scale flow field, how are they deformed due to Coriolis forces, and especially what is their contribution to the convective heat transport through the cell. The project was proposed and conducted by Denis Funfschilling (project leader) and Viswa Moturi (both University of Strasbourg) during 20 user days at our facility. Results were presented at the International conference on Rayleigh-Bénard convection in Göttingen (June, 2015).

6. Rotating turbulent Rayleigh-Bénard convection at high Prandtl numbers (PrandtlRotConvec)

The goal of this project was to investigate the behavior of plumes in a fluid of high Prandtl numbers in Rayleigh-Bénard convection under rotation. Within 8 user days experiments were performed using two-color laser induced fluorescence thermometry. The project was proposed and conducted by Denis Funfschilling (project leader) and Viswa Moturi (both University of Strasbourg). The project is still continuing as collaboration between the University of Strasbourg and MPIDS.

7. Rotating thermal convection at very large Rayleigh numbers (Turb_Rot_RBC)

The goal of this project was to investigate how slow and moderate rotation rates influence the heat transport in turbulent thermal convection. One particular focus was to investigate the geostrophic regime. Understanding this regime, where pressure gradients are balanced by Coriolis forces, is most relevant for atmospheric convection. Experiments were performed during 180 days. Project leader was Dennis van Gils (TU Twente, The Netherlands). Results have been reported during the Annual conference of the Division of Fluid Dynamics of the APS in Portland (USA), 2017.

8. Heat Transfer at Supercritical conditions in Natural Convection (HTSCRB)

This project aim was to investigate how strong deviations from Boussinesq conditions affect the heat transport in Rayleigh-Benard convection. As the working fluid, sulfur heaxafluoride (SF6) was used above its critical point, where its physical properties depend strongly on the temperature. It was found that the heat transport changes under non-Boussinesq conditions. More particular an increase of up to 15% was found in comparison to the OB conditions at constant Rayleigh- and Prandtl numbers. Measurements were done within 67 days of use. The project leader was Valentina Valori (TU Delft, The Netherlands). Results will be published in her PhD thesis and in a journal paper currently in preparation.

9. Distribution of separations and relative velocities of droplets in turbulence (DiSeRe)

This ongoing project covered 23 user days of access to GTF3 under the supervision of Bernhard Mehlig (Gothenburg) with contributions by Kristian Gustavsson (Gothenburg). The aim of this project was to observe Lagrangian velocities of droplets in the Göttingen von Kármán mixer and their relative separation with regard to time.

10. Dense particle tracking of inertial and Lagrangian particles in isotropic turbulence flows (DTrack)

This user project occupied the GTF3 facility for 112 days under the leadership of Vicente Pérez-Muñuzuri. The project made measurements of densely-seeded fluid particle trajectories over a range of Reynolds numbers with the Shake-The-Box Lagrangian particle tracking algorithm, pushing the envelope of dense particle tracking in turbulence. Analysis of the large (40TB) experimental dataset is still ongoing and will provide insights into the dynamics of three-dimensional flow structures at the smallest lengthscales of turbulence.

11. Experimental investigation of the refined similarity hypothesis (K62SCAN)

This project covered 75 user days of access to GTF3 under the supervision of Nicholas Worth (NTNU) and John Lawson (MPIDS) with experimental assistance from Anna Knutsen (NTNU) and contributions from James Dawson (NTNU) and Eberhard Bodenschatz (MPIDS). The aim of this project is to provide the first, direct experimental assessment of Kolmogorov's refined similarity hypothesis without resort to surrogates for the volume average dissipation rate, which has confounded the results of previous experimental investigations of this hypothesis. Spatially resolved volumetric measurements of the velocity and velocity gradient fields were obtained using Scanning PIV, in addition to two-dimensional measurements made with Stereo PIV. The Scanning PIV dataset is of unprecedented size (70TB) and high measurement fidelity and will be suitable for direct assessment of a profound theory of turbulence which has eluded direct experimental assessment for over half a century.

List of Deliveries and Milestones

No deliveries, no milestones in this WP

Dissemination Activities

Publication/Oral presentation/Poster to a scientific event:

Stanley Corrsin Award Lecture: Lagrangian Measurements in Turbulence: From Fundamentals to Applications

E. Bodenschatz, American Phyisical Society 67th Annual DFD Meeting, Nov. 23-25, San Francisco, USA

The Göttingen rotating turbulent Rayleigh-Bénard convection facility
Dennis van Gils, Xiaozhou He, Guenter Ahlers, Eberhard Bodenschatz, 15th European Turbulence Conference, August 25th-28th 2015, Delft, Netherlands

The Göttingen rotating turbulent Rayleigh-Bénard convection facility

E. Bodenschatz, D. P. M. van Gils, X. He, G. Ahlers, 68th Annual Meeting of the American Physical Society's Division of Fluid Dynamics (DFD), Boston, USA

Turbulence decay downstream of an active grid

G. Bewley, E. Bodenschatz, 68th Annual Meeting of the American Physical Society's Division of Fluid Dynamics (DFD), Boston, USA

Dense Lagrangian particle tracking in homogeneous turbulence

F. Huhn, D. Schanz, A. Schröder, D. Garaboa-Paz, V. Pérez-Muñuzuri, J. Lawson, E. Bodenschatz. 12th International Symposium on Particle Image Velocimetry, Busan, Korea, June 2017

Dense Lagrangian particle tracking in homogeneous turbulence

D. Garaboa-Paz, V. Pérez-Muñuzuri, F. Huhn, D. Schanz, A. Schröder, J. Lawson, E. Bodenschatz. 21st Congress of Statistical Physics, Seville, Spain, April 2017

K62SCAN: Experimental assessment of the refined simiarity hypothesis

A. N. Knutsen, J. M. Lawson, N. A. Worth, J. R. Dawson, E. Bodenschatz. 16th European Turbulence Conference, Stockholm, Sweden, August 2017

Conferences:

International Conference on Rayleigh-Bénard Turbulence

Göttingen 1.6. - 5.6. 2015

Scientific Committee:

Guenter Ahlers (University of California, Santa Barbara, USA)
Eberhard Bodenschatz (Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany)
Detlef Lohse (University of Twente, Enschede, The Netherlands)
Olga Shishkina (Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany)
Ke-Qing Xia (The Chinese University of Hong Kong, Shatin, Hong Kong)

Organising Committee:

Olga Shishkina
Susanne Horn
Sebastian Wagner

EuHIT Turbulence Conference

Göttingen, 2.5.-4.5. 2016

Web sites:

http://www.ds.mpg.de

Exhibition stands:

15th European Turbulence Conference 2015

Delft, Netherlands, August 25-28, 2015

American Physical Society 68th Annual DFD Meeting

Boston, Massachusetts, November 22-24, 2015

Video presentations:

https://www.euhit.org/infrastructures/gottingen-turbulence-facilities

Scientific Publications

Kevin Griffin, Nathan Wei, Willem van de Water and Greg Bewley, **"Stirring and decay of turbulence"** (to be submitted)

Personnel Statistics:

Scientific Coordinator

Prof. E. Bodenschatz (m)

Work package leaders:

Prof. E. Bodenschatz (m)

Experienced researchers:

Prof. E. Bodenschatz (m)

Prof. G. P. Bewley (m)

Prof. H. Xu (m)

Prof. X. He (m)

Dr. H. Nobach (m)

Dr. S. Weiß (m)

Dr. G. Bagheri (m)

Dr. M. Sinhuber (m)

Dr. J. Lawson (m)

Dr. J. Molacek (m)

Dr. F. Nordsiek (f)

PhD students:

P. Prabhakaran (m)

Undergraduate students:

Leo de Maeyer (m)

Christian Küchler (m)

Other:

Engineer: Dr. A. Kubitzek (m)

Technicians: A. Kopp (m), A. Renner (m), M. Meyer (m)

Task: Access to Göttingen High-Turbulence Facilities (GTF)

Acoustic Lagrangian Measurements (AcLag)

Installation:	GTF1
Project Leader:	M. Bourgoin (LEGI, now ENS Lyon)
Team:	Christophe Baudet (LEGI) Nicolas Mordant (LEGI) Mathieu Gibert (Institut Neel)
Significant results:	The users performed promising experiments of ultrasonic scattering, allowing a spectral measurement of turbulent vorticity in GTF1. The feasibility of using such acoustic diagnosis in a high pressure SF6 facility open new metrology possibilities.
Publications:	In preparation

How Turbulence Decays (tdecay)

Installation:	GTF1
Project Leader:	W. van de Water
Team:	Nathan Wei Kevin Griffin
Significant results:	Results were obtained that showed a large influence of the stirring protocol on the correlation properties of the flow. In addition, a subtle effect on the downstream decay of turbulence was observed.
Publications:	In preparation

Array of Anemometers in Grid Turbulence (AiRTiGhT)

Installation:	GTF1
Project Leader:	P. Roche

Team:	G. Bewley J. Puczylowski J. Salort Y. Borisenkov
Significant results:	Ongoing project

Turbulence Generated by Sparse 3D Multi-Scale Grid (M3DSG)

Installation:	GTF1
Project Leader:	Jose M. Redondo
Team:	Jacek Kopeć Kamil Kwiatkowski Nadeem A Malik Jackson Teller Alvarez
Significant results:	The grid was successfully constructed and the turbulent flow fiel was measured. Data are currently still being analysed and compared with theoretical models.
Publications:	Presentation at the EGU General Assembly conference, Vienna (Austria), April 2017 Abstract submitted for the 12th Ercoftac Workshop on Synthetic Turbulence, Paris (France), July 2017

Plumes visualization by Light Induced Fluorescnece in a rotating Rayleigh-Bénard convection (VisPlumes)

Installation:	GTF2
Project Leader:	D. Funfschilling
Team:	V. Moturi
Significant results:	Ongoing project
Publications:	International Conference of Rayleigh-Bénard convection, Göttingen, June 2015

Rotating turbulent Rayleigh-Bénard convection at high Prandtl numbers (PrandtlRotConvec)

Installation:	GTF2
Project Leader:	D. Funfschilling
Team:	V. Moturi
Significant results:	Ongoing project

Rotating thermal convection at very large Rayleigh numbers (Turb_Rot_RBC)

Installation:	GTF2
Project Leader:	D. van Gils
Team:	D. Lohse
Significant results:	Heat transport measurements in the geostrophic regime were conducted. These measurements are now useful for better modelling this regime theoretically.
Publications:	Talk at the Annual Conference of the Division of Fluid Dynamics of the APS, Portland (USA), 2017

Heat Transfer at Supercritical conditions in Natural Convection (HTSCRB)

Installation:	GTF2
Project Leader:	V. Valori
Significant results:	Under supercritical conditions the heat transport cannot be sufficiently described only by the Rayleigh and the Prandtl number. Depending exact location in the temperature-pressure-parameter space, heat transport was increased by up to 16% compared to the pure Boussinesq case.
Publications:	Results will be published in the PhD thesis of V. Valori. A journal publication is currently under preparation.

Distributions of separations and relative velocities of droplets in turbulence (DiSeRe)

Installation:	GTF3
Project Leader:	B. Mehlig
Team:	K. Gustavsson
Significant results:	Ongoing project

Dense particle tracking of inertial and Lagrangian particles in isotropic turbulence flows (DTrack)

Installation:	GTF3
Project Leader:	Vicente Perez-Munuzuri (U. Santiago de Compostela)
Team:	Angel Daniel Garaboa-Paz (U. Santiago de Compostela) Florian Huhn (DLR) Daniel Schanz (DLR) Andreas Schröder (DLR) John Lawson (MPIDS) Eberhard Bodenschatz (MPIDS)
Significant results:	A large dataset (40TB) of particle tracking images was collected over different Reynolds numbers, seeding density and particle sizes. Preliminary results demonstrate that the Shake-The-Box algorithm is able to instantaneously track up to 100,000 particles in a volume of $50x50x15mm^3$, pushing the envelope of high density particle tracking. The large dataset is still being processed, but will allow the evolution of three-dimensional flow structures at the Kolmogorov scale to be examined experimentally.
Publications:	Abstract submitted for the 12th International Symposium on Particle Image Velocimetry, Busan, Korea, June 2017 Abstract submitted to 21st Congress of Statistical Physics, Seville, Spain, April 2017

Experimental investigation of the refined similarity hypothesis (K62SCAN)

Installation:	GTF3
Project Leader:	Nicholas A. Worth (NTNU)
Team:	Anna N. Knutsen (NTNU) James R. Dawson (NTNU) John Lawson (MPIDS) Eberhard Bodenschatz (MPIDS)
Significant results:	An extremely large (70TB), well resolved Scanning PIV dataset was acquired of turbulence at R_λ=200 both with and without polymer additives. In addition, a complementary Stereo PIV characterisation dataset was also acquired. Preliminary analysis shows that the dataset is of high measurement fidelity. The data will be suitable for direct experimental assessment of Kolmogorov's 1962 refined similarity hypothesis and will provide a valuable experimental resource for the wider turbulence community. In addition, a new self-calibration method for Scanning PIV was tested. This test demonstrated the technique's ability to maintain calibration stability over weeks of continuous measurement.
Publications:	Abstract accepted for presentation at the 16th European Turbulence Conference, Stockholm, Sweden, August 2017

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 6: Access to Grenoble Helium Infrastructures

- Summary
- Dissemination Activities
- Project Meetings
- Publications
- Personnel Statistics

Summary:

The SHREK and Hejet facilities have been in operation since the beginning of the Euhit Contract (April 2013). This contract has been for us an opportunity to improve the flexibility and availability of our facilities. After hard work we have been able to fulfill all the access requested within EUHIT. The SHREK facility has been operated for 165 days (indeed 167, leading to slightly more than 20% => 165) for European Access (4 projects: FIONA, FELISIA, IFT-HighRe, GENEFIHR)), and the Hejet facility during 70 days as requested, although we had proposed more available days (3 projects: RHW4GreC, HWAST, MOVEMENT2; the MOVEMENT project was not fulfilled, as the PI resigned). The reason for that was probably due to a somewhat late advertising of this facility, which was certainly not the case for SHREK, where all the access planned was made. This interpretation is supported by the heavy use of the facilities over the last reporting period: the facilities became more and more renowned, leading to more access. It is also worth mentioning that applications to our facilities came not only from the Community of Low Temperature Turbulence: indeed, half of them came from scientists interested in High Reynolds numbers, and not involved in superfluid turbulence

Dissemination activities:

Many presentations and publications related to the SHREK and HEJET facilities were done during the reporting period (see below). The General Assembly of the EUHIT project was held in Grenoble, May 11-12 2015, with a local organizing committee composed of people from CEA/SBT and LEGI, which are the two Grenoble laboratories hosting TNAs in Euhit: Alain Girard (CEA/SBT), Bernard Rousset (CEA/SBT), Joël Sommeria (LEGI) and Mickaël Bourgoin (LEGI) were the main local organizers, in strong coordination with MPI. The industrial workshop was organized between the four cryogenic TNAs in October 2015 (26-29 October). The workshop took place mainly in Grenoble (principal organizer B. Rousset): the workshop lasted four days, three in Grenoble, and one in Geneva at CERN. It was organized in perfect coordination with the University of Warsaw who designed the website: https://www.euhit.org/events/euhit-cryogenic-turbulence-workshop , which was of great help for the organization of the event.

Two publications by Alain Girard took place in the french industry-oriented journal "Revue Générale du Froid" mentioning the great interest of the Euhit program for turbulence and cryogenics: Cryogénie pour la turbulence, 1ère et 2ème parties: Revue Générale du Froid, n° 1146 and 1147-1148, September and October/November 2014.

Oral presentations:

Rousset B, Bon-Mardion M, Bouleau E, Poncet J, Girard A, Diribarne P, Roche P, Gibert M, Hebral B, Castaing B, Salort J, Dubrulle B, Daviaud F, Saint-Michel B, Baudet C, Gagne Y, *The SHREK superfluid Von Karman flow experiment,* 19th joint CEC-ICMC 2013 (Anchorage, AK, June 17-21, 2013)

J. Burguete, "Slow dynamics of turbulent flows in a von Kármán experiment", New Challenges in Turbulence Research III, Les Houches, March 16-21, 2014

J. Salort, "The SHREK and HeJet superfluid facilities", ESF Exploratory Workshop on Reconnection Events in Classical, Quantum and Magnetized Fluids, Glasgow (UK), 15th-18th June 2014

Presented by B. Rousset (CEA/SBT) at the "11èmes journées de Cryogénie et Supraconductivité", 19..22 May 2015, Aussois, France: *Hydrodynamique et Turbulence.*

Presented by B. Rousset (CEA/SBT): *"Cryogenic turbulence test facilities at CEA/SBT",* Rousset B, Baudet C, Bon Mardion M, Bourgoin M, Braslau A, Daviaud F, Diribarne P, Dubrulle B, Gagne Y, Gallet B et al., Cryogenic Engineering Conference CEC / International Cryogenic Materials Conference ICMC (Tucson, AZ, June 28-July 2, 2015)

Presented by P. Diribarne (CEA/SBT): " Local Velocity Measurements in the Shrek Experiment at High Reynolds Number" C. Baudet, M. Bon Mardion, P. Bonnay, A. Braslau, B. Castaing, F. Chillà, L. Chevillard, F. Daviaud, P. Diribarne, B. Dubrulle, D. Durì, D. Faranda, B. Gallet, M. Gibert, A. Girard, B. Hébral, I. Moukharski, J. Poncet, J.-P. Moro, P.-E. Roche, B. Rousset, E. Rusaouën, B. Saint-Michel, J. Salort, E.-W. Saw, K. Steiros and C. Wiertel-Gasquet ETC15, Twente (2015)

Presented by P. Diribarne at NCTR "Les Houches" March 2016: *"SHREK: experimental challenges in He II turbulence"*

Presented by P. Diribarne at the "INTERNATIONAL WORKSHOP ON INTERPRETATION OF MEASUREMENTS IN SUPERFLUID TURBULENCE OF HE4" (Paris-Saclay, 14-18 September 2015): communication on hot wire signals in HeII during the session "Questracks" – see: http://homepages.warwick.ac.uk/~masbu/minimal-grey/editable.html#!page-home

Yury Mukharsky, C. Baudet, M. Bon Mardion, P. Bonnay, F. Chilla, L. Chevillard, F. Daviaud, P. Diribarne, B. Dubrulle, D. Faranda, B. Gallet, M. Gibert, A. Girard, J.M. Poncet, J.-P. Moro, P.-E. Roche, B. Rousset, E. Rusaouen, J. Salort, E-W. Saw, S. Nazarenko, A. Golov, (SHREK collaboration) , "Quantum turbulence in 4He studied using the SHREK facility" , International Conference on Quantum Fluids and Solids 2016 , 10th – 16th August 2016, Prague, Czech Republic

A. Fuchs, A. Girard, J. Peinke, P. Diribarne, J. Moro and G. Guelker,"INTEGRAL FLUCTUATIONS THEOREM FOR HIGHEST REYNOLDS", to be presented at ETC 16, Stockholm 2017.

Y. Mukharski et al , to be presented at LT20 (Low Temperature Conference, Goteborg, August 2017)

Seminar:

J. Burguete, "First results of the Fiona experiment", CEA Grenoble, May 28th

Project Meetings:

For all planned Euhit projects visits of users, or videoconferences, or both, were organized with users. Except for the GENEFIHR project, where the experiments were performed while the PI was in the UK (however almost daily reports and exchanges took place), for all other projects, users came to the facilities, also during the experiments. Experiments were prepared with the users, and realized in strong connection with them, pushing often the facilities to their limits.

Publications:

"Superfluid high REynolds von Karman experiment" Rousset B, Bonnay P, Diribarne P, Girard A, Poncet JM, Herbert E, Salort J, Baudet C, Castaing B, Chevillard L et al, Review of Scientific Instruments **85** (2014) 103908 (Euhit is mentioned, but not acknowledged, as all the experiments mentioned in the paper were done BEFORE Euhit was launched)

"Probing quantum and classical turbulence analogy in von Karman liquid helium, nitrogen, and water experiments" Saint-Michel B, Herbert E, Salort J, Baudet C, Mardion MB, Bonnay P, Bourgoin M, Castaing B, Chevillard L, Daviaud F et al, Physics of Fluids 26 (2014) 125109

"Hot-wire anemometry for superfluid turbulent coflow", Duri D, Baudet C, Moro J-P, Roche P-E, Diribarne P, Review of Scientific Instruments **86** (2015) 025007

"Local Velocity Measurements in the Shrek Experiment at High Reynolds Number", C. Baudet, M. B. Mardion, P. Bonnay, A. Braslau, B. Castaing, F. Chillà, L. Chevillard, F. Daviaud, P. Diribarne, B. Dubrulle, D. Durì, D. Faranda, B. Gallet, M. Gibert, A. Girard, B. Hébral, I. Moukharski, J. Poncet, J.-P. Moro, P.-E. Roche, B. Rousset, E. Rusaouën, B. Saint-Michel, J. Salort, E.-W. Saw, K. Steiros and C. Wiertel-Gasquet , European Journal of

Mechanics. (2015)

"Cryogenic turbulence test facilities at CEA/SBT" Rousset B, Baudet C, Bon Mardion M, Bourgoin M, Braslau A, Daviaud F, Diribarne P, Dubrulle B, Gagne Y, Gallet B et al. IOP Conference Series-Materials Science and Engineering **101** (2015) 012187

E. Rusaouen, B. Rousset and P.-E. Roche, "Detection of vortex coherent structures in superfluid turbulence", accepted to EPL.

Personnel statistics for the two facilities (personnel for all users):

SHREK facility: 6 scientists, 5 technicians
Manpower 89.5 technician months, 83.1 scientist months

Hejet facility: 2 senior scientist, 3 technicians, 2 fellows.
Manpower: 44 technician months, 25.65 scientist months

All scientists/technicians/fellows are male.

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 7: Access to Barrel of Ilmenau

Summary

Over the four years of the entire EuHIT project 215 user days (168 are eligible) have been spent to groups from ENS Lyon (97 days), University of Warsaw (31 days), City University London (37 days) and the Czech Academy of Sciences (50 days). This is slightly more than the 20 per cent limit of the total number of days of operation (840 days). The following projects have been finished successfully:

1. **Boudary layer structure near roughness in turbulent thermal convection**
   The project aims to study the convective heat transport at a rough surface and to compare this case with the heat transport at a smooth surface. It run from 16.12.2013 to 04.02.2014 and covered 38 user days. The project was supervised by Francesca Chilla (ENS Lyon). Julien Salort (ENS Lyon) and Olivier Liot (ENS Lyon) significantly contributed to the success of the project. The main result of the project was that a transition in the near-wall flow field was found which could be linked to a transition in the global heat flux observed in the Lyon water cell. It has been published in one peer-reviewed journal (JFM) and have been presented at several conferences.

2. **Preferential concentration of cloud-like droplets at various turbulent kinetic energy dissipation rates**
   The project aims to study the distribution of droplets in the highly turbulent environment of clouds which has been simulated in the Barrel of Ilmenau experiment. The project run from 22.09.2014 – 24.10.2014 and covered 31 user days. It was supervised by Szymon Malinowski (University of Warsaw). Two more scientists and one technician were also involved in this project. The measurements at the Barrel of Ilmenau presented a first test whether or not such experiments are feasible and what kind of visualization and measurement technique is required to obtain reliable results. A continuation of this work is desired by the partners.

3. **Velocity and temperature near roughness in turbulent Rayleigh-Bénard convection**
   This project is a continuation of the project listed under item 1. In progress to the first project, tomographic Particle Image Velocimetry has been applied to get a more comprehensive picture of the three-dimensional flow field. The velocity measurements have been complemented by highly resolved temperature measurements using an ultra-small thermistor of only 125 µm size. The project was supervised by Julien Salort (ENS Lyon). As a second member of the group, Olivier Liot contributed to the measurements. The project run from 05.01.2016 – 09.03.2016 and covered 59 user days. This extended number of days were required due to the extended measurement program and the adaptation of the tomographic Particle Image Velocimetry system to the specific requirements of the rough surface. The measurements have been finished right now and the data are still under analysis.

4. **Long-time wall shear stress patterns in enclosed turbulent Rayleigh-Bernard convection cells**
   This project aims to investigated the long-term structure of the flow in turbulent thermal convection near the wall. Newly developed sensors capable to measure the wall shear stress at low velocity along with a special camera technique for long-term recording was used to acquire very long time series of the local wall shear stress at the heating plate. The project run in the period 8.9.2016 – 14.10.2016 and covered 38 user days. It was supervised by Christoph Bruecker (City University London). Vladimir Mikulich (Technical University Freiberg) and Ramis Örlü (KTH Stockholm) significantly contributed to the success of the project. The data of the measurements is still under analysis, a few preliminary results will be presented at the European Turbulence Conference in Stockholm this year.
5. **Scaling and temperature profiles in turbulent Rayleigh-Bénard convection**
   The project aims to extend the knowledge about Non-Oberbeck-Boussinesq effects in turbulent Rayleigh-Bénard convection studying vertical temperature profiles in the centre of the cylindrical test cells. The project run from 8.2.2017 – 31.3.2017 and covered 50 user days. It was supervised by Pavel Urban (Czech Academy of Sciences). Jakub Drahotský, Michal Macek, and Vera Ludmila Musilova (all Czech Academy of Sciences) were also involved in this project. The measurements have been already finished at the end of the EuHIT project and the analysis is still running. The work is continued by Jakub Drahotský beyond the funding period of EuHIT. He is actually doing an ERASMUS internship at Technische Universitaet Ilmenau and he continues this work.

In summary, all five projects done under the EuHIT agreement foster the international collaboration between the project partners as well as the outreach to the scientific community. Almost all scientists involved in the various projects came together for a scientific workshop at the Research Infrastructure "Barrel of Ilmenau" on 15th and 16th February 2017. We also invited people to this meeting, who ever did own experimental work at the facility in the past. About 25 participants from five countries gave talks and visited the Barrel. The ideas cover many topics ranging from the study of so-called cloud holes over thermal convection above urbanized surfaces up to the development of novel technology measuring simultaneously the flow field and the temperature field in a convective airflow. There are also many discussions as well with the partners in the EuHIT program as with former collaborators to foster or to reinitialize future collaboration. Just to mention a few examples. The groups in Lyon and Ilmenau will prepare a joint research proposal on convection at rough surfaces in the near future. The same is true for the groups in London/Freiberg and Ilmenau. The Warsaw group intends to repeat the measurements to study the preferential concentration of droplets in clouds (Warsaw and Ilmenau) since more sophisticated flow measurement technique is available now at the Barrel of Ilmenau.

List of Deliveries and Milestones

no deliveries, no milestones in WP 7

Dissemination Activities

The dissemination activities listed below cover a webpage attributed to the Research Infrastructure ‘Barrel of Ilmenau’, the organisation of conferences/workshops as well as the oral/poster presentation of the results.

1. Title: Barrel of Ilmenau
   Type of activity: Webpage
   Main leader: Ronald du Puits
   Date: 01.04.2013 - …
   Place: Ilmenau, Germany
   Type of audience: scientists, engineers etc.
   Countries addressed: worldwide
2. Title: Local wall heat flux
   Type of activity: Conference talk (APS, DFD 2013)
   Main leader: Robert Kaiser
   Date: 24-26.09.2013
   Place: Pittsburgh, USA
   Type of audience: physicists
   Countries addressed: worldwide
3. Title: New tracer particles for Large-Scale Particle tracking velocimetry, State and Perspectives
   Type of activity: Conference talk (Workshop Turb. Convection, 2014)
   Main leader: Natalie Schemet
   Date: 18.-19.02.2014
   Place: Münster, Germany
   Type of audience: physicists
   Countries addressed: worldwide
4. Title: Local heat flux: measurement techniques
   Type of activity: Conference talk (Workshop Turb. Convection, 2014)
   Main leader: Robert Kaiser
   Date: 18.-19.02.2014
   Place: Münster, Germany
   Type of audience: physicists
   Countries addressed: worldwide
5. Title: Near-wall heat transport in turbulent Rayleigh-Bénard convection in air
   Type of activity: Conference talk (Phase Trans., Pattern Form. and Turb. 2014)
   Main leader: Ronald du Puits
   Date: 16.-18.06.2014

Place: Göttingen, Germany
Type of audience: physicists
Countries addressed: worldwide

6. Title: Novel tracer particles for large-scale 3D particle-tracking velocimetry in air
Type of activity: Conference poster (Phase Trans., Pattern Form. and Turb. 2014)
Main leader: Natalie Schemet
Date: 16.-18.06.2014
Place: Göttingen, Germany
Type of audience: physicists
Countries addressed: worldwide

7. Title: Local wall heat flux in turbulent Rayleigh-Bénard convection
Type of activity: Conference poster (Phase Trans., Pattern Form. and Turb. 2014)
Main leader: Robert Kaiser
Date: 16.-18.06.2014
Place: Göttingen, Germany
Type of audience: physicists
Countries addressed: worldwide

8. Title: Near-wall heat transport in turbulent Rayleigh-Bénard convection in air
Type of activity: Conference talk (Int. Symp. Laser, 2014)
Main leader: Hauke Hirsch
Date: 07.-10.07.2014
Place: Lisbon, Portugal
Type of audience: physicists, engineers
Countries addressed: worldwide

9. Title: Investigation of the turbulent boundary layer in high Rayleigh number convection using long PIV sequences
Type of activity: Conference talk (Int. Symp. Laser, 2014)
Main leader: Christian Willert
Date: 07.-10.07.2014
Place: Lisbon, Portugal
Type of audience: physicists, engineers
Countries addressed: worldwide

10. Title: 7th European Postgraduate Fluid Dynamics Conference (EPFDC)
Type of activity: Organisation of a conference
Main leader: Robert Kaiser
Date: 14.-17.07.2014
Place: Ilmenau, Germany
Type of audience: physicists, engineers
Countries addressed: worldwide

11. Title: Novel tracer particles for large-scale 3D particle-tracking velocimetry in air
Type of activity: Conference talk (EPFDC 2014)
Main leader: Natalie Schemet
Date: 14.-17.07.2014
Place: Ilmenau, Germany
Type of audience: physicists, engineers
Countries addressed: worldwide

12. Title: Rayleigh-Bénard convection: local wall heat flux at various aspect ratios

Type of activity: Conference talk (EPFDC 2014)
Main leader: Robert Kaiser
Date: 14.-17.07.2014
Place: Ilmenau, Germany
Type of audience: physicists, engineers
Countries addressed: worldwide

13. Title: Turbulent thermal convection: velocity inside the boundary layer near roughnesses
Type of activity: Conference talk (EFMC 2014)
Main leader: Olivier Liot
Date: 15.-18.09.2014
Place: Copenhagen, Denmark
Type of audience: physicists
Countries addressed: worldwide

14. Title: Rayleigh-Bénard convection: local wall heat flux at various aspect ratios
Type of activity: Conference talk (EFMC 2014)
Main leader: Robert Kaiser
Date: 15.-18.09.2014
Place: Copenhagen, Denmark
Type of audience: physicists
Countries addressed: worldwide

15. Title: Viscous boundary layers in turbulent Rayleigh-Bénard convection at low Pr
Type of activity: Conference talk (APS, DFD 2014)
Main leader: Ronald du Puits
Date: 23.-25.11.2014
Place: San Francisco, California, USA
Type of audience: physicists
Countries addressed: worldwide

16. Title: Rayleigh-Bénard convection: local scaling exponent in confned thermal convection
Type of activity: Conference talk (ETC 2015)
Main leader: Robert Kaiser
Date: 25.-27.08.2015
Place: Delft, NL
Type of audience: physicists
Countries addressed: worldwide

17. Title: Roughness-triggered turbulent boundary layers in Rayleigh-Bénard convection
Type of activity: Conference talk (ETC 2015)
Main leader: Julien Salort
Date: 25.-27.08.2015
Place: Delft, NL
Type of audience: physicists
Countries addressed: worldwide

18. Title: Collapse of the global flow structure
Type of activity: Conference talk (RBC 2015)
Main leader: Robert Kaiser

Date: 01.-05.06.2015
Place: Göttingen, D
Type of audience: physicists
Countries addressed: worldwide

19. Title: The evolution of the boundary layer in turbulent RB convection in air
Type of activity: Conference talk (RBC 2015)
Main leader: Ronald du Puits
Date: 01.-05.06.2015
Place: Göttingen, D
Type of audience: physicists
Countries addressed: worldwide

20. Title: Boundary layer structure in turbulent Rayleigh-Bénard convection in air
Type of activity: Conference talk (TSFP9)
Main leader: Ronald du Puits
Date: 30.6.-03.07.2015
Place: Melbourne, AU
Type of audience: physicists
Countries addressed: worldwide

21. Title: European High-Performance Infrastructures in Turbulence
Type of activity: Poster presentation (TSFP9)
Main leader: Ronald du Puits
Date: 30.6.-03.07.2015
Place: Melbourne, AU
Type of audience: physicists
Countries addressed: worldwide

22. Title: Tomographic particle image velocimetry in a convective boundary layer
Type of activity: Poster presentation (PIV 2015)
Main leader: Robert Kaiser
Date: 14.-16.09.2015
Place: Santa Barbara, USA
Type of audience: engineers, physicists
Countries addressed: worldwide

23. Title: Particle Tracking Velocimetry in large-scale convective air flows
Type of activity: Poster presentation (PIV 2015)
Main leader: Ronald du Puits
Date: 14.-16.09.2015
Place: Santa Barbara, USA
Type of audience: engineers, physicists
Countries addressed: worldwide

24. Title: Six years research on convective boundary layers. What have we learned?
Type of activity: Conference talk (FOR 1182 Meeting)
Main leader: Ronald du Puits
Date: 05.-06.04.2016
Place: Klosterneuburg, Austria
Type of audience: physicists
Countries addressed: worldwide

25. Title: What is EuHIT?

Type of activity: Conference talk (FOR 1182 Meeting)
Main leader: Ronald du Puits
Date: 05.-06.04.2016
Place: Klosterneuburg, Austria
Type of audience: physicists
Countries addressed: worldwide

26. Title: Distribution of wall heat flux in turbulent Rayleigh-Bénard convection
Type of activity: Conference talk (FOR 1182 Meeting)
Main leader: Robert Kaiser
Date: 05.-06.04.2016
Place: Klosterneuburg, Austria
Type of audience: physicists
Countries addressed: worldwide

27. Title: CERN Cryogenic Turbulence Facility (GReC)
Type of activity: Conference talk (EuHIT School on Turbulence)
Main leader: Robert Kaiser
Date: 04.-06.07.2016
Place: Warsaw, Poland
Type of audience: junior scientists
Countries addressed: worldwide

28. Title: Turbulent Rayleigh-Bénard convection: unrevelead insights into the near-wall transport process
Type of activity: Conference talk (8th European Postgraduate Fluid Dynamics Conference)
Main leader: Robert Kaiser
Date: 06. 09.07.2016
Place: Warsaw, Poland
Type of audience: junior scientists
Countries addressed: worldwide

29. Title: Boundary layers in turbulent Rayleigh-Bénard convection: A first insight into the 3D velocity field from experiment
Type of activity: Conference talk (ICTAM congress)
Main leader: Ronald du Puits
Date: 21.-26.08.2016
Place: Montreal, Canada
Type of audience: physicists
Countries addressed: worldwide

30. Title: Large-scale flow modes in turbulent Rayleigh-Bénard convection
Type of activity: Conference talk (ICTAM congress)
Main leader: Robert Kaiser
Date: 21.-26.08.2016
Place: Montreal, Canada
Type of audience: physicists
Countries addressed: worldwide

31. Title: Temperature field in turbulent Rayleigh-Benardonvection at a rough surface
Type of activity: Poster presentation (20. Deutsche Physikerinnentagung) Main

leader: Alice Loesch
Date: 03.-06.11.2016
Place: Hamburg, Germany
Type of audience: physicists
Countries addressed: worldwide

32. Title: Technical Workshop at the Barrel of Ilmenau
Type of activity: Organisation of a workshop
Main leader: Ronald du Puits
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists
Countries addressed: worldwide

33. Title: The Barrel of Ilmenau 1 ½ decades of collaboration
Type of activity: Conference talk (Barrel-of-Ilmenau workshop)
Main leader: Ronald du Puits
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists
Countries addressed: worldwide

34. Title: Tomographic PIV at the Barrel of Ilmenau: length scale analysis of the viscous boundary layer
Type of activity: Conference talk (Barrel-of-Ilmenau workshop)
Main leader: Robert Kaiser
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists
Countries addressed: worldwide

35. Title: CFD Application in Industrial Room Ventilation
Type of activity: Conference talk (Barrel-of-Ilmenau workshop)
Main leader: Ling Li
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists
Countries addressed: worldwide

36. Title: Flow structure in a Rayleigh-Bénard cell with rough plate
Type of activity: Conference talk (Barrel-of-Ilmenau workshop)
Main leader: Julien Salort
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists
Countries addressed: worldwide

37. Title: Using PIV as multi-point optical hotwire
Type of activity: Conference talk (Barrel-of-Ilmenau workshop)
Main leader: Chris Willert
Date: 15.2.-16.02.2017
Place: Ilmenau, Germany
Type of audience: engineers, physicists

Countries addressed: worldwide

Project meetings

Collaboration with ENS Lyon (F. Chillà, J. Salort)
In order to prepare the projects, to realize them and to publish the results several meetings between the project partners at the ENS Lyon and the TU Ilmenau took place. The meetings have been funded partially by the EuHIT consortium, the national funding organisations at France (ANR) and Germany (DFG, DAAD) and the partner institutions. Moreover the group members have met at various conferences or workshops. The activities for the reporting period 1.10.2014 to 31.3.2016 are listed below:

1. Type: Group meeting at the EMFC2014 Copenhagen, DK
   Participants: R. Kaiser (TUIL), O. Liot (ENS)
   Date: 15.-18.9.2014
2. Type: Group meeting at the APS, DFD Meeting, San Francisco
   Participants: R. du Puits (TUIL), O. Liot (ENS)
   Date: 23.-25.11.2014
3. Type: Group meeting at the RBC2015, Goettingen, D
   Participants: R. du Puits, R. Kaiser (TUIL), F. Chillà, O. Liot, J. Salort (ENS)
   Date: 01.-05.06.2015
4. Type: Group meeting at the ETC2015, Delft, NL
   Participants: R. Kaiser (TUIL), J. Salort (ENS)
   Date: 01.-05.06.2015
5. Type: Group meeting at the ENS Lyon, F
   Participants: R. du Puits (TUIL), F. Chillà, J. Salort, O. Liot (ENS)
   Date: 22.-30.09.2015
6. Type: Group meeting at the ENS Lyon, F
   Participants: R. Kaiser (TUIL), F. Chilla, J. Salort (ENS)
   Date: 25.-29.11.2015
7. Type: Joint measurements at the RI Barrel of Ilmenau, D
   Participants: R. du Puits, R. Kaiser (TUIL), J. Salort, O. Liot (ENS)
   Date: 05.01.-09.03.2016

The group of the ENS Lyon is also involved in the development of micro sensors (WP21 in the EuHIT project) which has been applied at the RI Barrel of Ilmenau.

Collaboration with University of Warsaw (S. Malinowski)
The project with the group from Warsaw University, the group leader is Szymon Malinowski, was prepared in the previous reporting period 01.04.2013 to 30.09.2014 and the activities for preparing this project took place in the first reporting period. The joint measurements were undertaken in Ilmenau from 22.09.2014 – 24.10.2014 and almost all members of both groups participated. After that experimental work various Skype meetings have been held to analyze and to discuss the data. A publication was not planned due to the very preliminary character of the work.

Collaboration with City University London (C. Bruecker)

In order to prepare the projects, to realize them and to publish the results several meetings between the project partners at the City University London (CUL) and the TU Ilmenau (TUIL) took place. The EuHIT consortium, the national funding organisations at UK and Germany and the partner institutions have funded the meetings partially. Moreover, the group members have met at various conferences or workshops. There were activities in the second reporting period 1.10.2014 to 31.3.2016 as well in the third reporting period 1.4.2016 to 31.3.2017 that are listed below:

1. Type: Meeting at the 17th Laser Symposium, Lisbon, P
   Participants: R. du Puits (TUIL), C. Bruecker (CUL)
   Date: 07.-10.7.2014
2. Type: Meeting at TU Ilmenau
   Participants: R. du Puits (TUIL), C. Bruecker (CUL), DI Rockenbach (TU Freiberg)
   Date: 19.08.2014
3. Type: Joint measurements at RI Barrel of Ilmenau
   Participants: R. du Puits, R. Kaiser (TUIL), C. Bruecker (CUL), V. Mikulich (TU Freiberg)
   Date: 23.-24.02. 2015
4. Type: Meeting at TU Freiberg
   Participants: R. du Puits (TUIL), C. Bruecker (CUL), V. Mikulich (TU Freiberg)
   Date: 07.05.2015
5. Type: Joint measurements at the RI Barrel of Ilmenau, D
   Participants: R. du Puits, V. Mitschunas, S. Abawi (TUIL), C. Bruecker (CUL), V. Mikulich (TU Freiberg)
   Date: 08.09.-14.10.2016

A first discussion of the results is planned for the near future in London. Moreover, the results of the joint measurements will be presented and discussed during the 16th European Turbulence Conference to be held in Stockholm August 2017.

Collaboration with Institute Neel Grenoble (P. Roche)

The collaboration with the Institute Neel exist for more than ten years and the partners meet regularly in Grenoble and Ilmenau. Actually, two Master students from Ilmenau are working in P. Roches group. One of their tasks is to develop a micro-machined sensor to measure temperature gradients in thermal convection. This sensor will be applied at the RI Barrel of Ilmenau to measure thermal dissipation rates. To that aim, the partners intend to apply for a TNA activity and various meetings took place to prepare such a proposal. A few of the recent activities are listed below:

1. Type: Group meeting at the RBC2015, Goettingen, D
   Participants: R. du Puits, R. Kaiser (TUIL), P. Roche, E. Rousaouen (Neel)
   Date: 01.-05.06.2015

2. Type: Group meeting at the Institute Neel, Grenoble, F
   Participants: R. du Puits (TUIL), P. Roche, E. Rousaouen (Neel)
   Date: 22.-30.09.2015
3. Type: Joint measurements at CERN, CH
   Participants: R. Kaiser, C. Resagk (TUIL), P. Roche, E. Rousaouen (Neel)
   Date: 05.11.-13.11.2015

Collaboration with Czech Academy of Sciences (P. Urban)
The project with the group from the Czech Academy of Sciences, Institute of Scientific Instrumentation was prepared in the previous reporting period 1.10.2014 to 31.3.2016 while the project was run in the third period. The activities are listed below:

1. Type: Meeting at the Rayleigh-Bénard workshop, Goettingen, D
   Participants: R. du Puits (TUIL), P Urban (CAS)
   Date: 1.-5.6.2015
2. Type: Joint measurements at the RI Barrel of Ilmenau, D
   Participants: R. du Puits, V. Mitschunas, S. Abawi (TUIL), P. Urban, J. Drahotský (CAS)
   Date: 8.2.-31.3.2017

Following the EuHIT activities, J. Drohatský stays at Technische Universitaet Ilmenau for other six month. As part of an ERASMUS internship he further proceed with the data and prepares the scientific discussion of the group leaders.

Publications

1. R. du Puits, C. Resagk and A. Thess 2013.
   Thermal boundary layers in turbulent Rayleigh-Bénard convection at aspect ratios between 1 and 9.
   New J. Phys. 15, 013040. (open access)
2. R. du Puits, Ling Li, C. Resagk and A. Thess 2014.
   Turbulent Boundary Layer in High Rayleigh Number Convection in Air
   Phys. Rev. Lett. 112, 124301.
3. O. Liot, J. Salort, R. Kaiser, R. du Puits and F. Chillà. Boundary layer structure in a rough Rayleigh Bénard cell filled with air. J. Fluid Mech. (2016), vol. 786, pp. 275-293.
4. O. Liot, J. Salort, R. Kaiser, R. du Puits and F. Chillà. Roughness triggered turbulent boundary layers in Rayleigh-Bénard convection. 15th European Turbulence Conference, 25-28 August, 2015, Delft, The Netherlands.
5. O. Liot, J. Salort, R. Kaiser, R. du Puits and F. Chillà. Roughness-triggered turbulent boundary layers in Rayleigh-Bénard convection. 68th Annual Meeting of the APS Division of Fluid Dynamics, Volume 60, Number 21, November 22–24, 2015; Boston, Massachusetts.

Personnel Statistics:

1. Name: Ronald du Puits
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Group Leader
   Gender: male

2. Name: Christian Resagk
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: PostDoc
   Gender: male

3. Name: Robert Kaiser
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Post Doc
   Gender: male

4. Name: Ling Li
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Post Doc
   Gender: female

5. Name: Natalie Schemet
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: PhD student
   Gender: female

6. Name: Vigimantas Mitschunas
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Technician
   Gender: male

7. Name: Sabine Abawi
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Technician
   Gender: female

8. Name: Klaus Henschel
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
   Task: Technician
   Gender: male

9. Name: Hauke HirschSven Hillebrand
   Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics

and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Master student
Gender: male

10. Name: Sven Hillebrand
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Master student
Gender: male

11. Name: Stefanie Rudolf
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Master student
Gender: female

12. Name: Alice Loesch
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Master student
Gender: female

13. Name: Anna Hertlein
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Master student
Gender: female

14. Name: Willi Pose
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Undergraduated student
Gender: male

15. Name: Genadi Dimov
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Undergraduated student
Gender: male

16. Name: Geovan Rezende
Affiliation: Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics, POB 100565, 98684 Ilmenau, Germany.
Task: Undergraduated student
Gender: male

Task: Access to the Barrel of Ilmenau (BOI)

Title of the user project (BoundRoughTTC)

Installation:	BOI
Project leader:	F. Chillà (ENS Lyon)
Team:	J. Salort (ENS Lyon) O. Liot (ENS Lyon)
Significant results:	The project aimed to study the nature of the heat transfer at a rough surface. Applying planar Particle Image Velocimetry (PIV) and Infrared Thermography (IRT) the local velocity field and the local wall heat flux has been measured and compared with the case of a smooth surface. It could be found that the heat transport is higher than expected due to the enhancement of the surface area.
Publications:	1 journal paper, 3 conference proceedings (details see topic Publications)

Title of the user project (PCCDrop)

Installation:	BOI
Project leader:	S. Malinowski (U. Warsaw)
Team:	A. Gorska (U. Warsaw) K. Karpinska (U. Warsaw) W. Kumala (U. Warsaw)
Significant results:	The project aimed to study how droplets cluster in stratocumulus clouds. Injecting droplets of various in the turbulent convection flow in the BOI, their motion has been studied using real-time Particle Image Velocimetry technique. Unfortunately, the light intensity of the available Laser and the sensitivity of the camera was not sufficient to produce data reliable enough to get published. However, requirements to the technique could be fixed to repeat the experiments in the future.
Publications:	no publication

Title of the user project (VTRoughTRBC)

Installation:	BOI
Project leader:	J. Salort (ENS Lyon)
Team:	F. Chillà (ENS Lyon) O. Liot (ENS Lyon)

Significant results: The project is a continuation of BoundRoughTTC. Instead of planar PIV, tomographic PIV has been applied to measure the fully three dimensional velocity field near the roughness elements. In addition, the local temperature field has been measured using very small thermistors of only 125µm size. The project has been finished right now and the data are still under analysis.

Publications: no publication

Title of the user project (WallCell)

Installation: BOI

Project leader: C. Bruecker (City University London)

Team: V. Mikulich (Technical University Freiberg)
R. Örlü (KTH Stockholm)

Significant results: Using a newly developed sensor the long-term structure of the flow in turbulent thermal convection near the wall has been investigated. The wind magnitude and direction is a footprint of the larger structures in the upper zones and correlates with the heat transfer at the wall. The results reveal the sudden reorganization of the large-scale motion in such cells which happens at time-scales several orders larger than the turnover time of the cell itself. There is evidence that pattern in the signal can be used as a precursor signature to such reorganization. The results for a single sensor were submitted for presentation at the 16th ETC Conference in Stockholm in August 2017. Ongoing post-processing is done for the 2x2 sensor array and results will be analysed in the next months.

Publications: 1 talk at the ETC 16 in Stockholm, Sweden

Title of the user project (ScaRaB)

Installation: BOI

Project leader: P. Urban (Czech Academy of Sciences)

Team: J. Drahotský (Czech Academy of Sciences)
M. Macek (Czech Academy of Sciences)
V. Musilova (Czech Academy of Sciences)

Significant results: The project was directed at the detailed study of vertical temperature profiles in turbulent Rayleigh-Bénard convection (RBC). The temperature profiles were measured by a novel method using the optical fibre system LUNA as well as conventional RTDs. While the RTD measurements could be finished successfully the fiber-optical measurements need to be improved. At the end, we obtained very preliminary data of the temperature profiles along the vertical axis of the RB cell with aspect ratio \Gamma=1 within the range of Ra numbers between 1E10 < Ra < 4E11. The data are still post processed, nevertheless: a) it should be possible to determine the thicknesses of the boundary layers for the different Ra numbers, b) on the base of Tc temperature measurement we evaluate the observed boundary layer asymmetry characterised by dimensionless measure defined as X=(Tc–Tt)/(Tb-Tc) or by Y=(Tc–Tm)/(Tb–Tt).

Publications: no publication

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Program

Grant Agreement Number 312778

Work Package 8: Access to Twente Turbulence Facilities (TTF)

Summary

The TNA project TIPTE "Studying particle translation and rotation dynamics using instrumented particles in the Twente Turbulence Facilities' from smartINST, LYON, France is finished. The Lyon side is providing the report. No material costs on the Utwente side were involved in this project.

The TNA project Rough_TC "Experimental investigation of highly turbulent Taylor-Couette flow" ran from week 13 up to week 44 of 2016 as a collaboration with Stephan Weiss from the MPIDS in Goettingen and finished succesfully. The experiment was performed as proposed in the Twente Turbulent Taylor-Couette facility (T3C). Most of the experimental work has been conducted by Dennis van Gils, Ruben Verschoof, and Dennis Bakhuis at the University Twente. The facility was in use for 951 hours for this project and no material costs on the Utwente side were involved. Stephan Weiss visited the Twente facility twice in light of the project. The results are currently being written up in a publication.

List of Deliveries and Milestones:

no deliveries, no milestones in this WP

Dissemination Activities

Publication/Oral presentation/Poster to a scientific event:

No.

Organization of Conferences:

The 2nd EuHIT meeting, Twente, May 12th-13th, 2014,

Organizers: Chao Sun and Holger Nobach

EuHIT partners, Size of audience ~ 50

Web sites:

Twente Turbulence Facilities (TTF): http://pof.tnw.utwente.nl/research/facilities

Project meetings

Göttingen, May 13th, 2013, Kick-off meeting

Twente, May 12th-13th, 2014, General assembly meeting

Grenoble, May 11th-12th, 2015, General assembly meeting

Publications

S. G. Huisman, R. van der Veen, C. Sun and D. Lohse,
Multiple states in highly turbulent Taylor-Couette flow,
Nature Communications 5, 3820 (2014). doi:10.1038/ncomms4820

S.G. Huisman, R.C.A. van der Veen, G.-W.H. Bruggert, D. Lohse and C. Sun,
The boiling Twente Taylor-Couette (BTTC) facility: Temperature controlled turbulent flow between independently rotating, coaxial cylinders,
Rev. Sci. Instrum. 86 (2015). doi:10.1063/1.4923082

V. Mathai, V. N. Prakash, J. Brons, C. Sun and D. Lohse,
Wake-Driven Dynamics of Finite-Sized Buoyant Spheres in Turbulence,
Phys. Rev. Lett. 115, 124501 (2015). doi:10.1103/PhysRevLett.115.124501

R.C.A. van der Veen, S.G. Huisman, S. Merbold, U. Harlander, C. Egbers, D. Lohse and C. Sun,
Taylor–Couette turbulence at radius ratio η=0.5: scaling, flow structures and plumes,
J. Fluid Mech. 799, 334 (2016). doi:10.1017/jfm.2016.352

R.C.A. van der veen, S.G. Huisman, O.-Y. Dung, H.L. Tang, C. Sun, and D. Lohse,
Exploring the phase space of multiple states in highly turbulent Taylor-Couette flow,
Phys. Rev. Fluids 1, 024401 (2016). doi:10.1103/PhysRevFluids.1.024401

V. Mathai, E. Calzavarini, J. Brons, C. Sun and D. Lohse,
Microbubbles and Microparticles are Not Faithful Tracers of Turbulent Acceleration,
Phys. Rev. Lett. 117, 024501 (2016). doi:10.1103/PhysRevLett.117.024501

Personnel Statistics:

Scientific Coordinator:

Prof. Dr. Detlef Lohse

Work package leaders:

Prof. Dr. Chao Sun

Experienced researchers:

Dr. Chao Sun

Dr. Elise Almeras (left 14-12-2016)

Dr. Dennis van Gils

PhD students:

Mr. Sander Huisman (graduated 31-08-2015)

Mr. Roeland van der Veen (graduated 24-03-2016)

Mr. Varghese Mathai

Ms. Biljana Gvozdić

Mr. Ruben Verschoof

Mr. Dennis Bakhuis

Other:

Technicians: Gert-Wim Bruggert, Martin Bos, Bas Benschop

Research engineer: Dennis van Gils

Task: Access to Twente Turbulence Facilities

Title of the user project (Acronym): Rough_TC

Summary:

The TNA project Rough_TC "Experimental investigation of highly turbulent Taylor-Couette flow" ran from week 13 up to week 44 of 2016 as a collaboration with Stephan Weiss from the MPIDS in Goettingen and finished succesfully. The experiment was performed as proposed in the Twente Turbulent Taylor-Couette facility (T3C). Most of the experimental work has been conducted by Dennis van Gils, Ruben Verschoof, and Dennis Bakhuis at the University Twente. The facility was in use for 951 hours for this project and no material costs on the Utwente side were involved. Stephan Weiss visited the Twente facility twice in light of the project. The results are currently being written up in a publication.

Installation:

The Twente Turbulent Taylor-Couette Facility (T3C)

Project leader:

Stephan Weiss (MPIDS, Goettingen)

Team:

Stephan Weiss (MPIDS, Goettingen), Dennis van Gils (UTWENTE, Enschede), Detlef Lohse (UTWENTE, Enschede), Eberhard Bodenschatz (MPIDS, Goettingen)

Significant results:

Yes, we refer to the final report as delivered by Stephan Weiss.

Publications:

Is currently being written up.

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 9: Access to CICLoPE

Summary

The Long Pipe (LP) in CICLoPE (Centre for International Cooperation in Long Pipe Experiment) has been operative and available for external user access since May 2014, as planned. Over the entire period of EuHitin which the LP was operative (1/4/2014 – ongoing), the LP provided a total of 212 external user days (of which 28 already reported in RP2). Thisfigure falls withinthe 20 per cent limit of the total number of days of operation (1060 total access days between April2014 and March 2017). The 212 user accesses are divided in 7 user projects, as described below:

- **Reynolds stress tensor scaling in turbulent pipe flow (ReScale)**

The true nature of the kinematics of turbulent pipe flows remains elusive, both due to the scarcity of data from direct numerical simulations (DNS) and well-resolved experiments and the uncertainties and discrepancies in the available data. Despite high Reynolds number data from the Princeton Superpipe, even the qualitative scaling of the streamwise variance profile remains unclear, not to mention the scaling of the other components of the Reynolds normal stresses. With this present project the research team attempts to close this gap by measuring the Reynolds stress tensor with traditional (i.e. established) single and multi-wire hot-wire probes in the Long Pipe at CICLoPE in order to address those open questions with regards to the kinematics of wall-turbulence that could not been addressed due to the scarcity of well-resolved and statistically converged data. Such an endeavour calls for a large-scale facility such as the Long Pipe in CICLoPE in order to address the scaling of the variance profiles, the spectral scaling and amplitude modulation (top-down influence of outer-layer structures). The usage of CICLoPE allowed the team to acquire unique data, that exceeded all DNS and experiments that provide the Reynolds stress tensor by an order of magnitude in Reynolds number, while at the same time ensuring converged and resolved statistics.

- **Holographic near wall measurements in a high Reynolds number turbulent pipe flow (HoloPipe)**

  Since the LP facility offers unique possibilities to characterize a high Reynolds number wall-bounded flow with a relatively large length scale, the objective of the project is to use the recent developments in digital microscopic holography to perform 3C-3D velocity measurement at the wall with high spatial resolution. The aim of this project is to obtain statistics on the turbulent wall friction and the velocity fluctuations very close to the wall at high Reynolds numbers. Since this type of measurement has never been performed using this technique under these condition, they will be validated with a reliable 2C-2D micro PIV technique, which is quite novel it its own right and was recently demonstrated in another EUHIT project, providing time resolved data, thus also complementing the holographic data.

- **Spectral scaling of turbulence in CICLoPE at high Reynolds numbers (SST-CICLOPE)**

  This work aims at investigating the large-scale and the very large-scale structures of turbulent CICLoPE pipe flow at high Reynolds numbers which are of vital importance with respect to the turbulent kinetic energy production and the Reynolds stresses. According to recent studies some open questions remain unsettled for identifying accurate sizes of these turbulent behaviors. Meandering structures have been identified and usually referred as VLSM (very large-scale motions) with claimed extension up to 20R, where R is the pipe radius. The LP facility is providing an opportunity to approach high Reynolds number flows with high resolution in terms of viscous length scale, which gives the advantage to investigate various velocity ranges similar to the large pipe facility, CoLa-Pipe, at LAS BTU-Cottbus-Senftenberg to study the behavior of turbulent structures.

- **Very-large-scale motions measurement in pipe flows at high Reynolds numbers (LargeView)**

  The objective of the project is to study the very-large-scale structures present in pipe flows at high Reynolds numbers. Such features are reported to extend up to 20 pipe radii. The experimental observation of very-large-scale structures with current experimental techniques is quite challenging for both hot-wire anemometry (HWA) and Particle Image Velocimetry (PIV). HWA relies on the Taylor hypothesis and provides only pointwise measurements; large scale measurements, on the other hand, are extremely challenging for PIV. The CICLoPE facility enables access for performing PIV measurement over small regions and extensive access for HWA. For the purpose of the present research we plan to integrate synchronized non-time-resolved PIV and time-resolved HWA measurements for dynamic estimation of turbulent structures. The expected outcome of the experimental campaign is a modal decomposition of the structures in the pipe centreline. The combination of PIV with HWA in the CICLoPE facility would give a unique opportunity to study the behaviour of turbulent structures at high Reynolds number flows with high spatial/temporal resolution.

- **Velocity and vorticity cascades in high Reynolds number pipe flows (CASCADES)**

CICLoPE is a unique facility providing a high Reynolds number (Re) turbulent flow in a large-scale pipe that permits the use of relatively large velocity measurement. This feature will be exploited to make the first simultaneous measurements of vorticity and velocity in a high Re pipe flow and use these to further our understanding of the mechanisms of wall-turbulence at high Reynolds numbers. Further, recent theories and models of wall-turbulence are informed by Princeton Superpipe data, which has remained beyond compare for two decades. The LP facility will be used to acquire a comparative streamwise velocity database using the Princeton NSTAP hot-wire probes.

- **Properties and Role of Small Scales in High-Reynolds number pipe flow (PRoSS)**

The main goal of the proposed project is to study the properties and the role of small scales (as exhibited by the field of velocity derivatives) in high Re turbulent pipe flow and their bidirectional interaction with the rest of the flow. This is intended to achieve via performing experiments in the CICLoPE employing a system developed in Tel Aviv University. The main features in these experiments are the use of a micro-fabricated probe with an overall scale about 0.6 mm, and the ability of access - along with the three velocity components - to all nine components of the space derivatives tensor, the first and unique attempt to apply such technique in a pipe flow. On the technical side we will perform a number of new tests of the probe performance in the pipe flow conditions especially in the proximity of the wall.

- **Pipe Research On Boundary Effects and Scaling of probes (Probes)**

So far, the highest Reynolds number experimental turbulence data from a laboratory have been obtained in a single facility, the pressurized Princeton Superpipe, with the NSTAP micro-probe of unusual design. These data do not extend the trends for turbulence intensity observed in the many lower Reynolds number facilities. In particular, the existence of a region governed by a power-law description below the logarithmic region, the values of the log law coefficients, a Re-independent inner peak of the streamwise velocity fluctuations, and the emergence of a Re-dependent outer peak contradict classical knowledge of wall-bounded turbulence. The question is whether these new observations are the manifestations of new physics at very high Re or whether they represent facility/probe effects. In this project we propose to analyze the effect of the NSTAP probe geometry on the turbulent flow, including blockage effects and upstream influence of the delta-wing shape. To this end, we will manufacture identical probes, scaled up by a factor of 6.5, and perform experiments in the LP over a significant Re range to assess possible geometrical effects on the measurements.

List of Deliverables and Milestones:

nodeliverables, no milestones in this WP

Dissemination Activities

The historical location of the facility, as well as the scientific relevance of the installation has attracted the attention of the media, so the research activities have been reported in several newspapersand national TVs that complemented the regular scientific dissemination activities. Due to the intensive experimental activity connected to the EUHIT project, many scientific publications are still under preparation, and will be presented and published in the coming months and years.

High-Reynolds number turbulence Workshop – Bertinoro (Italy) 5-6/9/2016, Euhit*workshop organized by Univeristy of Bologna and University of Torino*

iTi - 2016 – Conference on Turbulence – Bertinoro (Italy), 7-9 – 9 -2016
International conference organized by University of Bologna

G.Bellani& A. Talamelli “The LONG PIPE facility in CICLOPE Near-wall turbulence exploration” – 21-27/2/2016 - AGU Ocean Science meeting – Tutorial Session – New Orelans (USA)

G. Bellani, A. Talamelli, T. Fiorini “Il LONG PIPE in CICLOPE
uno strumento per lo studio della turbolenza” Seminar series for localindustry – 2015/2016

Facility introduction video (www.euhit.org)

Bologna, November 2015, A. Talamelli – “EuHIT- European High-performance Infrastructures in Turbulence”- H2020 and Infrastructures- Meeting organized by University of Bologna

Forli’, March 2015, ”Presentation of the Infrastructure to the Region Emilia Romagna”

iTi - 2014 – Conference on Turbulence – Bertinoro (Italy), 21-25 – 9 -2014
International conference organized by University of Bologna

Project meetings

Grenoble, May 4th- 7th, 2015, General assembly meeting

Lille (France), 18-20 June 2015, LML workshop at University of Lille

Stockholm (Sweden), 7-8 January 2015, FLOW meeting 2015

Stockholm (Sweden), 15-16 January 2016, FLOW meeting 2016

Goettingen (Germany), 1-4 May 2016, General Assembly meeting 2016

Goettingen (Germany), 13-15 Feb 2017, Final EuHit meeting 2017

Publications

Talamelli A., Bellani G., The New High-Reynolds Number Pipe Flow Facility at CICLoPE, Nagare, 2014, vol. 33, pp. 259-266

A. Talamelli, G. Bellani, A. Rossetti "The 'Long Pipe' in CICLoPE: A Design for Detailed Turbulence Measurements", Progress in Turbulence V 2015, 127-131, Springer

G.Bellani& A. Talamelli "The Final design of The Long Pipe Facility in CICLOPE" Progress in Turbulence VI, 2016 – 205-209, Springer

R. Örlü, T. Fiorini, A. Segalini, G. Bellani, A. Talamelli & P. H. Alfredsson "Reynolds stress scaling in pipe flow turbulence—first results from CICLoPE", Philos Trans A MathPhys Eng Sci. 2017 Mar 13;375(2089)

Personnel Statistics:

Given the intensive use of the facility, support from several experienced researchers as well as technicians, that ensured continuous support for external accesses and regular use of the facility, was required.

Scientific Coordinator:

Prof. Alessandro Talamelli (m)

Work package leaders:

Prof. Alessandro Talamelli (m)

Experienced researchers:

Prof. Borghi Carlo Angelo (m)

Prof. Davide Moro (m)

Prof. Fabrizio Giulietti (m)

Dr. Andrea Cristofolini (m)

Dr. Gabriele Neretti (m)

Dr. Gabriele Bellani (m)

PhDstudents:

Mr. Tommaso Fiorini (m)

Ms. Lucia Mascotelli (f)

Other:

Technicians: Dr. Alessandro Rossetti (m)
Dr. Paolo Proli (m)

Ms. Mauro Ricci (m)

Task: Access to the Long Pipe in CICLoPE (LP)

Title of the user project: Reynolds stress tensor scaling in turbulent pipe flow

Installation: LP

Project leader: P.HenrikAlfredsson (KTH - Sweden)

Team: RamisÖrlü (KTH – Sweden)
Antonio Segalini (KTH - Sweden)

Significant results: The project aimed at measuring the Reynolds stress tensor in the Long Pipe with traditional (i.e. established) single and multi-wire hot-wire probes in order to address those open questions with regards to the kinematics of wall-turbulence that could not been addressed due to the scarcity of well-resolved and statistically converged data in other facilities.

Publications: R. Örlü, T. Fiorini, A. Segalini, G. Bellani, A. Talamelli & P. H. Alfredsson "Reynolds stress scaling in pipe flow turbulence—first results from CICLoPE", Philos Trans A MathPhys Eng Sci. 2017 Mar 13;375(2089)

- **Title of the user project: Holographic near wall measurements in a high Reynolds number turbulent pipe flow - HoloPipe**

Installation: LP

Project leader: Michael Stanislas (Ecole Centrale de Lille, France)

Team: Cuvier Christophe (Ecole Centrale de Lille, France), Willert Christian (DLR, Germany); Klinner Joachim (DLR, Germany); Graf Norbert (Innolas, Germany); Soria Julio (University of Monash, Australia): Michael P. Eisfelder (University of Monash, Australia): Omid Amili(University of Monash, Australia);

Significant results: High-resolutoin 2D-2C near-wall PIV measurements were collected in an a wide Range of Reynolds number (Re_tau 4000 to 40000) with unprecedented resolution. The resulting dataset is one of the most complete and accurate Two-components database for near-wall velocity statistics. Parallel to this, a Holographic PIV campaign was setup to measure instantaneous values of the wall-shear stress. The results were reported in numerous international conferences, and are reported in a peer-review publication under-review. Data have been uploaded in Turbase

Publications: Willert, C.; Soria, J.; Stanislas, M.; Amili, O.; Bellani, G.; Cuvier, C.; Eisfelder, M.; Fiorini, T.; Graf, N.; Klinner, J.

"Time resolved, near wall PIV measurements in a high Reynolds number turbulent pipe flow", American Phisical Society, DFD, Nov 2016.

- **Title of the user project: Spectral scaling of turbulence in CICLoPE at high Reynolds numbers (SST-CICLOPE)**

Installation: LP

Project leader: Emir Öngüner(BTU Cottbus, Germany)

Team: Christoph Egber(BTU Cottbus, Germany); El Sayed Zanoun (Benha University, Egypt)

Significant results: An extensive Hot-wire campaign was setup and performed to obtain accurate spectral measurements of turbulent pipe flow. The results were compared to measurements performed in other pipe-flow facilities of different size, to evaluate the effect of geometry on the structure and scaling of large-scale motions. The results are collected in two PHD thesis and in various international conferences. Data are uploaded in Turbase.

Publications: In preparation

- **Title of the user project: Very-large-scale motions measurement in pipe flows at high Reynolds numbers (LargeView)**

Installation: LP

Project leader: Stefano Discetti (Universidad Carlos III, Spain)

Team: Andrea Ianiro (Universidad Carlos III, Spain), Marco Raiola (Universidad Carlos III, Spain); Carlos S. Villa (Universidad Carlos III, Spain); Jacopo Serpieri (TU Delft, Nederlands); RamisÖrlü (KTH, Stockholm).

Significant results: 2D-2C PIV measurements with a large field of view have been performed on a wall-normal / streamwiseplane of the Long PIPE. PIV measurements were synchronized with simultaneous measurements done with a rake of 5 HW located at the edge of the PIV domain. The combination of these two measurements yields a time-resolved dataset of the large-scale motions in a turbulent pipe flow. The results can be used to characterize in full detail the impact of the large-scale motions on the near-wall dynamics. Several Peer-revied publications are in preparation and the datasets have been uploaded on Turbase.

Publications: In Preparation

- **Title of the user project: Velocity and vorticity cascades in high Reynolds number pipe flows (CASCADES)**

Installation: LP

Project leader: Bharathram Ganapathisubramani (University of Southampton, UK)

Team: Jason Hearst (University of Southampton, UK), Eda Dogan (University of Southampton, UK); Jason P Mony (University of Melbourne, Australia); MiladSamie (University of Melbourne, Australia); Spencer Zimmerman (University of Melbourne, Australia); Romain Mathis (Laboratoire de Mecanique de Lille, France)

Significant results: Two-point hot-wire measruements were performed in a wide range of high-Reynolds numbers. These measurements were combined with instantaneous wall-shear measurements. This combinations allows to study the correlation between high-shear stress events with turbulent fluctuations at various scales. The measurements were repeadted with nano-scale hw probes (NSTAP) to validate such probes against conventional Hot-wires. Furthermore, a mulit-wire probe was used to measure the components of the vorticity vector at various wall position to study the corrlation of velocity and vorticity. The results will be reported in various scientifc reports and the data ar uploaded in Turbase.

Publications: In preparation

- **Title of the user project: Properties and Role of Small Scales in High-Reynolds number pipe flow - PRoSS**

Installation: LP

Project leader: Arkady Tsinober (University of Tel Aviv, Israel)

Team: Michael Kholmayansky (University of Tel Aviv, Israel), Grigori Gulitski (University of Tel Aviv, Israel); Youri Borisenkov (University of Tel Aviv, Israel);

Significant results: A micro-fabricated multi-wire probe of overall-size of 0.6 mm was used to acquire near-wall profiles the full velocity gradient tensor as well as the 3 velocity components at high-Reynolds number (Re_tau>10000) with an unprecedented resolution for these type of probe. Data are uploaded in turbase.

Publications: In preparation

- **Title of the user project: Pipe Research On Boundary Effects and Scaling of probes (PROBES)**

Installation: LP

Project leader: Arne Johansson (KTH, Sweden)

Team: Ricardo Vinuesa (KTH, Sweden); Philip Schlatter (KTH, Sweden); Hassan Nagib (IIT-Chicago, USA); Peter Monkewitz (EPFL, Switzerland)

Significant results: A prliminary measurement campaign to setup and evaluate the design of a scaled-up version of the NSTAP probe has been carried out. We saldered a standard hot-wire over a 3D -printed scaled-up version of the NSTAP and evaluated structural stiffness. We simultaneusly collected collateral measurements that will help setup the next experimental campaign that will take place in the near future. The data collected in this phase were uploaded in Turbase.

Publications: Under preparation

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package: 10 (ICTP High Rayleigh Number Cryogenic Facility)

Summary

The High Rayleigh Number Cryogenic Facility was involved in co-organizing the EuHIT Cryogenic Turbulence Workshop held 26 - 29 October 2015 in Grenoble, France

The lab is undergoing renovation and updating and is prepared to receive new users starting August 1, 2016.

Personnel Statistics:

Joseph Niemela, Lab director, Male

Najmeh Foroozani, Postdoc, female

EuHIT European High-Performance Infrastructures in Turbulence

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

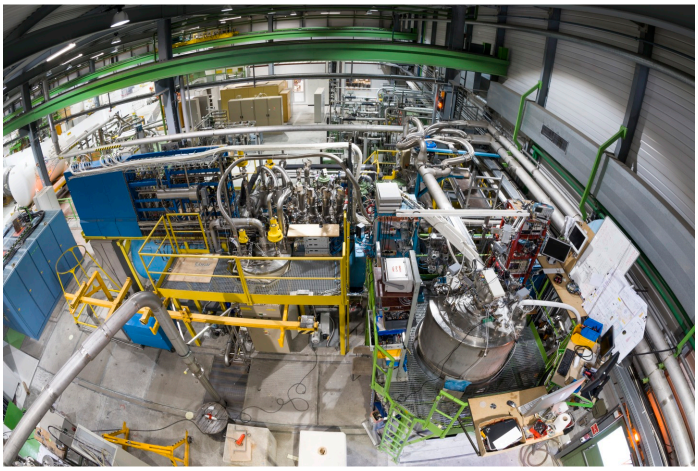
Work Package 11: CERN cryogenic turbulence Facility

Summary

CERN's turbulence facility is a cryogenic helium jet developing in a 3-m-high cylindrical enclosure. This experiment offers amazing perspectives for the study of ultrahigh Reynolds number (Re-lambda up to 6000), thanks to its unusually large dimension for a cryogenic flow.

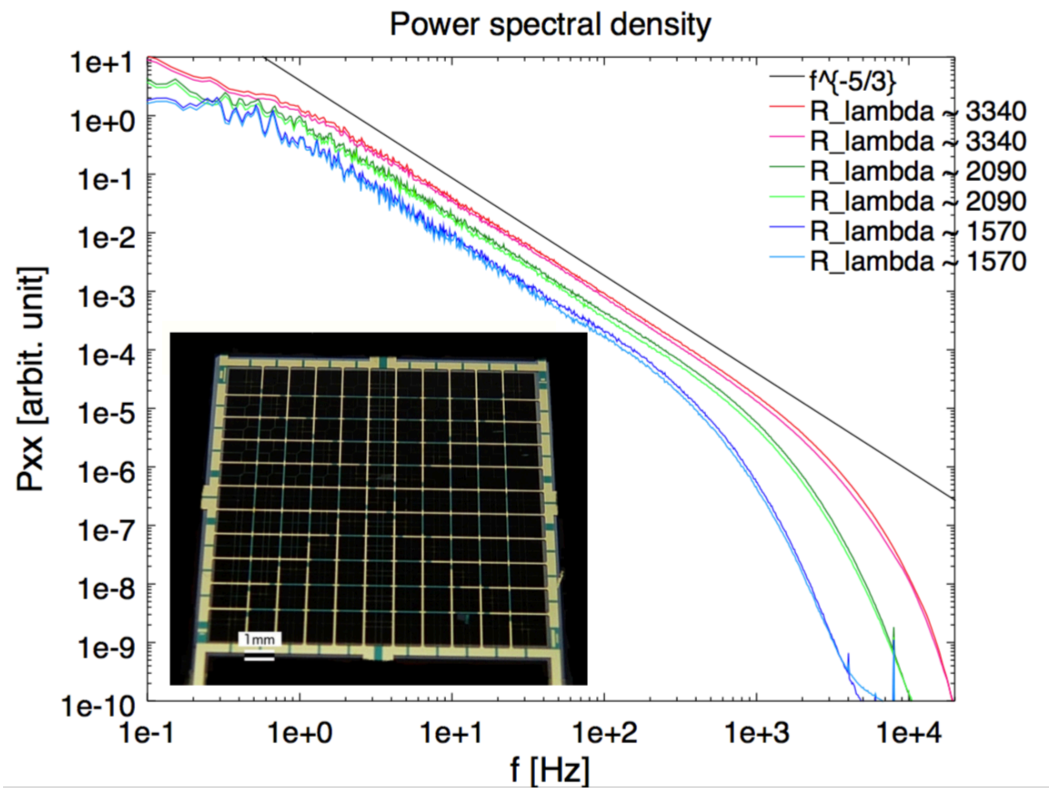
The facility was opened to external users during the last 3 years of the EuHIT project, and for a total of 6 weeks of access. Given this limited access time and the long time required to plan and operate large scale cryogenic experiments, access has been open to groups of users, rather than separately to different users. Consequently the EuHIT projects "TRITiUM" (2 weeks in 2015) and "APeRITiF" (4 weeks in 2016 and 2017) involved users from 4 institutes and 3 countries (France, Israel and Germany). In each project, various types of measurements were conducted both for scientific and technical (instrumentation, flow quality characterisation,) purposes.

Prior each of these project, the facility was adapted to meet the needs of the users, and safety refurbishments to welcome external users were performed (e.g. extension of the experimental platform). For instance, plugs of two cryogenic valves found to be critical for mass flow control, were changed and new cryogenic thermometers with appropriate electronics were installed in order to better control the helium jet temperature. In addition, dedicated tests of the transfer line heating system were performed to optimize the heating control system, with assistance from RTD WP21. An upgrade of the control system of the refrigerator were also implemented which allows now to better interface between external EuHIT users and the CERN operators of the refrigerator. These facility improvements were partly presented in an invited talk given in an international scientific conference in 2016 (see the section "Dissemination Activities" below).



TNA picture from CERN Bulletin issue 32-33, 2015

The *APeRITiF* project was mainly aimed at raising to the highest standard the “flow quality” and not at performing reference measurements (*APeRITiF* is the acronym for *AdaPtation of gRec to Intense Turbulence Fluctuations experiments*). Nevertheless the measurement campaigns produced some remarkable data, which are presently being analysed. They will be presented during two upcoming international workshop and conference (see the section “Dissemination Activities”). To illustrate these datasets, raw spectra are shown in the plot below, with an insert showing the micro-machined anemometer.



Raw spectra from the network of micro-machined hot films (APeRITiF project). Note the exceptional dynamics of the y-axis and the absence of noise peaks

List of Deliveries and Milestones

No deliveries, no milestones in this WP

Dissemination Activities

CERN bulletin

Title: Area of turbulence, CERN Bulletin Issue No. 32-33/2015

Type of activity: publication in CERN journal

Main leader: A. Schaeffer

Date: August 2015

Place: Geneva,
http://cds.cern.ch/journal/CERNBulletin/2015/32/News%20Articles/2038715?ln=en

Type of audience: CERN & scientific community

Countries addressed: international

EuHIT Cryogenic Turbulence Workshop (26 - 29 October 2015)

Title: CERN cryogenic turbulence Facility

Type of activity: Oral Presentation

Main leader: P. Roche

Date: October 2015

Place: Geneva

Type of audience: Potential TNA users (About 40 people visited the facility)

Countries addressed: Europe

European Cryogenics Days : Academia meets industry on developments in cryogenics

Title: *GReC experiment : probing ultra high-intensity turbulence*

Organizer: Cryogenics Society of Europe (CSE)

Type of activity: Invited oral Presentation

Speaker: P. Roche

Date: 9-10 June 2016

Place: CERN, Geneva,
https://indico.cern.ch/event/486602/contributions/1164413/attachments/1288209/1917705/GReC_ROCHE_2016_EuropeanCryogenicsDays-Diffusion.pdf

Type of audience: specialists of cryogenics, scientific community (higher education, Research) & Industry

Countries addressed: Europe

Workshop : New Challenges in Wall Turbulence

Title: *Array of ultra-miniature hot-films for very high Reynolds number flows*

Type of activity: Oral Presentation

Speaker: P. Roche

Date: 14–16 June 2017

Place: Lille

Type of audience: Specialists of turbulence

Countries addressed: World

16th European Turbulence Conference

Title: *Array of ultra-miniaturized hot-films for high Reynolds number flows*

Type of activity: Oral Presentation

Speaker: P. Roche

Date: 21-24 August 2017

Place: Stockholm

Type of audience: Specialists of turbulence

Countries addressed: World

Youtube channel:

https://www.youtube.com/channel/UCGBUTlIgmbciBzRIfVb9WmQ

https://www.euhit.org/videos/EuHIT_CERN.mp4

Project meetings

Meetings were organized between the external users and the CERN operation and support staff in order to discuss and implement the measures to improve the stability and controls of the flows to the cryostat. About 20 meetings took place between 2014 and 2017 (see previous reports for the dates).

General assembly meetings :

- 11-12 May 2015 : EuHIT GA meeting in Grenoble

- 22 July 2015 : EuHIT GA meeting via Webex

Publications

"Joint temperature and velocity local sensor for turbulent flows", J. Salort et al., submitted to Review of Scientific Instruments (June-2017)

Personnel Statistics:

<u>Scientific & Work Package Coordinator:</u>

Olivier Pirotte (M), affiliation CERN

<u>Experienced researchers:</u>

Vladislav Benda (M): Cryogenic engineer, affiliation CERN

Juan Casas-Cubillos (M): Cryogenic instrumentation engineer, affiliation CERN

<u>Other:</u>

Ludovic Alaux (M): Helium refrigerator operator technician, affiliation CERN

Remi Gueydan (M): Cryogenic mechanical technician, affiliation CERN

Nicolas Guillotin (M): Helium refrigerator operator engineer, affiliation CERN

Jérôme Hebert (M): Helium refrigerator operator technician, affiliation CERN

Jean-Paul Lamboy (M): Helium refrigerator operator technical engineer, affiliation CERN

Laurent Le Mao (M): Cryogenic mechanical technician, affiliation CERN

Jeremy Mouleyre (M): Cryogenic mechanical technician, affiliation CERN

Jean-Marc Quetsch (M): Cryogenic instrumentation technician, affiliation CERN

Task: Access to GReC, CERN cryogenic turbulence Facility

Access to GReC, CERN cryogenic turbulence facility has been granted to two projects :

Tailoring gRec for ultra Intense TUrbulence Measurements (TRITiUM)

Installation:	GReC

Days of access	14 days
Project Leader:	Philippe-E ROCHE (CNRS-Institut Néel)
Team:	CNRS-Institut Néel, Ilmenau University of Technology, CNRS-ENS de Lyon, and University Joseph Fourier
Significant results:	- Characterisation of the flow and infrastructure stability, up to 70 g/s - Qualification in cryogenic helium gas of several sensors from work package WP21 (Pitot tubes, hot films, micro-cantilever and micro thermometers); - Qualification in cryogenic helium gas of commercial hot wires provided by the Ilmenau University of Technology; - Test of a micro-machined hot-wire from the University of Tel Aviv (WP23)
Publications:	No publication

AdaPtation of gRec to Intense Turbulence Fluctuations experiments (APeRITiF)

Installation:	GReC
Days of access	28 days
Project Leader:	Philippe-E ROCHE (CNRS-Institut Néel)
Team:	CNRS-Institut Néel, Ilmenau University of Technology, CNRS-ENS de Lyon, and University of Tel Aviv
Significant results:	- Characterisation of the flow and infrastructure stability; - Qualification in cryogenic helium gas of several sensors family such as Pitot tubes, micro-hot films, hot wires, micro-cantilever and micro thermometers provided by the cryogenics technologies work package WP21 and WP23; - Qualification in cryogenic helium gas of hot wire electronics developed in WP23. - Measurement of velocity fluctuations at Taylor-microscale Reynolds numbers exceeding R_λ=3000, and simultaneously at positions separated by 1-3 mm (corresponding to few Taylor microscales)
Publications:	Abstract “Joint temperature and velocity local sensor for turbulent flows”, J. Salort et al., submitted to Review of Scientific Instruments (June-2017) Talk “Array of ultra-miniaturized hot-films for high Reynolds number flows” at the 16th European Turbulence Conference, Stockholm, Sweden, August 2017

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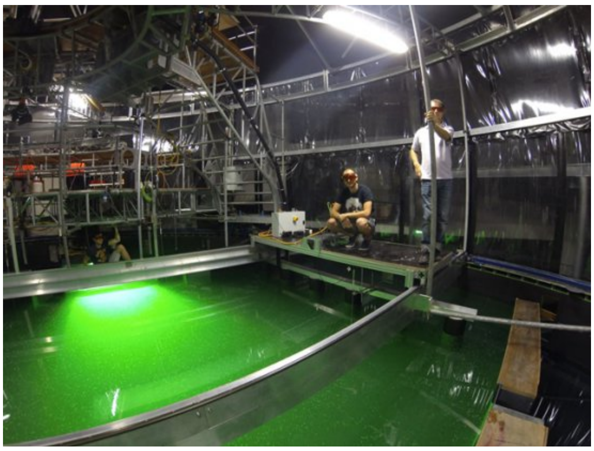
Grant Agreement Number 312778

Work Package 12: Access to the Coriolis rotating platform at LEGI (Coriolis)

Summary

The new Coriolis facility has been partly achieved in June 2014, but tests and adjustments had still to be done until the end of 2015, which was not appropriate for external access projects. Then access for external visitors has been grouped from May 2016 to March 2017. Finally five access projects have been successfully performed, involving 135 access days, far exceeding the contractual minimum of 90 access days. This access involved 22 invited researchers from 7 countries. The projects produce about 40 Tbytes of raw data (mainly images) which are stored in a dedicated storage bay and made available for remote access. Data processing still under way, as well as analysis and publication.



Work progress and achievements during the period

The first project, MILESTONE, has been selected in September 2015 and realised in May-June 2016. Four more projects have been selected in January 2016, and realised in 2016- 2017. This leads to a total access of 135 days, as detailed in the table:

MILESTONE: This first access project involves the fundamental study of turbulence in a stably stratified fluid, with and without background rotation. A preparatory visit had been organised on 11-12 January 2016, and specific equipment has been built at LEGI/CNRS, including a channel equipped with a motorized carriage, 13 m long, crossing the whole tank to generate turbulence behind an array of cylinders. A thorough instrumentation has been implemented. This involves 5 high resolution scientific cameras for Particle Imaging Velocimetry (PIV), and conductivity probes. Preliminary results have been published in the VIIIth International Symposium on Stratified Flows, Aug. 29 - Sept. 1, 2016, San Diego, USA, and a journal publication is in preparation.

CREST: This second project studies buoyancy-driven flows in channels under the effect of the Coriolis force. Beside fundamental issues in turbulence, the project is motivated by sediment laden flows in sea canyons, the main transport pathway between shallow slope regions and the deep sea. A preparatory visit was organized on 17-18 May 2016 and the project itself was performed on 12 Sept.-21 Oct. 2016. A 13 m long channel had to be built for this project, and a thorough instrumentation, combining acoustic Doppler velocimetry and PIV has been installed. A proceeding paper has been written for the 4th International Symposium of Shallow Flows, to be held in Eindhoven on 26-28 June 2017. A longer journal paper is in preparation.

ResEK: This third project deals with the transmission of wind surface stress to the deep ocean through turbulent transport under the effect of the Coriolis force. This extends the classical problem of the Ekman layer to the case of time periodic or random forcing. This study is relevant to better estimate the effect of storms for ocean circulation and mixing. The project has been prepared by a meeting on 7-8 June 2016 and performed on 07 Nov.-2 Dec. 2016. A big 4 x 4 m altuglass plate had to be made for the project, with a motorized driving mechanism to control its oscillations. Instrumentation involved two high resolution scientific cameras for PIV. Preliminary results have been presented at a conference of the Hungarian academy of Sciences, the Statistical physics days, on 21st April 2017. A journal paper is in preparation.

ANNI: This fourth project studies the development of the boundary layer on a curved surface. This begins by the onset of instabilities (shear instability or Goertler instability), followed by the development of turbulence. For that purpose the Coriolis platform was used as an empty rotating cylindrical tank, and the study focused on the vertical outer boundary. The rotation rate was suddenly changed to initiate the flow (spin-up and spin-down). In some experiments density stratification was introduced to block spurious vertically recirculating flow. Measurements relied on six high resolution scientific cameras to provide turbulent fields at different scales and distances to the wall by PIV and stereo PIV. A proceeding paper has been written the 12th International Symposium on Particle Image Velocimetry to be held in Busan, Korea, June 19-21 2017, and a longer article is in preparation.

SLOCET: This project is related to coastal oceanography and is motivated by two main questions: 'How does the variation of the bathymetric slope affect the propagation of Topographic Rossby Waves (TRW)?' and 'How does it affects the dynamics of Coastal Currents?' To address the first question, a wave maker has been built, and to address the second question a system of current injection has been built. A 3 m wide 10 m long slope had to be built to produce the requested topographic effect on the flow. Measurements were obtained by three high resolution scientific cameras. Results are still very recent and are currently being actively analysed.

List of Deliveries and Milestones

The possibility of access has been advertised by e-mails sent to a list of researchers in the field and advertised in several scientific meetings. A visit was organised during the general meeting of EuHIT organised at Grenoble on 11-12 May 2015. A visit has been also organised during a colloquium organised at Grenoble in 11-13 May 2016 http://ejh2016.sciencesconf.org/ (outside the budget of EuHIT).

The projects are summarized in the following table:

Acronym	**Title**	**Contact**	**Duration (access days)**	**Prepa-ration visit**	**Access period**
16MILESTONE	Mixing and length scales in Stratified Turbulence	erikl@mech.kth.se	45	11-12 Jan. 2016	17 May- 22 July 2016
16CREST	Coriolis and Rotational Effects on Stratified Turbulence	j.peakall@leeds.ac.uk	30	17-18 May 2016	12 Sept.- 21 Oct. 2016
16ResEk	Wind stress resonance and deep ocean energy transfer -- laboratory experiments	nor.fenyvesi@gmail.com vincze.m@gmail.com	20	7-8 June 2016	07 Nov.-2 Dec. 2016
17ANNI	Vorticity Annihilation at High Reynolds Numbers - A Question of Initial Conditions?	kriegseis@kit.edu	15	21 June 2016	09 Jan. – 30 Jan. 2017
17SLOCET	Shelf sLOpe impact on Coastal Eddy Turbulence	e.johnson@ucl.ac.uk	25	20 Oct. 2016	13 Feb. -17 March 2017
TOTAL			**135**		

Dissemination Activities

The possibility of access has been advertised by e-mails sent to a list of researchers in the field and advertised in several scientific meetings. A visit was organised during the general meeting of EuHIT organised at Grenoble on 11-12 May 2015. A visit has been also organised during a colloquium organised at

Grenoble in 11-13 May 2016 http://ejh2016.sciencesconf.org/ (outside the budget of EuHIT).

Project meetings

General meeting of EuHIT organised at Grenoble on 11-12 May 2015.
Preparation visit for each access project granted, see table above.

Personnel Statistics:

Personal directly involved in the maintenance and development of the Coriolis platform, whose salary is included in the calculation of the dayly user fee

Name	Status	Role	Manmonth since 2014
Sommeria Joël	Senior researcher CNRS (DR1)	General management	14
Augier Pierre	junior researcher CNRS (CR2)	Instrumentation development and data processing	16
Campagne Antoine	Postdoc UGA	Instrumentation development	3
Viboud Samuel	Engineer CNRS (IE1)	Technical management	19.4
Valran Thomas	Engineer CNRS	Technical design of experiments	10.8
Moreau Gabriel	Engineer CNRS (IR2)	Design and maintenance of the computer system	9.4
Lagauzere Muriel	Engineer CNRS	Electronics and instrumentation	5.1
Vandenberghe Tristan	Engineer CNRS	Mechanical design	0.6
Kukudja Mile	Engineer Grenoble-INP	Mechanical design of projects	5
Virone Joseph	Technician CNRS	Mechanical fabrication and mounting	3.8

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Grant Agreement Number 312778

Work Package 13: Access to LML wind tunnel

4 EUHIT projects were conducted in the LML wind tunnel:

Investigation of inertial particle dynamics in turbulent channel flows (IDyn)

Project leader: Eberhard Bodenschatz, MPIDS, Goettingen, Germany

Team:

- Javier Jimenez, U. Politecnica de Madrid, Madrid, Spain
- Jan Molacek, Max Planck Institute, Göttingen, Germany
- Zellman Warhaft, Cornell University, Ithaca, United States
- Haitao Xu, Max Planck Institute, Göttingen, Germany

LML people involved:

- Michel Stanislas, LML
- Jean-Marc Foucaut, LML
- Christophe Cuvier, LML

Number of access days: 27

Schedule of project: October and november 2014

Significant results:

To investigate droplets dynamics in turbulent boundary layer, some sprays were placed inside the LML wind tunnel test section. Flow diagnosis was conducted through a large streamwise wall-normal particle image velocimetry (PIV) fields 10m downstream of the sprays and through droplets size distributions measurements with a double PDI probe. The PIV set-up was composed of four 2k x 2k cameras in series to obtain the large field of view and to keep a good spatial resolution. The database has been completed (see deliverable WP13.3) in January 2016. The team is now working to analyse the data.

Publications: There is no publication yet

Large scale structures under adverse pressure gradient (LSS)

Project leader: Christian J Kähler, Universität der Bundeswehr München, Germany

Team:

- Callum Atkinson, Monash University, Melbourne, Australia
- Rainer Hain, Bundeswehr University Munich, Neubiberg, Germany
- Agocs Janos, German Aerospace Centre (DLR), Goettingen, Germany
- Sven Scharnowski, Bundeswehr University Munich, Neubiberg, Germany
- Andreas Schroeder, German Aerospace Centre (DLR), Goettingen, Germany
- Janos Agocs, German Aerospace Centre (DLR), Goettingen, Germany
- Matteo Novara, German Aerospace Centre (DLR), Goettingen, Germany
- Reinhard Geisler, German Aerospace Centre (DLR), Goettingen, Germany
- Julio Soria, Monash University, Melbourne, Australia
- Christian Willert, German Aerospace Center (DLR), Koeln, Germany

LML people involved:

- Michel Stanislas, LML
- Jean-Marc Foucaut, LML
- Christophe Cuvier, LML
- Sricharan Srinath, LML
- Jean-Philippe Laval, LML

Number of acces days: 52

Schedule of project: January to May 2015

Significant results:

The experiments were performed over a ramp assembled on the floor of the LML wind tunnel. The main experiment was conducted between the 4th and 22nd of May 2015. In order to characterize the adverse pressure gradient turbulent boundary layer in detail, different measurement techniques were applied: 2D2C PIV with 16 sCMOS cameras, Stereoscopic PIV with 2 x 2 cameras, instantaneous and time-resolved long-range Micro-PIV measurement for capturing the wall-shear stress and time dependence of near-wall structures at specific stream-wise locations. Wall-shear stress measurements were also conducted using PIV parallel to the wall in the viscous sublayer.

The database has been completed (see deliverable WP13.3) in January 2016. The different teams are now working to analyse the data. The experiments have been presented in several conferences.

Publications:

- R. Hain, S. Schamowski, N. Reuther, C.J. Kahler, A. Schroder, R. Geisler, J. Agocs, A. Rose, M. Stanislas, C. Cuvier, J.-M. Foucaut, S. Srinath, C. Willert, J. Klinner, O. Amili, C. Atkinson, Coherent large scale structures in adverse pressure gradient J.-P. Laval, J. Soria, turbulent boundary layers, Proceedings of the 18th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal, 4-7 July 2016
- J. Soria, C. Willert, O. Amili, J. Klinner C. Atkinson, M. Stanislas, A. Schroder, R. Geisler, J. Agocs, A. Rose, C.J. Kahler, S. Schamowski, R. Hain, J.-M. Foucaut, C. Cuvier, S. Srinath, J.-P. Laval, Spatially and temporally resolved wall shear stress measurements and their relationship with uniform momentum zones in a high Reynolds number adverse pressure gradient turbulent boun dary layer, Proceedings of the 18th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal, 4-7 July 2016
- S. Srinath, C. Cuvier, M. Stanislas, J. M. Foucaut, J. P. Laval, C. J. Kähler, R. Hain, S. Scharnowski, A. Schröder, R. Geisler, J. Agocs, A. Röse, C. Willert, J. Klinner, J. Soria, O. Amili, C. Atkinson, Experimental characterisation of a high Reynolds number turbulent boundary layer subjected to adverse pressure gradient, European Turbulence Conference Stockholm, 21-24 August, 2017
- C. Willert, C. Cuvier, J.-M. Foucaut (2017). Experimental Evidence of Near-Wall Reverse Flow Events in a Zero Pressure Gradient Turbulent Boundary Layer, *Submitted to Experiment in Fluids.*
- C. Cuvier, S. Srinath, M. Stanislas, J.-M. Foucaut, J.-P. Laval, C. J. Kähler, R. Hain, S. Scharnowski, A. Schröder, R. Geisler, J. Agocs, A. Röse, C. Willert, J. Klinner, O. Amili, C. Atkinson, J. Soria (2017). Extensive characterization of a high Reynolds number decelerating boundary layer using advanced optical metrology. *Submitted to Journal of Turbulence*

Non-equilibrium turbulence in an axisymmetric wake (NET)

Project leader: John Christos Vassilicos, Imperial College London, UK

Team:

- Martin Obligado, Imperial College London, UK

LML people involved:

- Jean-Marc Foucaut, LML
- Christophe Cuvier, LML

Number of access days: 20

Schedule of project: March 2016

Significant results:

A fractal plate was mounted centred at the entrance of the 20m test section. Single and Crossed Hot Wire measurements were performed at 21 locations from one diameter behind the object up to 7.4m downstream (115 diameters). The data analysis are still in progress.

Publications: No publication yet

Enhanced Turbulent Outer Peak using uniform Micro-Blowing Technique (ETOPMBT)

Project leader: Brandenburg University of Technology Cottbus-Senftenber

Team:

- Gazi Hasanuzzaman, BTU Cottbus-Senftenberg, Cottbus, Germany
- Christoph Egbers, BTU Cottbus-Senftenberg, Cottbus, Germany
- Sebastian Merbold, BTU Cottbus-Senftenberg, Cottbus, Germany
- Vasyl Motuz, BTU Cottbus-Senftenberg, Cottbus, Germany

LML people involved:

- Jean-Marc Foucaut, LML, France
- Jean-Philippe Laval, LML, France
- Christophe Cuvier, LML, France

Number of access days: 13

Schedule of project: February and March 2017

Significant results:

The project was devoted to investigate the interaction between turbulent boundary layer and blowing air from uniformly distributed perforated wall (Micro-Blowing Technique-MBT) at LML boundary layer wind tunnel. The campaign was aimed to make SPIV measurements in the Large Boundary Layer Facility of Laboratoire de Mécanique de Lille (LML). This LML facility was appropriate to observe modifications of BL using uniform vertical blowing from a perforated plate at high Reynolds. Reynolds number dependence for magnitude and wall normal location of turbulence intensity outer peak of all 3 velocity components was intended to investigate using SPIV measurements. During this campaign, 4 uniform blowing ratios were measured at 3 different free-stream velocities. A total of approx 5.3 TB data of raw images were obtained for the 12 test cases studied. Part of the data were analysed during the experiment to validate the acquisition parameters.

Publications:

- G. Hasanuzzaman , V. Motuz , S. Merbold, C. Egbers, C. Cuvier , J.-M. Foucaut, Turbulent boundary layer statistics under the influence of uniform micro-blowing, 16th European Turbulence Conference, 21-24 August 2017, Stockholm, Sweden

Task : Development of a unique database of near wall turbulence on the EUHIT TurBase interface

Responsible partner: CNRSd (LML)

Collaborators:

- Jean-Philippe Laval (Researcher)
- Arnaud Beaurain (Research Engineer)
- Christophe Cuvier (Short term contract Engineer)

A significant amount of ressources were spent for the extra proposal **"Development of a unique database of near wall turbulence on the EUHIT TurBase interface ".**

The aim of this proposal was to provide a unique databases for the validation of turbulence models on Zero pressure gradient and Adverse Pressure Gradient wall turbulent flows. Part of this database is composed of prior results obtained in the LML wind tunnel and the second part is the results from the large EUHIT project "Large scale structures under adverse pressure gradient". Additional measurements were performed by LML to complement the main experiments of this project. The work has been divided on 4 deliverables.

Deliverables	Description	Man Month	Status
WP13-1	Loading of the existing LML database in TurBase	2	**Delivered 12/07/2016**
WP13-2	Check and write documentation for additional LML data and load raw data and statistics in Turbase	4,5	**Delivered 19/12/2016**
WP13-3	Write documentation and load data of the 2 EUHIT projects on the LML facilities in TurBase	3,5	**Delivered 15/02/2016**
WP13-4	Additional measurements on the LML joined experiment on APG flows ; Validation and Post-processing of the data ; Loading of data and documentation in Turbase	3,5	**Delivered 25/04/2016**

For each set of data, this includes checking the data, putting the data in suitable shape and format, writing some scripts in Matlab to read the data and writing a report to present the experiments and the databases. Then the data have been loaded into the turbase database

Datasets associated to the deliverable WP13-3

1. **[large_scale_piv_boundary_layer_with_spray]** Water droplets dynamics in turbulent boundary layer

2. **[lml_apg_turbulent_boundary_layer_near_wall_profiles]** Adverse Pressure Gradient Turbulent Boundary Layer: Near wall profiles

3. **[lml_apg_turbulent_boundary_layer_2d2c_16scmos]** Adverse Pressure Gradient Turbulent Boundary Layer: streamwise plane

Datasets associated to the deliverable WP13-4

1. **[lml_apg_turbulent_boundary_layer_pressure_distribution]** Adverse Pressure Gradient Turbulent Boundary Layer: Pressure distribution and wind tunnel and ramp model description
2. **[lml_apg_turbulent_boundary_layer_inlet_conditions]** Adverse Pressure Gradient Turbulent Boundary Layer: inlet conditions
3. **[lml_apg_turbulent_boundary_layer_side_walls_flow]** Adverse Pressure Gradient Turbulent Boundary Layer: Characterisation of side walls flow
4. **[lml_apg_turbulent_boundary_layer_fpg_flow]** Adverse Pressure Gradient Turbulent Boundary Layer: Favourable pressure gradient region

Datasets associated to the deliverable WP13-1

4. [dns_channel_flow_with_apg] Direct Numerical Simulation of channel flow over a smooth geometry
5. [fp_tbl_wallturb_hwa_profiles] Flat plate turbulent boundary layer: hot-wire profiles
6. [fp_tbl_wallturb_multiple_spiv_planes] Flat plate turbulent boundary layer: multiple SPIV planes
7. [fpg_tbl_wallturb_double_spiv_planes_n_hotwire_rake] Flat plate turbulent boundary layer: WALLTURB double SPIV planes and hot-wire rake
8. [fpg_tbl_wallturb_high_speed_spiv_plane_n_hotwire_rake] Flat plate turbulent boundary layer: WALLTURB high speed wall parallel SPIV plane and hot-wire rake
9. [apg_tbl_wallturb_hwa_profiles] Adverse pressure gradient turbulent boundary layer: AEROMEMS hot-wire profiles
10. [apg_tbl_wallturb_multiple_spiv_planes] Adverse pressure gradient turbulent boundary layer: AEROMEMS multiple SPIV planes
11. [apg_tbl_wallturb_high_speed_spiv_plane_n_hotwire_rake] Adverse pressure gradient turbulent boundary layer: WALLTURB high speed wall parallel SPIV plane and hot-wire rake
12. [apg_tbl_wallturb_double_spiv_planes_n_hotwire_rake] Adverse pressure gradient turbulent boundary layer: WALLTURB double SPIV planes and hot-wire rake

Datasets associated to the deliverable WP13-2

1. **[fp_tbl_spiv_two-perpendicular_planes]** Flat plate turbulent boundary layer: two synchronize stereo-PIV perpendicular planes in the near wall region
2. **[fp_tbl_piv_long_streamwise_plane]** Flat plate turbulent boundary layer: long streamwise 2D2C PIV plane

3. [fp_tbl_spiv_pressure_velocity_correlation] Flat plate turbulent boundary layer: spanwise Stereo-PIV plane synchronize with unsteady pressure fluctuations in the field

Use of resources:

The work associated to the generation of databases has been performed essentially by two permanents from LML with the help of a research Engineer in short term contract (not hired on EUHIT). The EUHIT ressources spent on this task within the reporting period are:

- Jean-Philippe Laval (Researcher) : **107 days**
- Arneaud Beaurain (Research Engineer) : **88 days**

https://turbase.cineca.it/turbase/default/ - /view_dataset/39

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 14: Access to Czech Cryogenic Turbulence Facility (CCTF)

Summary

Three installations belong to this facility: the Liquid Helium Flow Visualization (CCTF1) and the He II Quantum Turbulence (CCTF2) are located in Prague (Charles University), while the Helium Cryostat for Experimental Study of Natural Thermal Convection (CCTF3) is in Brno (Institute of Scientific Instruments). Two projects were performed in CCT2 and one in CCTF1, see the previous report and below for more details. Additionally, as already reported, L. Skrbek (the facility leader) decided not to claim access resources, due to the large amount of administrative work required, when compared to the actual amount of resources employed to perform experiments. In other words, solely travel expenses have been claimed, by the foreign researchers visiting the facility and by the Czech researchers taking part in the facility workshop.

Dissemination Activities

The facility workshop was held in October 2015, see ‘https://www.euhit.org/events/euhit-cryogenic-turbulence-workshop’ and the previous report for more details.

Publications

The work package resulted in five journal publications, as detailed below.

Personnel Statistics

Charles University, Prague: L. Skrbek (facility leader, male), M. La Mantia (researcher, m), D. Schmoranzer (researcher, m), M. J. Jackson (researcher, m), D. Duda (student, m), E. Varga (student, m); Institute of Scientific Instruments, Brno: P. Urban (researcher, m), V. Musilová (researcher, female).

Task: Access to CCTF

Title of the user project (Acronym): FISHOS

Installation: CCTF2

Project leader: V. Tsepelin (Lancaster University)

Team: A. J. Woods (Lancaster University), D. Schmoranzer (Charles University, Prague)

Significant results: The second sound attenuation technique was employed in order to quantify the vortex line density produced by quartz tunig forks vibrating in superfluid helium 4 (see the previous report for more details). The project resulted in two journal publications.

Publications: M. J. Jackson, O. Kolosov, D. Schmoranzer, L. Skrbek, V. Tsepelin, A. J. Woods (2016) *Measurements of vortex line density generated by a quartz tuning fork in superfluid 4He*, J Low Temp Phys 183, 208; D. Schmoranzer, M. J. Jackson, V. Tsepelin, M. Poole, A. J. Woods, M. Človečko, L. Skrbek (2016) *Multiple critical velocities in oscillatory flow of superfluid 4He due to quartz tuning forks*, Phys Rev B 94, 214503

Title of the user project (Acronym): V-Front

Installation: CCTF2

Project leader: V. S. L'vov (Weizmann Institute of Science, Rehovot)

Team: A. Pomyalov (Weizmann Institute of Science, Rehovot), L. Skrbek (Charles University, Prague)

Significant results: The project aim was to investigate experimentally channel flows of superfluid helium 4 at various distances from the flow source by using the second sound attenuation technique (see the previous report for more details). The project resulted in three journal publications.

Publications: J. Gao, W. Guo, V. S. L'vov, A. Pomyalov, L. Skrbek, E. Varga, W. F. Vinen (2016) *Decay of counterflow turbulence in superfluid 4He*, JETP Lett 103, 648; E. Varga, S. Babuin, V. S. L'vov, A. Pomyalov, L. Skrbek (2016) *Transition to quantum turbulence and streamwise inhomogeneity of vortex tangle in thermal counterflow*, to be published in J Low Temp Phys; S. Babuin, V. S. L'vov, A. Pomyalov, L. Skrbek, E. Varga (2016) *Coexistence and interplay of quantum and classical turbulence in superfluid 4He: decay, velocity decoupling, and counterflow energy spectra*, Phys Rev B 94, 174504

Title of the user project (Acronym): QuantumPC

Installation: CCTF1

Project leader: M. Bourgoin (CNRS Lyon)

Team: B. Rousset (CEA Grenoble), M. Gibert (CNRS Grenoble), P. Diribarne (CEA

Grenoble), L. Skrbek (Charles University, Prague), M. La Mantia (Charles University, Prague)

Significant results: The project aim was to investigate experimentally, by visualization, particle preferential concentration, if any, in quantum flows. Relevant experiments were designed in 2016 (1 visit) and performed in 2017 (2 visits). The corresponding data processing is currently in progress. Preliminary results indicate that particle preferential concentration in thermal counterflow of superfluid helium 4 might have features different from those observed in flows of classical viscous fluids. It is very likely that a joint publication will be submitted in due course and that the collaboration started between the researchers thanks to the project will continue in the coming years.

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Grant Agreement Number 312778

Work Package 15: Access to Refractive Index Matched Tunnel of LSTM-Erlangen (RIMT)

Summary

There is now an active grid designed for RIMT. Nevertheless, there was no applicant to conduct research at RIMT. One important reason is the running fluid inside. The experiments can be conducted only by optical measurement methods and the test objects has to be designed from special glass so that the refractive index can be matched.

List of Deliveries and Milestones:

No deliveries, no milestones in this WP

Dissemination Activities

Type: Video recordings of RIMT broadcasting
Main Leader: Prof. Dr. Eberhard Bodenschatz, Prof. Dr. Holger Nobach
Date: July- 2015
Place: LSTM, Erlangen, Nürnberg
Type of audience: Scientific community and engineering community
Size of audience: N /A
Countries addressed: All

Project meetings

Göttingen, May 13th, 2013, Kick-off meeting

Twente, May 12th-13th, 2014, General assembly meeting

Brussels, January 28th, 2015, Midterm Review Meeting

Publications

There are no publications within the access program to RIMT, as no collaborative research done within the framework of EUHIT using this facility.

Personnel Statistics:

Personal responsible for the access program were not active.

- Scientific Coordinator: Asst. Prof. Dr.-Ing. Özgür Ertunç (m)
- Work package leaders: Asst. Prof. Dr.-Ing. Özgür Ertunç (m), Dipl.-Ing. Hermann Lienhart (m)
- Technician: Heinz Hedwig

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Grant Agreement Number 312778

Work Package 16: Access to Cottbus turbulence experimental facilities

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Summary

- **Summary**
  CoGeoF have been established by the BTU Cottbus, Department of Aerodynamics and Fluid Mechanics within the Center of Flow and Transport Modeling and Measurement (CFTM2). CoGeoF is equipped with advanced measurement technologies (Stereo PIV, Tomo PIV, LIF, LDA, infrared thermography, X-Tripping, inlet fences). CoGeoF and CoLaPipeF are part of the Fluid-Center-Building located on the Campus of the Technical University Cottbus.
  - CoGeoF1 – Baroclinic Wave Tank
  - CoGeoF2a/b – Two Inertial Wave Tanks
  - CoGeoF3 – Taylor-Couette-System
  - CoLaPipeF – Large Pipe Facility.

  The CoGeoF setups are particularly useful for geophysical applications, i.e. for studies on rotating stratified flows. CoLaPipeF is designed and built up to investigate highly turbulent pipe flow with particular regard to the nature of transition, turbulent structures, scaling theory and turbulent transport processes at high Reynolds numbers.

- **List of Deliveries and Milestones**
  No deliverables and milestones

- Dissemination Activities

  Press article for the Civil Society (Brandenburg, Germany):
  "Geheimnisvolle Turbulenzen faszinieren BTU", Lausitzer Rundschau, Sa./So. 13./14. Sept. 2014

Presentation of Department Aerodynamic and Fluid Mechanic BTU C-S and the TNA for EuHIT, (youtube)

EuHIT booth at 19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Oral presentations where EUHIT projects have been promoted. The audience was the Scientific community.

DFG Conference on Turbulent flows: FOR 1182, Pottenstein, Germany, 2013

European Turbulence Conference, Lyon, France 2013

General Assembly of the European Geophysical Union, Vienna, Austria, April 2014

DFG-SPP-Turbulence-Meeting, Frankfurt, Germany, July 2014

LIA ISTROF-meeting, LeHavre, France 2014

European Fluid Mechanics Conference, Copenhagen, Denmark 2014

GALA-Meeting for Laser measurments, Karlsruhe, Germany 2014

ITI workshop, Bertinoro, Italy 2014

Presentation of Department Aerodynamic and Fluid Mechanic BTU C-S and the TNA for EuHIT, (youtube)

EuHIT booth at 19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Öngüner, E., Dittmar, M., Meyer, P., Egbers, Ch., 2015
PIV-Messungen in horizontaler Rohrströmung bei hohen Re-Zahlen
GALA - Fachtagung Lasermethoden in der Strömungsmesstechnik, 8-10.09.2015, Dresden, Germany, ISBN 978-3-9816764-1-9

Öngüner, E., Egbers, C., PIV and Hot-Wire Measurements in a Incompressible Horizontal Pipe Flow, Workshop: Mechanics of Rotating Fluids, 24.04.2015, Politechnika Poznanska, Poznan, Poland

Froitzheim, A., Merbold, S., Egbers, Ch., 2015
PIV Messungen in einer Taylor-Couette Strömung mit weitem Spalt
GALA - Fachtagung Lasermethoden in der Strömungsmesstechnik, 8-

10.09.2015, Dresden, Germany, ISBN 978-3-9816764-1-9

Froitzheim, A., Merbold, S., Egbers, Ch., 2015
Torque measurements ans flow visualisation in a wide gap Taylor-Couette Flow, 15. European Turbulence Conference ETC, 25.-28. August, Delft, The Netherlands

Seelig, T., Kielczewski, K., Tuliszka-Sznitko, E., Harlander, U., Egbers, Ch., Bontoux, P., 2015
Taylor-Couette flow with asymmetric end-walls boundary conditions
15. European Turbulence Conference ETC, 25.-28. August, Delft, The Netherlands

Hoff, M., Harlander, U., Egbers, Ch., 2015
Experimental study of the fluid flow in a spherical shell induced by librations of the inner sphere: Linear and non-linear features
19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Triana, S. A., Hoff, M., Egbers, Ch., 2015
Inertial Modes driven by differential rotation in a spherical Couette configuration
19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Martinez-Arias, B., Peixinho, J., Froitzheim, A., Merbold, S., Egbers, Ch., Mutabazi, I., 2015
Influence of the radius ratio on the torque in turbulent Taylor-Couette flow, 19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Früh, W.-G., Szabo, P., Seelig, T., Hoff, M., Egbers, Ch., 2015
Spectral features of the transition to Structural Vacillation in the baroclinic annulus, 19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Le Gal, P., Vincze, M., Harlander, U., 2015
The baroclinic instability of an initially stratified fluid layer
European Geosciences Union (EGU) General Assembly 2015, held 12.-17. April 2015, Vienna Austria

Hoff, M., Harlander, U., Jahangir, S., Egbers, Ch., 2015
Experimental study of inertial waves in a spherical shell induced by librations of the inner sphere
European Geosciences Union (EGU) General Assembly 2015, held 12.-

17. April 2015, Vienna Austria

Seelig, T., 2015
Taylor-Couette flow with asymmetric vertical boundary conditions
Mechanics of rotating fluids, Workshop on co-operations in fluid dynamics in Poznan, Poland
Öngüner, E., Egbers, C., Streamwise and Cross-sectional PIV Studies in Cottbus Large Pipe, DFG / FOR1182 Workshop; Turbulence Spring School, 5.-6.04.2016, Vienna, Austria

Hoff, M., Harlander, U., Triana, S. A., Egbers, Ch., 2016
Inertial modes and their transition to turbulence in a differentially rotating spherical gap flow, European Geosciences Union (EGU) General Assembly 2016, Vienna, Austria, 17-22. April 2016

Hoff, M., U.Harlander, S.A. Triana, Ch. Egbers: Inertial modes and their transition to turbulence in a differentially rotating spherical gap flow. EuHIT Turbulence Conference, Göttingen, Germany, May 2016

Hoff, M., U. Harlander, S.A. Triana: Interacting Inertial modes and their instability in a differentially rotating spherical gap flow, 31st IUGG Conference on Mathematical Geophysics (CMG) 2016, Paris, France, June 2016

Froitzheim A., Merbold S., Egbers Ch.: Experimental investigations on turbulent Taylor-Couette flow - A summary of two EuHIT campaigns. EuHIT Turbulence Conference, Göttingen, Germany, May 2016

Öngüner, E., Selvam, K., Peixinho, J., Zanoun, E.-S., Egbers, C., An Overview of Turbulent Pipe Flow Activities in Cottbus Large-Pipe Test Facility, EuHIT (European High-Performance Infrastructures in Turbulence) Conference, 2.-3.05.2016, Göttingen, Germany

Zanoun, E.-S., Öngüner, E., Motuz, V., Egbers, Ch., Fiorini, T., Örlü, R., Bellani, G., Talamelli, T. 2017: Direct and In-Direct Measurements of Momentum Structure in CoLaPipe, 16th European Turbulence Conference, 21-24 August 2017, Stockholm, Sweden

- Project Meetings

  EUHIT Kichoff meeting, Frankfurt 2013

  EUHIT meeting, Twente 2014

  EUHIT General Assembly Meeting in Grenoble, France, 2015

  EUHIT General Assembly Meeting in Göttingen, Germany, 2016

- Publications

Franziska König, El-Sayed Zanoun, Emir Öngüner, and Christoph Egbers (2014) The CoLaPipe—The new Cottbus large pipe test facility at Brandenburg University of Technology Cottbus-Senftenberg, REVIEW OF SCIENTIFIC INSTRUMENTS,85, 075115.

M. Vincze, U. Harlander, and P Le Gal (2014) The baroclinic instability of an initially stratified fluid layer. Americal Physical Socienty 67th Annual DFD Meeting, San Francisco; Open Access.

Seelig, T., Harlander, U., 2015: Can zonally symmetric inertial waves drive an oscillating zonal mean flow? Geophysical & Astrophysical Fluid Dynamics 109(06), 541-566 (2015), DOI 10.1080/03091929.2015.1094064

R.C.A. van der Veen, S.G. Huisman, S. Merbold, U. Harlander, C. Egbers, D. Lohse, C. Sun, 2016: Taylor-Couette turbulence at radius ratio of eta=0.5: scaling, flow structures and plumes. Accepted by Journal of Fluid Mechanics.

Hoff, M., Harlander, U., Egbers, Ch., 2016: Experimental survey of linear and nonlinear inertial waves and wave instabilities in a spherical shell Journal of Fluid Mechanics Volume: 789 pages 589-616

M. Hoff, U. Harlander, and S.A. Triana. Study of turbulence and interacting inertial modes in a differentially rotating spherical shell experiment. Physical Review Fluids, 1, 043701, 2016.

M. Vincze, I.D. Borcia, U. Harlander, and P. Le Gal. Double-diffusive convection and baroclinic instability in a differentially heated and initially stratified rotating system: the barostrat instability. Accepted by Fluid Dynamics Research, 2016

Miklós Vincze, Ion Dan Borcia and Uwe Harlander, 2017: Temperature fluctuations in a changing climate: an ensemble based experimental approach, Scientific Reports, 7:254, DOI:10.1038/s41598-017-00319-0.

- Personnel Statistics
  - Scientific Coordinators:

    Christoph Egbers BTU Cottbus-Senftenberg, Cottbus, Germany (m)

Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany (m)

- Work package leaders:

  Santiago Andres Triana KU Leuven, Leuven, Belgium (m)

  Anthony Randriamampianina Centre National de la Recherche Scientifique (CNRS), Marseille, France (m)

  Santiago Andres Triana KU Leuven, Leuven, Belgium (m)

  Ewa Małgorzata Tuliszka-Sznitko Poznan University of Technology, Poznan, Poland (f)

  Roeland C. A. van der Veen University of Twente, Enschede, Netherlands (m)

  Borja Martínez Arias CNRS, Le Havre, France (m)

  Wolf-Gerrit Fruh Heriot-Watt University, School of Engineering and Physical Sciences, Edinburgh, United Kingdom (m)

  Ramis Örlü KTH - Royal Insitute of Technology, Sweden (m)

  Tomasso Fiorini University of Bologna, Italy (m)

  Patrice Le Gal CNRS - Aix Marseille University, Institut de Recherche sur les Phénomènes Hors Equilibre, Marseille, France (m)

  Miklos Vincze Hungarian Academy of Sciences, MTA-ELTE Theoretical Physics Research Group, Budapest, Hungary (m)

  Jorge Peixinho CNRS, Le Havre, France (m)

  Alessandro Talamelli, University of Bologna, Italy (m)

- Experienced researchers (incl. information m/f)

  Sander Huisman University of Twente, Enschede, Netherlands (m)

  Detlef Lohse Univ of Twente, Enschede, Netherlands (m)

Chao Sun University of Twente, Enschede, Netherlands (m)

Innocent Mutabazi LOMC, UMR 6294 CNRS-Université du Havre, Le Havre, France (m)

Jorge Peixinho CNRS, Le Havre, France (m)

Andrea Ianiro Universidad Carlos III de Madrid, Spain (m)

Stephano Discetti Universidad Carlos III de Madrid, Spain (m)

Zanoun El Sayed Mahmoud, Benha University, Faculty of Engineering, Benha, Egypt

- PhD students (incl. information m/f)

  Kamil Konstanty Kielczewski Poznan University of Technology, Poznan, Poland (m)

  Sebastian Merbold Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany (m)

  Gazi Hasanuzzaman, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany (m)

  Emir Öngüner, Brandenburg University of Technology, Cottbus, Germany (m)

- Other (incl. information m/f)

Main tasks

The Chair provides trans-national access to 4 facilities; CoGeoF1-CoGeoF3 cover experiments on rotating platforms suited for applications in the geophysical context, CoLaPipeF is a closed-return air pipe facility with constant temperature conditions.

Responsible partner:

Interdisciplinary exchange is planned with Göttingen High Pressure Turbulence Facility (WP5), Twente Turbulence Facilities (WP8), Barrel of Ilmenau (WP7), CICLoPE (WP9). The facilities contribute to Turbulence Generation (WP20).

Collaborators:

Objectives of Period (month 1 - 48):

Main objective was to provide access to our facilities for the European research teams. A further objective was to store the data in a format convenient for the users of our facility and to provide software for data analysis.

Concise overview:

In the first (month 1 - 18) period 4 projects have been funded, in the second period (19-36) period 5 research teams used our facilities at BTU Cottbus-Senftenberg and in the last one (37-48) 4 projects have been funded. Hence in total 13 projects have been funded. In all funding periods we hence fulfilled the main objective given above. In the following we list all the projects.

Completed projects

Measurements of the boundary layer in turbulent Taylor-Couette flow at small radius ratios

CoGeoF3

Project leader: Roeland C. A. van der Veen University of Twente, Enschede, Netherlands

Team: Christoph Egbers BTU Cottbus-Senftenberg, Cottbus, Germany; Sander Huisman University of Twente, Enschede, Netherlands; Detlef Lohse Univ of Twente, Enschede, Netherlands; Sebastian Merbold Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany; Chao Sun University of Twente, Enschede, Netherlands

Significant Results: In this work we investigate the turbulent flow in counter rotating Taylor-Couette flow. Using a high speed Particle Image Velocimetry system with high resolution cameras the flow between the cylinders is observed. By this the boundary layers at the inner as well as the outer cylinder are resolved and measured. In addition the acting dimensionless torque for the same Configuration is measured to compare effective torque with the gradients at the wall and the resulting fluid flow between the both boundary layers.

Turbulent Taylor-Couette Torque Measurement

CoGeoF3

Project leader: Borja Martínez Arias CNRS, Le Havre, France

Team: Christoph Egbers BTU Cottbus-Senftenberg, Cottbus, Germany; Sebastian Merbold Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany; Innocent Mutabazi LOMC, UMR 6294

CNRS-Université du Havre, Le Havre, France; Jorge Peixinho CNRS, Le Havre, France

Significant results: During this project we analyze the influence of different states in the Taylor-Couette flow. In previous to this project the Le Havre group already measured the influence of different wavelengths of the Taylor-Vortices to the effecting torque to the inner wall for a narrow gap Taylor Couette flow (Radius ratio 0.91). In the present project this investigation is employed to the turbulent Taylor-Couette experiment with radius ratio 0.5. Different flow states were observed using the acceleration of the inner cylinder to a constant Reynolds number. The torque is being measured, fluid flow visualization is performed to count the number of vortices and Laser Doppler Velocimetry is adapted to measure turbulent fluctuations at different positions in the flow.

Baroclinic instability of an initially stratified layer

CoGeoF1

Project leader: Patrice Le Gal CNRS - Aix Marseille University, Marseille, France

Team: Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany; Miklos Vincze BTU Cottbus-Senftenberg, Cottbus, Germany

Significant results: Our project aims to describe the baroclinic instability that destabilizes an initially stratified layer of fluid. Classically, this instability is studied using pure fluid. Here, the originality of the project comes from the use of a layer of water initially stratified. A conductimeter is used to measure the salt water density stratification. Before rotation is started, double convection sets in within the stratified layer with a strongly non-homogeneous pattern consisting of a double diffusive staircase at the bottom of the container in the very dense water layers and a shallow convective cell in the top surface layer. As radial motions take place due to the presence of these convective cells, the action of the Coriolis force generates strong zonal flows as soon as rotation is started. Thus, above a rotation rate threshold whose value depends on the horizontal temperature and salinity gradients and on the uncontrolled thickness of the convective cell, the baroclinic instability destabilizes the flow in a shallow layer, generating a ring of pancake vortices. These original observations will surely open new routes in the study of atmospheric baroclinic instabilities. In particular let us remark that the stable stratified zone that sets under the unstable shallow layer in the experiment mimics perfectly well the stratosphere that sits above the atmospheric baroclinically unstable layers.

Investigations of the transitional and turbulent flows in rotor/stator cavities

CoGeoF2b

Project leader: Ewa Małgorzata Tuliszka-Sznitko Poznan University of Technology, Poznan, Poland

Team: Kamil Konstanty Kielczewski Poznan University of Technology, Poznan, Poland

Significant results: We considered a Taylor-Couette flow with asymmetric upper/lower boundary conditions. The inner cylinder together with the upper lid rotated, the outer cylinder and the bottom lid was fixed. This system is a modification of the classical Taylor-Couette setup, but can be seen also as a particular rotor-stator flow with several applications in engineering (turbines, pumps,…). For different aspect ratios (height/gap width) the flow was measured using the Stereo-PIV technique. We measured the flow structure in the Bödewadt boundary layer (bottom) as well as the Ekman layers (top). In both layer certain instabilities occur that shape the structure of the flow. We measured the structures as a function of the Reynolds number and the aspect ratio. Preliminary results show interesting flow structures that are in accordance with numerical simulations.

Detection of Inertia Gravity Waves in a Water-filled Rotating Baroclinic Wave Tank

CoGeoF1

Project leader: Anthony Randriamampianina Centre National de la Recherche Scientifique (CNRS), Marseille, France

Objectives and main results: The objectives of the project proposed here can be summarized as follows: (i) Modify the existing BTU experimental facility to enable inertia gravity wave detection (inserting co-rotating thermometers); (ii) Carry out the measurement campaign using subsurface thermometers and surface infrared thermography simultaneously; (iii) Conduct numerical simulations with the same geometric and physical parameters and compare the experimental and numerical results.

A detection of gravity waves in the Cottbus facility using water (Pr = 7) would clearly point to a wave generation mechanism different from the type discussed by Gill and Davey (1969), interpreted as a localized thermal boundary layer instability.

The measurements show signatures of gravity waves but the results were rather difficult to interpret. Later numerical simulations [1] could show that Kelvin-Helmholtz type shear instability is responsible for gravity wave generation at Pr=7.

[1] A. Randriamampianina1, E. Crespo del Arco 2015: Inertia-gravity waves in

a liquid-filled, differentially heated, rotating annulus. J. Fluid Mech. (2015), vol. 782, pp. 144-177.

Inertial Mode Excitation: The Role of Critical Layers

CoGeoF2a/b

Project leader: Santiago Andres Triana KU Leuven, Leuven, Belgium

Team: Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany

<u>Objectives and main results:</u> Inertial modes can be excited efficiently in a fluid-filled spherical shell with a differentially rotating inner sphere. Previous experimental and analytic studies suggest that critical layers (i.e. corotation resonances) have a fundamental role in the excitation process, but so far there are no direct measurements of the shear flow exciting the inertial modes. We used the Cottbus spherical shell facility to perform laser Doppler velocimetry (LDV) and Particle Image Velocimetry (PIV) measurements to study and characterize in detail the differential rotation profile of the fluid. This study is invaluable for further development and validation of the existing theoretical model involving corotation resonances. Critical layer phenomena, analogous to the one described here, play a key role in the excitation mechanism of both internal gravity waves and gravito-inertial waves in stellar interiors. Moreover, for strong forcing the excited waves might transit to wave turbulence, a process not well understood for inertial waves but of great importance for geophysical flows.

We found a so far not observed transition to turbulence. This transition is characterized by a severe drop of kinetic energy of the most dominant inertial wave mode and an increase in energy with respect to the mean flow. The results have recently been published [1,2].

[1] M. Hoff, U. Harlander, S.A. Triana 2016: A study of turbulence and interacting inertial modes in a differentially-rotating spherical shell experiment, submitted to *Physical Reviews: Fluids*

[2] M. Hoff, U. Harlander, and S.A. Triana. Study of turbulence and interacting inertial modes in a differentially rotating spherical shell experiment. Physical Review Fluids, 1, 043701, 2016.

Spatial and spectral features of the onset of turbulence in baroclinic flow

CoGeoF1

Project leader: Wolf-Gerrit Fruh, Heriot-Watt University, School of Engineering and Physical Sciences, Edinburgh, United Kingdom

Team: Christoph Egbers BTU Cottbus-Senftenberg, Cottbus, Germany

Objectives and main results: The thermally-driven baroclinic rotating annulus is a key system to investigate nonlinear dynamics and transition to turbulent flow in a rapidly rotating fluid. This project investigated the onset of turbulent flow in the Cottbus Baroclinic Wave Tank. Starting with a regular and large-scale baroclinic wave flow, and incrementally increasing the forcing, the structure of the flow features emerging alongside the large-scale wave will be observed in both, the temperature field in the surface layer using the Infrared camera and the horizontal velocity field in the interior using particle image velocimetry (PIV). Analysing the spatiotemporal features and their spectra have been used to explore the processes leading to turbulence in this stably stratified, rapidly rotating fluid. The results have been presented on a conference on Taylor-Couette flow [1].

[1] Früh, W.-G., Szabo, P., Seelig, T., Hoff, M., Egbers, Ch., 2015: Spectral features of the transition to Structural Vacillation in the baroclinic annulus, 19th International Couette-Taylor Workshop, 24-26 June 2015, Cottbus, Germany

Extremes in a Changing Climate - a Laboratory Approach (XCLIM Lab)

CoGeoF1

Project leader: Miklos Vincze Hungarian Academy of Sciences, MTA-ELTE Theoretical Physics Research Group, Budapest, Hungary (m)

Team: Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany

Objectives and main results: The extreme value statistics of temperature fluctuations have been investigated in the Cottbus baroclinic wave tank as a minimal experimental model of atmospheric circulation. The nonlinear, geostrophic turbulent nature of this model flow–-that has been found to produce surprisingly similar temperature statistics to the real atmosphere in several previous studies–-and the fact, that the experimental conditions are properly reproducible, makes this set-up a perfect test bed to apply and test some extreme statistical methods widely used in climatology. By gradually changing the lateral temperature temperature difference that drives the overturning flow in the system, it was possible to model a ”climate change-like” scenario. The laboratory investigation has supported a better understanding of the causal connections between the rapid global warming and the increasing number of unusually warm or cold seasons observed coincidentally in the past 30 years at the mid-latitudes of Earth. The work is in progress [1,2].

[1] Vincze, M: Modeling climate change in the laboratory, Teaching Physics Innovatively: selected contributions and invited talks (2016), Springer Verlag.

[2] Miklós Vincze, Ion Dan Borcia and Uwe Harlander, 2017: Temperature fluctuations in a changing climate: an ensemble based experimental approach,

Scientific Reports, 7:254, DOI:10.1038/s41598-017-00319-0.

Turbulence development of the high Reynolds number flow in the CoLaPipe

Project leader: Jorge Peixinho CNRS & Université du Havre, Le Havre, France

Team: Kamal Selvam, Normandy University, PhD Research Student, Le Havre, France

El Sayed Mahmoud Zanoun, Benha University, Faculty of Engineering, Benha, Egypt

RI staff: Emir Öngüner and Christoph Egbers, BTU Cottbus-Senftenberg, Department of Aerodynamics and Fluid Mechanics, Cottbus, Germany

Objectives and main results: This proposal aimed at investigating the effect of perturbations in the form of obstacles of different heights or tripping devices. This type of perturbation was already studied systematically in other experiments and the focus was on the spatial and temporal growth of turbulence from fully developed Poiseuille flow. Different heights and positions of the obstacle can be tested in order to check their effects on the development turbulence. Our goal was to measure the wall pressure at various positions along the pipe before and after the tripping position. The (spectral, wavelets, etc.) analysis of the high frequency signal will help reveal some of the flow properties. The correlations of the pressure and the velocity signal will also permit the identification of the flow structure.

Velocity fluctuations is one of the main flow component that is mostly used to identify the behaviour of developing turbulent flow. The pressure field on the other hand, which is strongly coupled with the gradient of mean velocity and fluctuations is less explored. The wall pressure fluctuation along the axial direction is measured to identify their growth and behaviour. It is found that the pressure fluctuations grow exponentially with axial distance. In addition, measurements are scaled, showing a selfsimilarity of the wall pressure fluctuation along the pipe. This exponential growth of pressure fluctuation saturates after reaching a certain position, which in turn qualitatively agrees with the critical point of transition, that was obtained from velocity fluctuations. We also provide results to show that the exponentially growth of pressure fluctuation is very robust to different size of obstacle ring perturbation. Finally, we discuss the behaviour of pressure fluctuations as a function of Reynolds number up to 106. Additional tuft visualisation suggest the emergence of large scale vortices emanating from the wall.

The work is in progress and a manuscript [1] will be submitted to a journal soon.

[1] K. Selvam, E. Öngüner, J. Peixinho, E.-S. Zanoun and Ch. Egbers 2016: Wall pressure in developing turbulent pipe flow. Submitted.

Turbulence in two-fluid rotating experiments: coupling between interface and inertial waves (T2FII)

CoGeoF2a/b

Project leader: Jorge Peixinho CNRS, Le Havre, France

Team: Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany

Objectives and main results: This project aimed at studying gravity-capillary wave turbulence between two immiscible fluids in a vertical cylindrical tank. When two-layers fluid systems are disturbed or sheared, gravity, viscosity and capillarity act to restore the interface. It is planned to measure the wave height at the interface between both flowing fluids. It is anticipated that the modulation of the angular velocity of the inner cylinder and the fluids heights will significantly influence the gravity and capillary wave turbulence regimes. The waves properties and morphologies as well as their breakup will be monitored. It will serve as a test case for multiphase flow problems.

Searching for Internal Gravity Waves in the Barostrat Instability (SIGWBI)

CoGeoF1

Project leader: Patrice Le Gal CNRS - Aix Marseille University, Institut de Recherche sur les Phénomènes Hors Equilibre, Marseille, France (m)

Team: Uwe Harlander BTU Cottbus-Senftenberg, Cottbus, Germany, Miklos Vincze, Hungarian Academy of Sciences, MTA-ELTE Theoretical Physics Research Group, Budapest, Hungary (m)

Objectives and main results: The purpose of this project was to investigate the generation and the propagation of internal gravity waves excited by convection at the stratified/convective zones interface by the baroclinic instability of an initially stratified layer with salt. Encouraged by our first observations (Project EuHIT Barostrat), we now investigated more deeply the possible generation and propagation of IGWs for this new, salt-stratified version of the baroclinic instability. The objective was first to explore the parameter space where IGWs can be observed. That is to describe their physical properties like amplitude, frequency, wavelength as a function of the input parameters. Moreover, we have investigated these properties also for the IGWs that are emitted into the passive layer mimicking the stratosphere. This includes to search for those parameters that will give the strongest radiation of waves into the passive layer. The confirmation of the generation of Internal Gravity Waves in this set-up is a remarkable discovery, useful in particular for atmospheric sciences.

Comparative turbulence statistics in pipe flows (ComStat)

CoLaPipeF

Project leader: Alessandro Talamelli, University of Bologna, Italy

Team:

Gabriele Bellani, University of Bologna, Italy; Christoph Egbers, BTU Cottbus-Senftenberg, Cottbus, Germany; Gazi Hasanuzzaman, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany; Emir Öngüner, Brandenburg University of Technology, Cottbus, Germany; Ramis Örlü, Royal Institute of Technology, Stockholm, Sweden; El Sayed Mahmoud Zanoun, Benha University, Benha, Egypt

Objectives and main results: The present work aimed at performing comparative and complementary simultaneous measurements using laser Doppler velocimetry and hot-wire anemometry in the turbulent pipe flow of the CoLaPipe facility. A number of open questions remain in wall turbulence, due to the scarcity of high-quality high-Reynolds number data. The aim was to use X-wire sensors and a 2-D LDV system to measure two components of the instantaneous velocity. The non-intrusive nature of LDV makes possible to have the measuring volume just upstream or closer to the wall than the x-wire sensor, without disrupting the flow up to a friction Reynolds number R+ of 1.7 x 104. The finding from the two measuring techniques can be compared and they can be used in a complementary way to obtain a better result.

High-Dynamic-Range Measurements in Pipe Flows at High Reynolds Numbers (HIDRA)

CoLaPipeF

Project leader: Ramis Örlü,Royal Institute of Technology, Stockholm, Sweden

Team: Stefano Discetti, Universidad Carlos III de Madrid, Leganes, Spain; Christoph Egbers, BTU Cottbus-Senftenberg, Cottbus, Germany; Carlo Salvatore Greco, Università di Napoli Federico II, Napoli, Italy; Emir Öngüner, Brandenburg University of Technology, Cottbus, Germany; Carlos Sanmiguel Vila, University Carlos III of Madrid, Leganes, Spain; El Sayed Mahmoud Zanoun, Benha University, Benha, Egypt

Objectives and main results: The main objective of this project was to provide a detailed representation of the flow organization in pipe flows at high Reynolds numbers from very large-scale structures to small-scale near-wall features. Very large-scale structures are reported to extend up to 20 pipe radii while the viscous length in state-of-art pipe facilities has a size down to tens of microns. The CoLaPipe at Cottbus Turbulence Experiment Facilities provides full optical access to perform Particle-Image Velocimetry (PIV) and Laser Doppler Velocimetry (LDV) measurements over the entire pipe length as well as extensive access for hot-wire anemometry (HWA) measurements. For the purpose of the present research, we measured up to 20 pipe radii in streamwise direction with PIV, utilizing simultaneously 4 to 8 cameras. This allows a spatial resolution down to 2 vectors/mm, i.e. up to five times the viscous length scale (for viscous scales of 100 microns) thus enabling field measurements with an unprecedented dynamic range in a turbulent pipe flow at high Reynolds numbers. Non-time-resolved PIV measurements has been synchronized with time-resolved LDV measurements and HWA measurements for the dynamic estimation of turbulence structures; this, moreover, allows to quantify the accuracy of the Taylor hypothesis, commonly employed for HWA studies in wall-bounded flows. The expected outcomes of the experimental campaign are high resolution statistics and a modal decomposition of the coherent structures of the pipe flow. The combination of the PIV with LDV and HWA in the CoLaPipe facility would give a unique opportunity to study the behaviour of turbulent structures at high Reynolds-number flows and their contribution to Reynolds stresses as function of the Reynolds number.

EuHIT – European High-Performance Infrastructures in Turbulence
funded by the European Commission under the 7th Framework Program

Grant Agreement Number 312778

Work Package 17: Access to Turin Rotating Platform Facility

Summary

The first experiment at Turlab was "Wave-induced turbulence and mixing in upper ocean: how important is the role of breaking and non-breaking waves" by the group leaded by Alessandro Toffoli (University of Melbourne). The experiments required substantial modifications of the rotating tank for producing an anular wind and were performed between March 24, 2014 and April 11, 2014.

During the second period (October 1, 2014 – March 31, 2016) Turlab had the access of three experimental groups within EuHIT project. The group of Mehmet Ilicak (Bjerknes Center for Climate Research, Bergen, Norway) performed a set of experiments for the project "Investigation of brine rejection process in a rotating laboratory tank" between November 24, 2014 and December 5, 2014. The researchers involved in the experiments are Mehmet Ilicak, Martin King and Maria Jensen. Together with the preparation and dismounting, the experiments Brine used 40 days at Turlab.

The second experiments were performed by the group of Sylvie Dagoret-Campagne (Laboratoire de l'Accelerateur Lineaire, Orsay, France) within the project "Detection and Imaging of turbulent states of ocean and atmosphere by means of a JEM-EUSO-like detector at the TurLab facility" during two periods in January and July 2015. The group performing the experiment included the Guillaume Prevot, Simon Bacholle, Aera Jung, Pierre Barrillon, Jarr Julio Rabanal, Camille Moretto (Laboratoire de l'Accelerateur Lineaire) and Joerg Bayer (University of Tubingen). In total with preparation and dismounting the experiment EUSOAtTurlab spent 44 days at Turlab.

The third experiment was prepared in January and February 2016 and the first set of data were acquired in February 8-19, 2016. The PI of the project "Cyclone-Anticyclone Asymmetry in Turbulent Rotating Thin Layers" Stefano Musacchio (CNRS, University of Nice Sophia Antipolis, France) spent the first 10 days at Turlab in January 2016 (while a second phase of the experiment will be done in May 2016). For the preparation and the first phase of the project, CycloTurtle used 27 days at

Turlab.

During this period we also developed a new bottom for the rotating platform for the EuHIT project Beta-WTD (PI Peter Read, to be performed in the fall of 2016). The proposed experiment requires a conical sloping bottom which covers the entire floor of the tank (about 20 square meters) for generating a topographic beta-effect. The installation of the bottom and its preliminary test required 20 days of activity.

During the third period (April 1, 2016 – March 31, 2017) Turlab had the access of three experimental groups within EuHIT project.

The group of Stefano Musacchio (CNRS, University of Nice Sophia Antipolis) performed a second set of experiments within the project "Cyclone-Anticyclone Asymmetry in Turbulent Rotating Thin Layers" between April 28, 2016 and May 11, 2016. The cylone-anticyclone asymmetry has been investigated by the statistic of the vertical vorticity components in experiments at different Rossby numbers and fluid thickness. The experiment CycloTuRTLe used 10 days at TurLab.

The second experiments were performed by the group of Peter Read (University of Oxfordwithin the project "Waves, Turbulence and Diffusion in Beta-Plumes" during two periods in November-December 2016 and in February-March 2017. The group performing the experiment included, together with the PI, Helene Scolan, Roland Young and Stefania Espa. Experiments were performed with a conical bottom (slope 11 degrees) in the rotating tank to produce the beta-effect. With preparation and dismounting the experiment Beta-WTD spent 36 days at Turlab.

The third experiment, "Effect of Rotation on Plumes Entrainment", has been done in two periods: October-November 2016 and March 2017 with PI Pietro Salizzoni (Ecole Centrale de Lyon). The project studied the effect of background rotation on freely propagating buoyant plumes, as a model for atmospheric downwelling flow. Together with preparation and dismounting ERPE spent 33 days at Turlab.

List of Deliveries and Milestones:

no deliveries, no milestones in this WP

Dissemination Activities

Publication/Oral presentation/Poster to a scientific event:

S. Dagoret-Campagne, 2015
LAL Scientific Council on Turlab
talk at the Laboratoire de l'Accelerateur Lineaire, September 14, 2015, Orsay

A. Jung, 2015
EUSO-Turlab Campaign
talk at EUSO-SPB Progress Meeting, October 29, 2015, Paris

G. Boffetta, 2014

Quasi-2D-turbulence under rotation and stratification
Lab. Dieudonne, Universite de Nice, November 18, 2014, Nice

H. Miyamoto, 2015
Progress in the TurLab experiments
JEM-EUSO 18th International Meeting, December 7-11, 2015, Stockholm

A. Toffoli, D. Proment, H. Salman, J. Monbaliu, M. Manfrin, and M. Onorato M. 2015
Non-Gaussian properties of wind-generated waves: an experimental model in a circular wave flume
KOZWaves, December 6-9 2015, Adelaide, Australia

Canellas E. N., 2015. **Wind turbulence over water waves in an angular flume**. Master Dissertation. K.U. Leuven (Supervisor J. Monbaliu)

A. Toffoli, D. Proment, H. Salman, J. Monbaliu, F. Frascoli, and M. Onorato M. 2016
Non-Gaussian properties of wind-waves: An experimental model in a circular wind-wave flume
WEH-Seminar on 'Extreme Events and Rogue Waves', May 30 - June 3 2016, Bad Honnef, Germany

S. Musacchio,
Turbulence in rotating thin fluid layers
talk at the workshop High Reynolds number turbulent flows, September 5-6 2016, Bertinoro (Italy)

G. Boffetta,
Dimensional transition in turbulent flows
University of L'Aquila, November 11, 2016, L'Aquila (Italy)

G. Boffetta,
Dimensional transition in thin fluid layers
Simons Center workshop, March 20-24 2017, Stony Brook (USA)

Web sites:

Turin Rotating Platform (TurLab) - http://www.turlab.ph.unito.it/

Project meetings

Periodic meetings of the personnel at the facility

Personnel Statistics:

Scientific Coordinator:

Prof. Guido Boffetta - Unito

Work package leaders:

Prof. Guido Boffetta - Unito

Experienced researchers:

Prof. Enrico Ferrero - Unipmn
Prof. Miguel Onorato – Unito
Dr. Filippo De Lillo - Unito
Prof. Claudio Cassardo – Unito
Prof. Mario Bertaina – Unito
Dr. Massimiliano Manfrin – Unito

Personnel hired within EuHIT:

Francesco Toselli

PhD students:

Francesco Santamaria – Unito
Alessandro Sozza - Unito
Matteo Borgnino – Unito

Technicians:

Dr. Renato Forza - Unito
Dr. Davide Bertoni - Unito

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 18: Digital Library of Turbulence Data (DLTD) - Service

Summary

As its main objective, WP18 provides the technical and hardware infrastructure to TurBase, that is the Digital Library of Turbulence Data. During the first 18 months, the work package set up the DLTD service architectural design. The CINECA Fermi and PLX system represented the HPC machines for the service and PICO machine represented the data analytics system. In a second time the HPC Systems in CINECA have been updated to the new HPC systems Marconi and Galileo[1]

As specified in the DoW, we have made available 400 TB of storage space, 150 TB online (disks, $DATA area) and 250 TB on tape. The tape storage was available by December 2014, when Cineca renewed its tape library and migrated to the new hardware. The tape library is an IBM TS3500 based on LTFS[2] technology with a current capacity of 18 PBytes.

The DLTD is based on the iRODS (Integrated Rule-Oriented Data System) data system[3].

The iRODS system provides an abstraction from the back-end storage resources, hiding their complexity to the users; it includes a rule engine able to trigger data changes and operations and it allows to manage data both via command line client and API.

Afther the initial set up of the architecture we have enabled a first version of the Turbase portal, developed together with WP4, to interact directly with the DLTD through the iRODS client layer (pyRods library[4]).

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1 http://hpc.cineca.it/content/hardware

2 http://www.redbooks.ibm.com/abstracts/sg248143.html

3 http://irods.org/

4 https://code.google.com/p/irodspython/wiki/PyRods

When creating datasets, the iRODS folders are prepared through the web portal interface. After uploading the data, the web portal is synchronized with iRODS and the data may be accessed through a user-friendly interface for a first screening.
As regards the data transfers, once analyzed the user requirements in terms of accessibility and usability, we have chosen the Globus Online (GO)[5] web portal as the default channel to upload to/download from the DLTD, exploiting the GridFTP server capability to adopt iRODS as back-end. Therefore in order to decrease the burden of the users, we have implemented a single identity mechanism which allows them to register only once, at Turbase web portal, and then to get a short living credential valid for GO and the GridFTP server.

In a second phase, the iRODS data system has been updated to the 4.1 release. Besides iRODS itself, a certain number of related components have been updated also, like the Globus GridFTP server, which has been updated to version 8.5 and the back-end DB, a Postgres instance, which has been updated to the version 9.5.
The DLTD includes a storage infrastructure with an advanced set of services which can be used to efficiently move and preserve data.
The DLTD hardware is currently hosted by the PICO cluster at CINECA[6] (see Fig. 1). The core of the library software is deployed on two nodes for redundancy. Each node is equipped with 2 Intel Xeon E5-2650 CPUs and 64GB memory.

Figure 1: *PICO cluster hosted in CINECA.*

[5] https://www.globus.org/
[6] http://www.hpc.cineca.it/hardware/pico

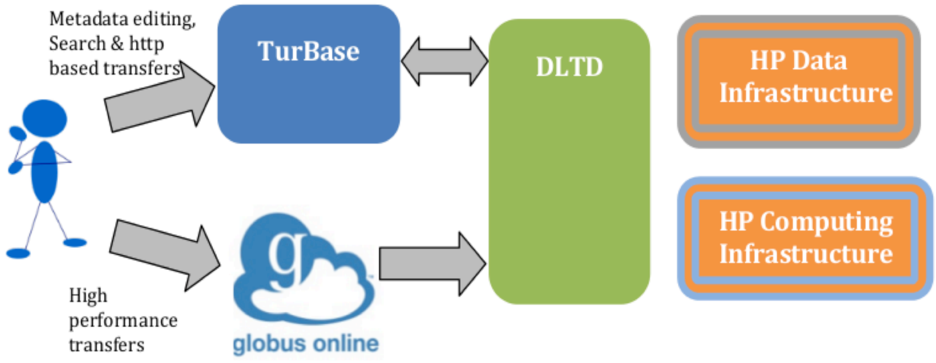

Figure 2: *TurBase and Digital Library for Turbulence Data (DLTD) architecture sketch. The DLTD is reachable via the web portal and the Globus Online service.*

The node hosting the back-end DB of iRODS is a specifically designed node equipped with Intel Xeon E5-2670 with 128 GB of memory, connected through a 100 GB fiber-channel. The back-end file-system is a IBM GSS (GPFS Storage Server) integrated with the Tape Library through a 10 GB channel.
WP18 also provides the hardware for the TurBase web server and for the additional TurBase-service, the service developed by WP4 to allow the users to preview and post-process data directly online through a web Jupyter notebook platform[7]. Both TurBase and TurBase-service machines are virtual machines running under the OpenStack [8] cloud operating system. The underlying hardware is composed by nodes equipped with 2 Intel Xeon 10 core E5-2670v2 at 2.50GHz and 128 GB of memory. The virtual environment potentially allows to easily resize the machines according to the needs of the users. A sketch of the architecture is provided in Fig. 2.
During the 18-48 months activity, WP18 members worked in tight collaboration with WP4 to support the new *in-house* implementation of the TurBase portal and service.
At month 18, the quality and quantity of services provided by WP18 have been assessed by an external board composed by two leading scientists Prof. J. Schumacher (Illmenau University, Germany) and Prof. C. Meneveau (JHU Baltimore, USA). The comments and the suggestions of the assessment activity (i.e. improve the tagging, provide a graphical interface for a more appealing preview, improve the "*how to*" and the user documentation, etc.) have been strongly considered during the development of the service in the final releases.
The upgrade of the TurBase service platform has been particularly appreciated by Prof. Charles Meneveau, member of the EuHIT Advisory Committee:
I looked around and found the new iPython notebook examples and capabilities very nice. This is excellent additions to the EuHIT project and Turbdata environment.
During the 36-48 months activity, WP18 members continued working in tight collaboration with WP4 to support the final implementation of the TurBase portal and service. Even if the main development of TurBase is in charge of WP4, WP18 support was crucial to devise and implement the middleware layer which interconnects the portal to the Digital Library for Turbulence Data facility. The TurBase web-portal has been completely rewritten in the last year to add new important features and to prepare the code to be possibly shared as open-source community code. Figure 3 provides a view of the portal main page. The middleware allows to integrate the

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[7] http://jupyter.org/

[8] https://www.openstack.org/

functions of the DLTD with the web portal with particular care to the integration with the Globus Online[9] service, required to get the best performances to move huge amount of data. Details on the last implementation of TurBase are presented in the WP4 deliverable. WP18 worked on the update of the scripts synchronizing the:

- X509 certificates to be used for Globus Online
- iRODS accounts
- datasets permissions related to the embargo statuses

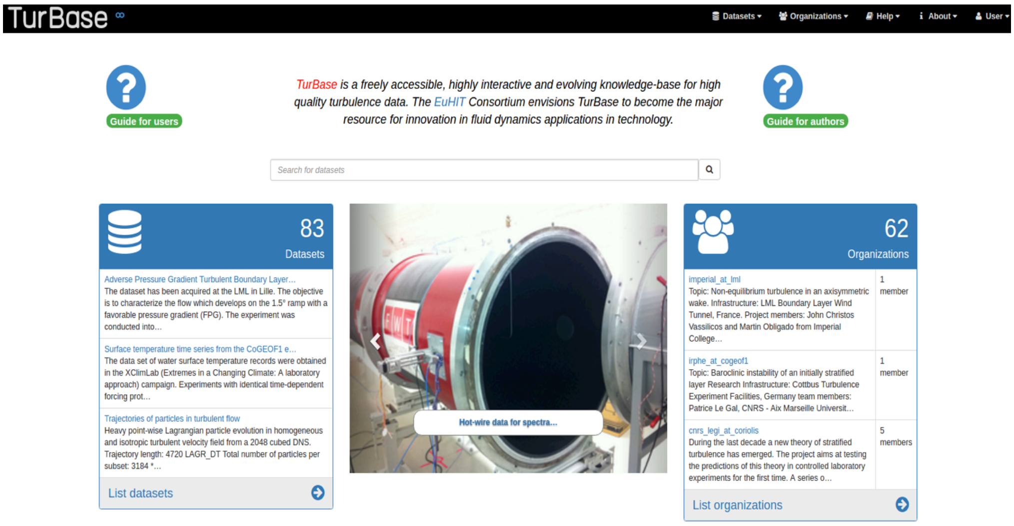

Figure 3: *TurBase web-site main page. 83 datasets and 62 organizations are available.*

WP18 also actively supported WP4 with respect to the TurBase reference guide now available online (http://turbase.cineca.it/docs/index.html).
In the last year, the developed infrastructure – Turbase and DLTD – proved to be a valuable and stable platform for the needs of the EuHIT community.
The new TurBase supports the interaction with different storage resources. This allows to manage a distributed storage environment based on TurBase, an important feature to improve the possibility of TurBase to survive the project. Currently, the vast majority of datasets are hosted on the CINECA DLTD (hosting site named *cineca_repo* in TurBase) but also a second hosting site, named *cineca_dres*, is configured and active. Two datasets are hosted on *cineca_dres* and the web interface transparently manages the two different types of storage resources. However, the syncronization of certificates to be used with Globus Online is only available for the DLTD. WP4 and WP18 also succesfully tested a hosting site located at the University of Rome Torvergata.

Statistics on TurBase data

During the entire project, special effort to force EuHIT users to create and upload datasets has been required. After the Steering Committe decision to force users to

[9] https://www.globus.org/

upload data in order to be refunded, the number of datasets significantly increased but a big percentage of datasets were created only in the very last part of the project. The dataset creation is still on progress even after the formal end of the project and for that reason we only report about the status of the repository before 12nd April 2017.
The summary on the statuses of datasets with respect to the EuHIT calls, we refer to the final WP4 deliverable. In that document, an explicit table with the status of approved EuHIT projects with respect to the datasets on TurBase is provided. In the present report, we give additional details on some data statistics more useful in the context of WP18. Indeed, this EuHIT initiative of public sharing of data in the turbulence community is much wider than similar previous attempts. To minimize the sharing effort, we decided to let the users freely select the formats of files and the file-tree organization of them. We just gave them a few recommendations on the data, mainly:

- upload binary or compressed files
- if possible limit the size to 1TB or contact us to upload more
- upload source codes capable of reading/writing/visualizing the data
- limit the number of files to 1000 (soft limit) or 10000 (hard limit).

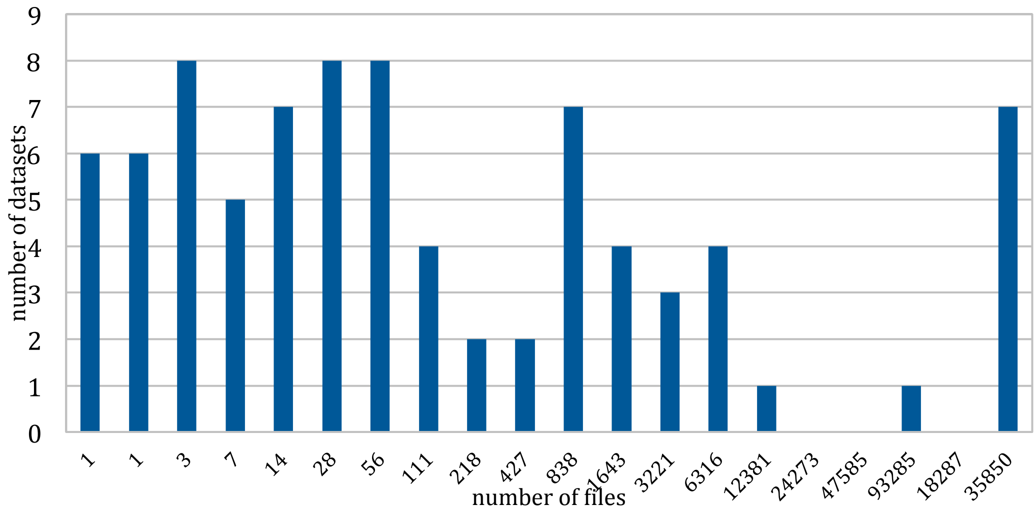

Figure 4: *Distribution of the number of datasets versus the number of files of a dataset. The horizontal scale is logarithmic to show details on the different scales. Some datasets (8) contain a huge amount of files (more than 100000).*

Actually the third and fourth recommendations were added during the project because we realized that some users uploaded data using formats and content very difficult to decipher without existing codes and instructions. In addition, we found that the having a huge number of files is not the best option to share them, given the difficulty in browsing and downloading them. Actually the issues on the huge number of files can be circumvented by Globus Online, but it seems still optimal to avoid huge number of

files at least to allow for a good browser experience in the TurBase website.

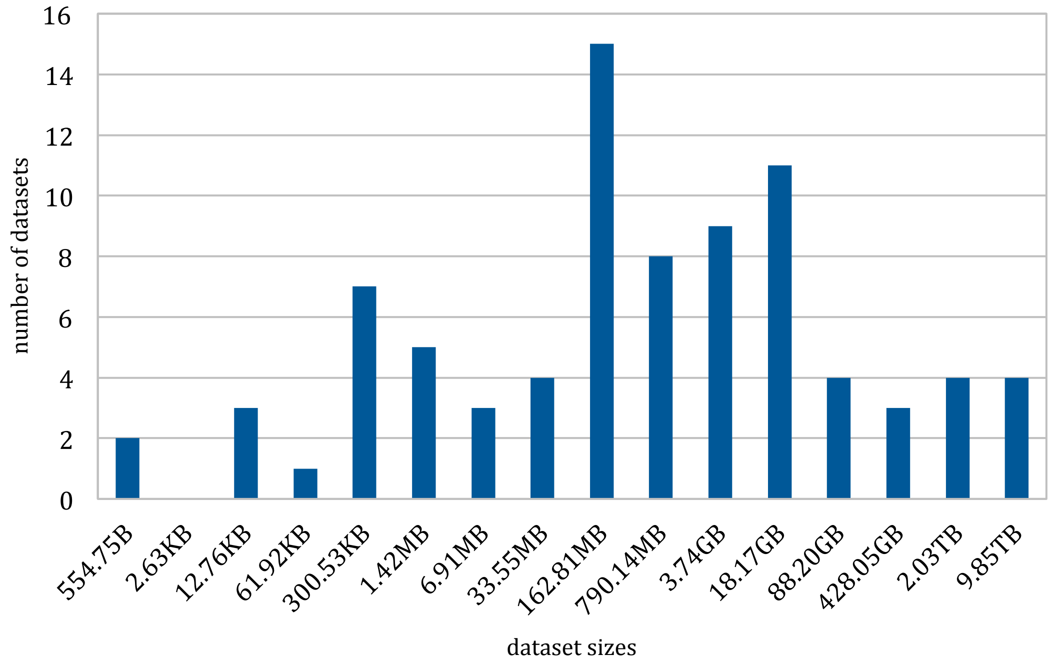

Figure 5: *Distribution of the number of datasets versus the size of a dataset. The horizontal scale is logarithmic to show details on the different scales. The range of sizes is very wide.*

It is interesting now to present some statistics on the uploaded data.
Currently the TurBase repository includes:

- 83 datasets (including some test datasets)
- 1175819 files
- 152TB data occupation

Figure 4 shows the distribution of the number of files for each dataset. The horizontal scale is logarithmic (base 10) to allow a better visualization. The number of datasets having less than 1000 files is the majority but some datasets have much more files. In particular 7 datasets have a huge number of files (greater than 100000) which makes them very difficult to manage when browsing or transferring them. Nevertheless, Globus Online can adequately manages the data transfer for that cases as well.
Figure 5 summarizes the sizes of the datasets. Considering the logarithmic scale again used on the horizontal axis, the range of values is wide. It probably also depends on the kind of data which have been uploaded, if raw data or pre-processed data.
Figure 6 refers to the files of the repository disregarding the corresponding dataset.

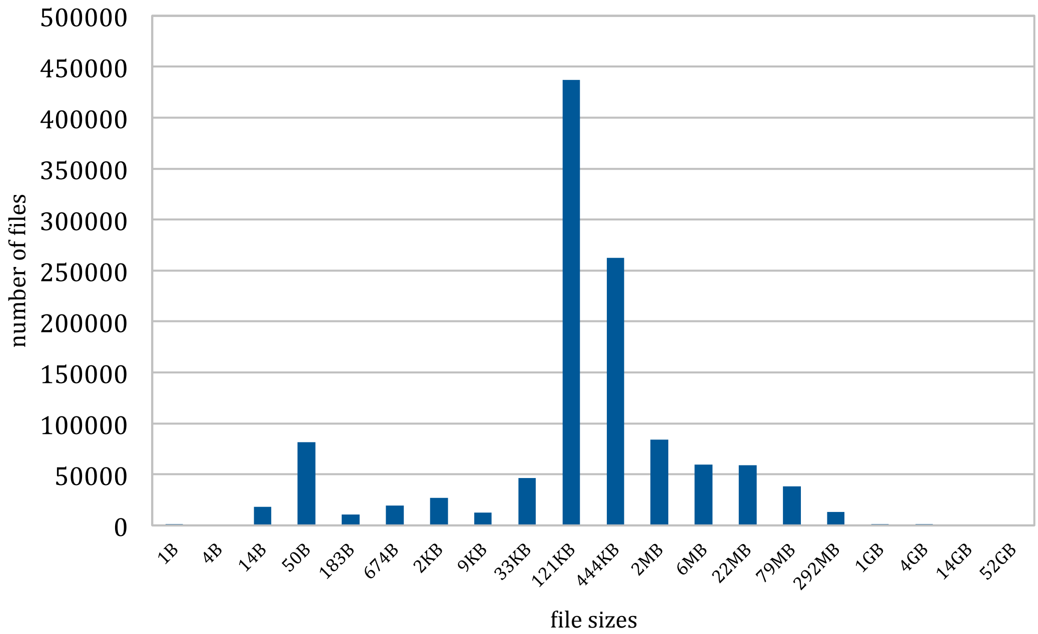

Figure 6: *Distribution of number of files versus the size of a file. The horizontal scale is logarithmic to show details on the different scales. The range of sizes is wide but a significant predominance of files with MB order of magnitude can be noted.*

The distribution of files sizes is provided. We note that the vast majority part of files are rather small files (order of MB). This can be good to allow for a simple online analyses using TurBase notebook service. Considering the entire sizes of datasets, such small files are probably not optimal for file transferring purposes. However, the usage of Globus Online can adequately manage these conditions.

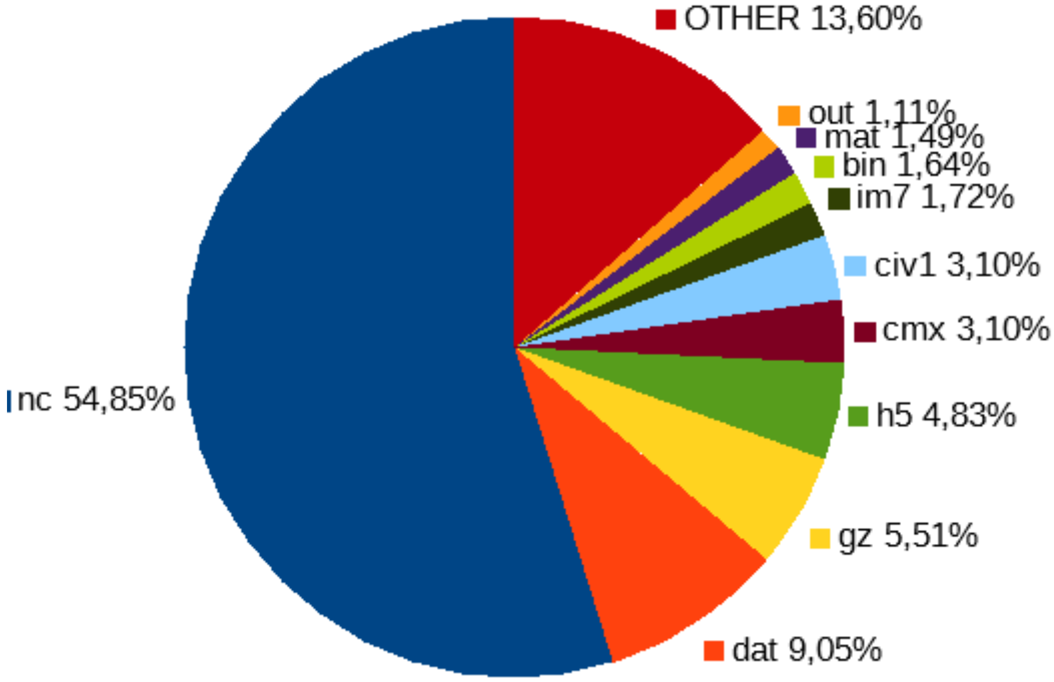

Figure 7: *Distribution of files versus format extensions. NetCDF files (.nc) represent the major part of uploaded files.*

The figure 7 refers to the formats of uploaded files.
It turns out that the most used formats are *.nc* (NetCdf), *.dat*, *.gz* (gzipped files), *.h5* (HDF5), *.cmx* (CorelDRAW), *.civ1*, *.im7* (Davis graphics), *.bin*, *.mat* (MatLab). Given that the complete freedom the users has in the choice of formats, it is worth noting that NetCDF and HDF5 are the most popular formats. For that reason, we decided to particularly work on notebooks managing that data in the TurBase service platform.

List of Deliveries and Milestones

Even if the WP18 is not directly responsible for any deliverables, being a TNA activity, people of WP18 supported heavily the WP4 activity and contributed actively to the production of Deliverables and the achievement of Milestones of WP4.

Dissemination Activities

The Digital Library of Turbulence Data can be accessed directly through the TurBase web portal developed by WP4. The support of WP18 has been crucial to develop an *ad-hoc* interface to connect to iRODS using the web interface:

Turbase - https://turbase.cineca.it

However, to get optimal performances especially in the upload stage, the usage of Globus Online is strongly recommended:

Globus Online – https://www.globus.org/

The usage of Globus Online has been automatized also for downloading purposes through a special group in TurBase.

The online data analysis service based on Jupyter notebooks is now also connected to a file system – mounted read-only – which contains all the public datasets of TurBase. The service has been transparently embedded in the TurBase dataset page and it is also reachable as a separate end-point at the address:

Turbase-service - https://turbaseservice.cineca.it

Organization of Conferences:

TurBase talks and demonstrations have been held in the context of different events as documented below:

- *"EuHIT Turbulence Conference*, 2-4 May 2016", Gottingen (Germany). In conjunction with WP14, WP18 has been involved in the presentation and demo of TurBase and DLTD activities.

- "*EuHIT School on Turbulence*", 4-6 July 2016 at University of Warsaw. The TurBase talk generated a significant interest of the student audience as well as of the professors which participated to the school. An important discussion on the policy rules on the data usage was raised. TurBase currently allows authors to include a customized policy rule to be approved by any user which wants to access the data.

- Workshop on "*High Reynolds number turbulence flows – a large-scale infrastructure perspective*", 5-6 September 2016 at Bertinoro (Italy). The workshop has been organized by EuHIT WP 9 in cooperation with WP17 and WP18. During the TurBase presentation, the assembly actively discussed the present and future role of the repository in the context of worldwide turbulence research community. In particular the researchers focused on the need of long-time preservation and accessibility of data.

Publication/Oral presentation/Poster to a scientific event:

To enlarge the TurBase community, an important activity to spread the idea and invite people has been issued by WP18: demonstrations and dissemination activities have been done during scientific Conferences, in particular at:

1. SC'13, Denver (USA), 17-22 November 2013: EuHIT poster at the Cineca's booth.
2. ISC'14, Leipzig (Germany), 22-26 June 2014: the Cineca booth hosted a EuHIT presentation.

3. HPC enabling OpenFOAM for CFD applications[10], Bologna (Italy), 26-28 March 2014: course with 32 people attending.
4. HPC Computer Aided Engineering, Milan (Italy)[11], 16-18 June 2014: course with 24 people attending.
5. SC'16, Salt Lake City (USA), 13-18 November 2016: EuHIT poster at the Cineca's booth (http://sc16.supercomputing.org).
6. ISC'16, Frankfurt (Germany), 19-23 June 2016: Cineca disseminated the activity in a flyer related to HPC and Data Infrastructure activity.

It is worth mentioning here the EUDAT project[12] and its related events where the technology at the base of the DLTD has been often advertised and discussed with users and communities. In particular during the following conferences:

a. "3rd EUDAT Conference: Bringing data infrastructures to Horizon2020, 24-25 September 2014", De Meervaart Conference Centre, Amsterdam, The Netherlands.
b. "EUDAT User Forum, 3-4 February 2016, Rome, Italy
c. "EUDAT Helsinki Meeting, 23-27 January 2017, Helsinki, Finland

Dissemination at training events:

1. I Workshop *"HPC enabling of OpenFOAM for CFD applications"*, CINECA, Bologna 25-27 March 2015;

2. Workshop *"HPC Methods for Engineering"*, Milano 17-19 June 2015;

3. *24th Summer School on Parallel Computing*, Rome 13-24 July 2015;

4. Workshop *"Tools and techniques for massive data analysis"*, Rome 14-16 December 2015;

5. *12th Advanced School on Parallel Computing*, Bologna 15-19 February 2016;

6. II Workshop "*HPC enabling of OpenFOAM® for CFD applications*", CINECABologna 6-8 April 2016.

7. Workshop *HPC enabling of OpenFOAM for CFD applications*, CINECA, Bologna (Italy), 6-8 April 2016: course with 27 people attending.

8. *HPC methods for Computational Fluid Dynamics and Astrophysics*, CINECA, Bologna (Italy), 6-4 November 2016: course with 31 people attending.

Project meetings

WP18 continuously collaborates with WP4 to develop and test the new TurBase features and to support the community of current and future users. In particular, we keep supporting users which need to upload and download their data at the end of their EuHIT access. Members of WP18 are included in the mailing list **turbase-support@cineca.it** in order to answer to the more technical issues coming from the

[10] http://events.prace-ri.eu/conferenceDisplay.py?confId=261
[11] http://events.prace-ri.eu/conferenceDisplay.py?confId=266
[12] http://www.eudat.eu

users (iRODS interaction, Globus Online, authentications, etc.). The raised topics are an important source of discussion for the WPs.

Publications

WP4 and WP18 teams have prepared a conference paper which has been accepted for "*The 2017 International Conference on High Performance Computing & Simulation* (HPCS2017, Genoa July 17-21, 2017)"[13]. The paper summarizes the core features of the whole TurBase infrastructure, from the developed software stack to the integration of the different hardware resources. The work will be presented at the "The 4th International Symposium on Big Data Principles, Architectures & Applications" during the HPCS2017 conference.

R. Benzi, L. Biferale, F. Bonaccorso, H. J. H. Clerx, A.Corbetta, W. Moebius, F. Toschi, F. Salvadore, C. Cacciari, G. Erbacci, *TurBase: a software platform for research in experimental and numerical Fluid dynamics*, 2017 International Conference on High Performance Computing & Simulation (HPCS), *accepted*.

A second publication more focused on the experience with the turbulence data is in progress.

Perspectives

WP18 strongly worked to structure and maintain the architectural infrastructure for the digital library in order to deploy a stable platform that will continue to maintain the data and accept new datasets, also after the end of the EuHIT project. The future provision of the architecture services will continue for two years after the EuHIT conclusion. Additional extensions can be agreed in case of further funding coming from an EuHIT continuation or other related projects.

Personnel Statistics:

Work package leaders:

Dr. Giovanni Erbacci (CINECA) coordinates the activities of the WP18 actively participating to the decisional process in conjunction with the WP4 and with the main EuHIT coordinator.

Data manager:

Dr. Claudio Cacciari (CINECA) is the main responsible of the setup, configuration and integration of Digital Library of Turbulence Data. As such, he is the iRODS (Integrated Rule-Oriented Data System) administrator of the library and takes care of the quality of the repository service with particular attention to the interaction with Globus Online service.

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[13] http://hpcs2017.cisedu.info/

Experienced developers:

Dr. Francesco Salvadore (CINECA) – involved in both WP4 and WP18 – is the main responsible of the integration work with WP4. As developer of TurBase he works on front-end and back-end services of the portal focusing both on the optimization of performances and on the ease of access of the services.

Many other people from CINECA have been involved in the day by day activity to maintain the infrastructure, to solidify its structure and to allow an automatic easy use of the service from the external users.

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commissionunder the 7th Framework Programme

Grant Agreement Number 312778

Work Package 19: Next generation and innovative instrumentation

Summary

The work package 19 contains 3 individual main tasks, each of which is looked after by one project partner. The project partners involved in the work package are VISION RESEARCH EUROPE B.V. (VRI-E), SMARTINST SAS (SMARTINST) and the CARL VON OSSIETZKY UNIVERSITAET OLDENBURG (UNOL).

The objective of task 19.1 is the development of electronics to increase the processing power of data recorded by high-speed cameras. This task is being handled by VRI-E.

Task 19.2 is carried out by SMARTINST and involves the development of particles that are used as large tracer particles in water with onboard sensors.

In task 19.3 an existing prototype of an anemometer should be further developed and modified by UNOL.

List of Deliveries and Milestones

MS 2: Design of CineCalc complete (VRI-E)

MS 3: Prototype of CineCalc available (VRI-E)

MS 4: Prototype of instrumented particles available (SMARTINST)

MS 5: Proof of the new 2d-LCA design (UNOL)

D 19.1: Application of CineCalc module in the Karm Mixer at MPIDS (VRI-E)

D 19.2: Application of instrumented particles in the Karman Mixer at MPIDS (SMARTINST)

D 19.3: Measurements with the 2d-LCA in the barrel of Ilmenau (UNOL)

D 19.4: Manufacturing and testing of new cantilever prototypes (UNOL)

D 19.5: Redesign of the 2d-LCA to adopt for small velocities (UNOL)

D 19.6: Development of a portable calibration unit for the 2d-LCA (UNOL)
D 19.7: Further improvement and manufacturing of cantilevers (UNOL)

Personnel Statistics

- Scientific Coordinator (incl. information m/f)
  - Dr. Michael Hölling, m, (UNOL)
  - Radu Corlan, m, (VRI-E)
  - Yoann Gasteuil, m, (SMARTINST)
- Work package leaders (incl. information m/f)
  - Prof. Dr. Joachim Peinke, m, (UNOL)
- Experienced researchers (incl. information m/f)
  - Dragos Nicolae, m (VRI-E)
  - Arnaud Rabilloud, m (SMARTINST)
  - Jean-Pierre Basirico, m (SMARTINST)
  - Maylis Lavayssière, Ph.D, f (SMARTINST)
  - Nicolas Tissot, m (SMARTINST)
  - Ivan Milicin, m (VRI-E)
- PhD students (incl. information m/f)
  - Jaroslaw Puczylowski, m (UNOL)
- Other (incl. information m/f)
  - Mohamed Chouchane, m (SMARTINST)

Project meetings

None.

Publications

J. Puczylowski, A. Hölling, J. Peinke, R. Bhiladvala and M. Hölling,
A new approach to highly resolved measurements of turbulent flow, Meas. Sci. Technol. 26 (2015) 055302 (12pp)

Dissemination Activities

Talk "2d-LCA – an alternative to x-wires" by Jaroslaw Puczylowski at DPG Spring meeting
Berlin, March 18th, 2015

Talk "2d-LCA – an alternative to x-wires" by Jaroslaw Puczylowski at ETC 15 conference
Delft, August, 25th, 2015

Talk “New approach to highly resolved measurements” by Jaroslaw Puczylowski at the 68th Annual Meeting of the APS Division of Fluid Dynamics
Boston, November 22, 2015

Task 19.1: High speed processing module

Responsible partner: VISION RESEARCH EUROPE B.V. (VRI-E)

Concise overview:

During the first half period of the project we have developed and produced the CineCalc module. Primarily, this includes the design of the main board (circuit and PCB) that is essential for the operation and other components such as mechanical parts or an interface board. The latter connects the module with the high-speed camera. In this course, milestone 2 (MS2) has been achieved.
Furthermore, tests of the whole system as required by milestone 3 (MS3) were successfully completed.
At present we have two complete CineCalc systems that are fully functional and available in conjunction with high-speed cameras from Vision Research. That way, we enable our partners to perform the measurements as specified in other sections of this project.
The main task of VRI-E is now completed. We remain available for the second period of the project for any support that might be needed with regard to the use of our CineCalc modules.

Use of resources:

Human resources were used for the development, designing and manufacturing of the CineCalc modules. All the costs related to hardware and materials were covered by Vision Research Inc.

Problems and corrective actions:

Task 19.2: Instrumented particles

Responsible partner: SMARTINST SAS (SMARTINST)

Concise overview:

smartINST has designed an industrial grade measurement system known as smartPART. This system is dedicated to investigate the flows in the industrial mixers, from the inside of them. smartINST has improved the design of the prototypes in order to achieve industrial grade reliability and performance. The improved design of the system has been produced and is under tests in various places. The commercial systems are now available.

Problems and corrective actions:
Delay of deliverable D19.2.

Task 19.3: Laser-Cantilever-Anemometer

Responsible partner: CARL VON OSSIETZKY UNIVERSITAET OLDENBURG (UNOL)

Concise overview:

The task 19.3 deals with the development of the 2d-Laser Cantilever Anemometer (2d-LCA). In particular, the 2d-LCA should be able to operate on spatial scales of about 100µm and at a frequency of up to 100kHz and also become operable by inexperienced researchers. During the lifetime of the EUHIT-project the 2d-LCA measuring system has experienced many modifications and improvements with the primary goal to develop a reliable and easy to use alternative to commercial x-wires. Besides modifications to the structural components, new sensing elements (cantilevers) with increased directional sensitivity have been developed. The challenge here was to equip the cantilever with a specific tip geometry and keep a high temporal resolution (resonance frequency) at the same time.
For measurements of small velocities (below 2m/s) a slightly modified version of the 2d-LCA has been developed. This version is equipped with a specific cantilever of 500μm in length. First measurements have been carried out at the University of Oldenburg (UNOL) and TU Ilmenau (TUIL).

The conversion of the previous 2d-LCA to a more functional and user-friendly design (**MS5**) has been concluded successfully. Figure 1 shows the new design of the 2d-LCA. The main amendments to the previous version are the increased numbers of degrees of freedom (slide #10 for adjustment of the position sensitive detector (PSD) and mount #10 for position adjustment of the cantilever) and the laser beam guidance (detailed illustration in fig. 2). The adjustment possibilities allow the user to precisely align the laser onto the active area of the PSD.

The modified laser path (see fig. 2) reduces ghosting by means of a thin beam splitter plate and therefore leads to an improved signal quality.

Other modifications involve improved electronics, cable connections and the signal-processing unit.

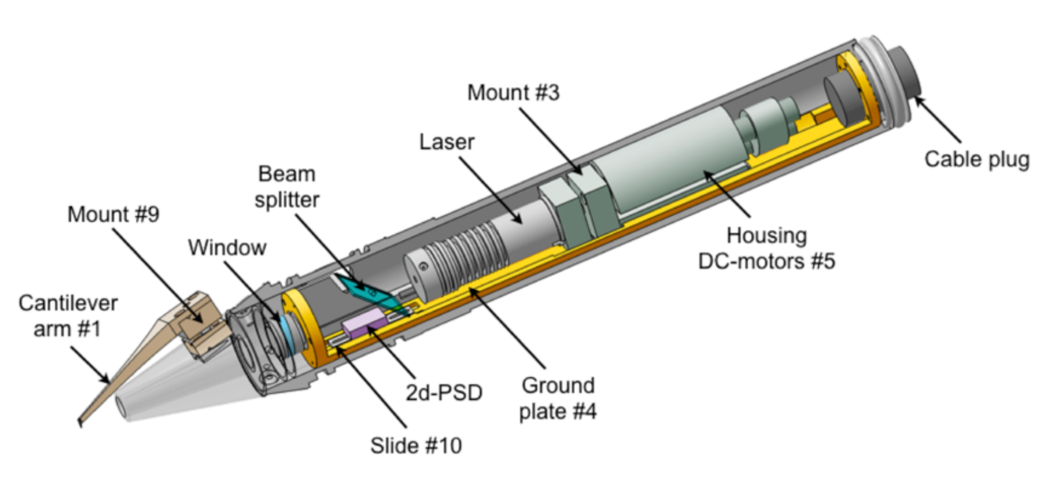

Figure 1. Design of the 2d-LCA.

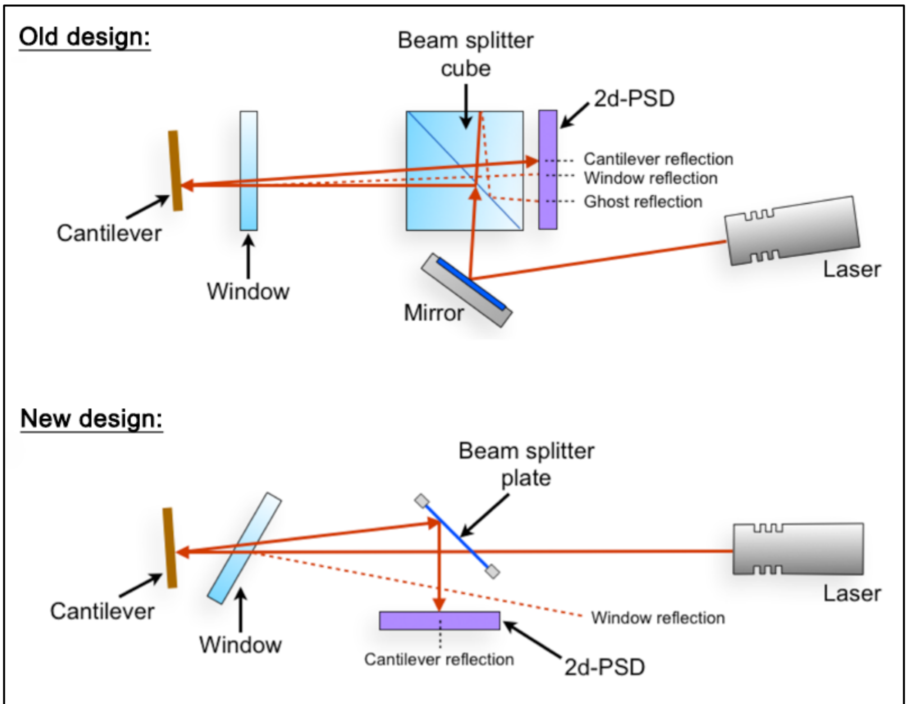

Figure 2. Design of the laser beam guidance.

In order to improve the mobility of the whole system a portable calibration unit has been designed but not yet fully tested. In addition, based on the design of new cantilevers (see D19.4) further cantilevers for other velocity ranges were manufactured and tested.

Problems and corrective actions:
None.

European High-Performance Infrastructures in Turbulence

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 20: Turbulence Generation

Summary

The aim of the WP20 is to reach very high Reynolds number turbulence under well-defined controlled conditions, so as to understand the influence of inhomogeneity and anisotropy on flow dynamics, mixing and dispersion issues. In traditional isotropic, homogeneous turbulence experiment, the energy is injected at large scale, and then cascade towards smaller scales, building a self-similar top to bottom cascade with an exponent close to -5/3.
A central part of this WP is to develop new devices to produce multi-scale energy injection into the flow, based on previous work of C. Vassilicos (Imperial College, London) with fractal grids, and make recommendation for implementation in GHI.

The active grid for RIMT at FAU was designed and constructed. After mechanical engineering of the support structure and the flaps, the chosen actuators were supplied, the power and dedicated control electronics were designed, produced and programmed. Control of the 24 independent servo motors activating the individual flaps is made by a real time FPGA system. The driving protocols which will be developed together with GHTI are delivered to the FPGA by WLAN. The electronic design and construction was completed. MS11 of this workpackage was reached. As the kinematic viscosity of air and the oil used at RIMT are approximately the same, the achievable Re_{λ} is very similar. Detailed measurements of the generated turbulence in the wake of the active grid were accomplished. The results were presented in the STAB-2016 symposium and were accepted to be published in a new upcoming volume of New Results in Numerical and Experimental Fluid Mechanics, Springer.

List of Deliveries and Milestones

Please list the deliverables and milestones here and give short statements about their status.

- Milestone MS10: Design of fractal propeller for GHI: completed (CEAb)
- Milestone MS54: Fractal propeller built and tested ;. Recommendation for implementation in Grenoble and Goettingen: completed (CEAb)
- Deliverable D20.2: Report on fractal propeller design for GHI: delivered (CEAb)
- D20.3: An active grid for FAU is completed (FAU)
- D20.4: Report on the properties of the active grid turbulence at RIMT is completed in the form of a conference publication (FAU)
- D20.5: Report on the interactions between turbulence and bluff bodies can not be delivered due to delays in the previous deliverables (FAU)
- MS11: An active grid for RIMT is complete (FAU)
- MS12: Flow in RIMT (with the active grid) is finalized in the wind tunnel of LSTM (FAU)

Dissemination Activities

Title: Charakterization of Turbulence Generated by an Active Grid with individually Controllable Paddles.
Type of activity: Conference presentation
Authors: T. Skeledzic, H. Lienhart, Ö. Ertunc, J. Jovanovic, J. Krauss, A. Delgado
Date, Place: 08. November 2016
Type of audience: Academic and industrial experts in fluid mechanics and aerodynamics
Countries addressed: Europe

Project meetings

Göttingen, May 2013, Kick-off meeting

Enschede, May 2014, General Assembly

Bruxelles, January 28th 2015, Mid-term review

Grenoble, Oct 30th, 2015, General assembly meeting

Göttingen, May 3th-5th, 2016, General assembly meeting

Göttingen, February 14, 2017, ICTR rebirth meeting

Publications

Thalabard, Simon; Saint-Michel, Brice; Herbert, Eric;Daviaud, F;, Dubrulle, B. A statistical mechanics framework for the large-scale structure of turbulent von Karman flows NEW JOURNAL OF PHYSICS Volume: 17 Article Number: 063006 Published: JUN 4 2015

Kuzzay, Denis; Faranda, Davide; Dubrulle, Berengere Global vs local energy dissipation: The energy cycle of the turbulent von Karman flow PHYSICS OF FLUIDS Volume: 27 Issue: 7 Article Number: 075105 Published: JUL 2015

E.-W. Saw, D. Kuzzay, D. Faranda, A. Guittonneau, F. Daviaud, C. Wiertel-Gasquet, V. Padilla, B. Dubrulle, Experimental characterization of extreme events of inertial dissipation in a turbulent swirling flow, Nature Communication, 7 12466 (2016)

D. Kuzzay, E.-W. Saw, J. W. A. Martins, D. Faranda, J.-M. Foucaut, F. Daviaud, B. Dubrulle New method to detect singularities in experimental incompressible flows Nonlinearities **30** 2381 (2017).

T. Skeledzic, J. Krauss, H. Lienhart, Ö. Ertunc, J. Jovanovic:
Characterization of Turbulence Generated by an Active Grid with Individually Controllable Paddles.,Accepted for publication in New Results in Numerical and Experimental Fluid Mechanics, Springer

Personnel Statistics:

Permanent Researchers:
Dr.-Ing. Özgür Ertunç (m), FAU, Project Management, Design of active grid

Dipl.-Ing. Hermann Lienhart (m) FAU, Design and construction of active grid, Facilities and measurement techniques

B. Dubrulle (f)-CEAb; B. Gallet (m) CEAb; I. Moukhraski (m) CEAb; A. Braslau (m) CEAb;

PhD- Students:

Jens Krauß (m), FAU, Data acquisition
Anand Sivaramakrishnan (m), FAU, Measurements

Denis Kuzzay (m)-CEAb;

Graduate:
Tanja Skeledzic (f), FAU, Turbulence Measurements

Post-doc: Ewe-Wei Saw (m)-CEAb;

Technicians:
Heinz Hedwig (m), FAU, Construction of active grid and maintenance of facilities

Task 20.1: Fractal propellers

Responsible partner: CEA-b

Collaborators: Imperial College

Objectives of the third Period (month 36 - 48):

Fractal propeller built and tested ;. Recommendation for implementation in Grenoble and Goettingen

Concise overview:

Because the first propeller failed to show interesting properties for GHI, xe have asked and received an additional amount of money of 61 901€ for designing and testing a new type of impeller, in collaboration with Imperial College

We have designed a new fractal propeller (see MS10) at CEA_b, built it and operated in a water experiments. We have measured several components of velocities at several locations, as well as torques, and compared with results using a non-fractal impellers and recommended its implementation in GHI.

The report was delivered (see D20.2). following its recommendation, the new fractal propeller has been used in January 2017 in GHI (see MS54).

Use of resources:

- Main amount of money (59 k€) have been used for the post-doc
- 3 k€ have been spent for necessary consumables and travel linked with the project.

Problems and corrective actions:

- None

Task 20.2: Influence of turbulence on objects

Responsible partner: FAU

Collaborators: UNOL, MPI-DS

Objectives of the second reporting period (month 19 - 36):

- Detailed tests of the active grid and quantification the properties of turbulence generated by the active grid in RIMT

Concise overview:

- The characterization of the turbulence generated by the active grid was conducted in the wind tunnel so that the characteristics of the turbulence could be used very fast to improve the active grid and its driving protocols. The measurements showed that the turbulence generated by the developed grid can reach to $Re_\lambda \approx 300$. This value could be varied between 200-400 depending on the motion protocol of the grid. The inhomogeneity in the turbulence field initially observed could be very much reduced by modifying the motion scheme of neighbouring paddles.
- All studies planned were accomplished, other than the measurements with an object exposed to high level of turbulence which is D20.5.

Use of resources:

Material Expenses:
Construction of active grid: 6,765 EUR

Software:
Update for measuring technique: 373 EUR

Personnel Costs:
Researcher: 3.5 PM, 18,148 EUR
Technician: 3.0 PM, 15,382 EUR

Travelling: 1,295 EUR

Problems and corrective actions:

- D20.5 which is the interaction of turbulence and flow around bluff body can not be accomplished within the project period because of the delays in the previous deliverables and the lack of experienced personal who left the project due to graduation. The investigations will be conducted after a dedicated PhD student is involved with the flow problem, but not within the regular project period.

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Grant Agreement Number 312778

Work Package 21: Cryogenic measurement technologies

Summary

Instrumentation is recognized as the main bottleneck in cryogenic turbulence experiments. This situation arises partly because there are almost no commercially available probes compatible with those temperatures and partly because of the stringent requirements associated with the high Reynolds and Rayleigh numbers of the experiments. In the context of the four cryogenic TNA facilities, we address the situation with the following objectives:

- Task1 : Fabrication of customized rugged velocity and temperature probes for the cryogenic TNA (pressure-based anemometer, miniature thermometer support,…) ;
- Taks2 : Development of cantilever anemometer / heat flux probe, both for room-temperature and cryogenic ones ;

An extra "Task", which extends Task #1, has been accepted in an internal Euhit call. It consists in the micro-fabrication of a network of micro-films with a spatial resolution better than 10 microns, which can be used as thermometers or anemometers (when overheated) depending on the requirements of the experiment.

List of Deliveries and Milestones

MS53 Prototype of a micro-machined network of cold-wires for room-temperature measurement in air. Test planned in Ilmenau (BOI) or in another TNA
Due month#39(delivered July 8th, 2016)

D21.5 Micro-machined cold wire compatible with operation in helium around 5K. Prototype tested in one cryogenic TNA
Due month#48(delivered April 13th, 2017)

Dissemination Activities

Given the RTD nature of this WP, our dissemination activity consisted in the participation to experiments conducted in various TNA facilities, with probes and electronics apparatus developed in this WP. Over the last 12 months (RP3), the WP21 probes and/or electronics have been used in 5 experiments.

TNA facility	Nature of work
CERN/GReC	Euhit project APERITIF (Sept 2016, Jan/Feb 2017) : cantilever + miniature Pitot tubes + network of micro-films
Grenoble/SHREK	Euhit project IFT-highRe (6/2016) : cantilever with hot film
Barrel of Ilmenau	Test of a network of cold wires. The electronics was initially developed in this WP for network of miniature Pitot tubes
Grenoble/HeJet	Euhit project MOVEMENT : Network of micro-films
Göttingen SF6 wind-tunnel	Euhit project AirTight (Feb/March, 2017) miniature Pitot tubes + network of micro-films
Czech Convection facility	Cantilever probes have been sent last March 2016 to be mounted and operated in this facility.

Another channel of dissemination is oral communication in the scientific community, in particular :

European Cryogenics Day 2016,
9-10 June 2016, CERN
• *GReC experiment : probing ultra high-intensity turbulence*

Institut Néel Monthly Seminar,
16 Dec 2016, Grenoble
• *Phénomènes intermittents en Turbulence quantique et classique*

Quantum Turbulence Workshop
10-12th (2017), Tallahassee, Florida
• *Observation of vortex bundles in highly turbulent He II*

New Challenges in Wall Turbulence
14-16 June 2017, Lille, France
• *Array of ultra-miniature hot-films for very high Reynolds number flows*

16th European Turbulence Conference
21-24 August 2017, Stockholm, Sweden
• *Array of ultra-miniaturized hot-films for very high Reynolds number flows*

Project meetings

Since two groups carry the WP21 development in 2 nearby cities (Lyon and Grenoble), informal meetings occured on a regular basis, typically every 1 or 2 months (in the worst case).

Publications

Detection of vortex coherent structures in superfluid turbulence
E. Rusaouen1, B. Rousset2 and P.-E. Roche
submitted to EPL, April 2017

Joint temperature and velocity local sensor for turbulent flows
Salort J. et al. (including Chillà, Rusaouen, Castaing and Roche)
submitted to RSI in May 2017

Other papers are in preparation.

Personnel Statistics:

- Scientific Coordinator (incl. information m/f)

  Ph. Roche (m)

- Work package leaders (incl. information m/f)

  Ph. Roche (resp. partner for CNRS-c) (m)

  F. Chillà (resp. partner for CNRS-a) (f)

- Experienced researchers (incl. information m/f)

  F. Chilla (f)

  Ph. Roche (m)

  J. Salort (m)

  J. Valentin (m)

  E. Rusaouen (f)

- PhD students (incl. information m/f)
- Other (incl. information m/f)

Task 21.1: Rugged anemometer and thermometer

Responsible partner: CNRS-c

Collaborators: J. Valentin, E. Rusaouen, P-E. Roche,

Objectives of the third reporting period (month 37 - 48):

The central objective of this task was to develop two technologies (micro-machined thermometer/cold wire support + rugged anemometer based on commercial pressure or temperature sensors and corresponding electronics), and to advertise them to relevant TNA.

Specifically in this 3th period, the objective was to spread out our technologies.

Concise overview:

As detailed in the "Dissemination" section, this task has been successful as specific probes have been made for several TNA facilities and contributed to several Euhit projects. Some miniature Pitot tubes have been used in the CERN/GReC TNA and in the Göttingen/SF6 tunnel TNA. The electronics initially developed for network of miniature Pitot tubes have been used with network of cold wire in the Barrel of Ilmenau TNA facility.

Some results obtained in the Grenoble/SHREK facility with pressure sensitive probes during the RP2 have been recently submitted for publication and presented in an international workshop held in Florida.

Use of resources:

- Human resources hired on this task consist in:

  J.V (Engineer) have been mostly working for the extra task of this WP but occasionally help out with clean room process.

  E. R (hired as Post-doc & Engineer) focused on rough probes of Task 21.1: fabrications, calibration, tests including at low temperature, mounting and operation in the TNA, probe validation by data post-processing… Her full time was shared with Task 21.2)

  P.R. was in charge of the coordination of development and tests.

- Direct costs mostly consist various clean room parts (wafer,…) and components for probe fabrication and mounting.

Problems and corrective actions: none

Task 21.1 : extension : Network of micro-machined cold wires for Room-temperature and Cryogenic flows

The extra task results from a successful application to the 2015 and 2016 "internal call". 9+9 months of support have been already allocated.

Responsible partner: CNRS-c

Collaborators: J. Valentin, P-E. Roche

Started: Oct. 15th, 2015 till March 31st, 2017

Objectives

A network of cold-wire substrates, based on Si technologies was developed within task 21.1. To turn these substrates into cold wires, temperature-sensitive-coatings had to be developed. This 18-months development was broken into 2 parts :
- 9 months (3 within RP3) : prototypes of cold-wire network for room-temperature
- 9 months in RP3 : upgrade, test in TNA and extension to cryogenics

Concise overview:

After selecting Pt as temperature sensitive material, several generations of networks of probes were fabricated.

Cryogenic helium : The first generation was operated in gaseous He in the CERN/GReC TNA (9/2016 and 2-3/2017). Only a few sensitive points (with 4 microns resolutions) were working but the signal was noise-free over more than 11 decades of power spectral density. This result will be reported in 2 workshops in 2017. Operation in a liquid helium TNA facility (Grenoble/HeJet) was also successful (3/2017, second generation of probes).

Room-temperature : The success of the first generation was more mitigated when the probes where operated at room temperature in the Göttingen SF6 tunnel facility (2-3/2017), due to a source of noise. An alternative network of thermometers (also micro-fabricated at CNRS-c) was successfully operated in the Ilmenau TNA facility (with electronics from WP21.1). The second and third generations of network of probes is expected to be free from this noise artifact. The relative spatial positions of probes was optimized.

Use of resources:

Since Oct. 15th 2015, J.V developed the probes network. He has been working nearly full-time on this project during all RP3. P.R. contributes in the design, mounting and tests in the different experiments.

Direct cost mostly consists in clean room parts for probe fabrication: wafers lithographic masks, disposable wafers...

Problems and corrective actions: none

Task 21.2: Cantilever probe

Responsible partner:

CNRS-a, CNRS-c

Collaborators:

F. Chillà, P.-E. Roche, E. Rusaouën, J. Salort

Objectives of third reporting period (month 37 - 48):

Task objective : Building of sensor prototypes, Demonstration of the heat-flux sensor at room temperature, in conventional fluids, Design and adaptation to cryogenic environment, First experiments at cryogenic temperatures with validation in a facility.

Specifically in this 3rd period, alike Task 21.1, the objective was to spread out the technologies to different facilities.

Concise overview:

As detailed in the "Dissemination" section, this task has been successful as specific probes have been mounted in the CERN/GReC TNA facility, in Grenoble/SHREK TNA facility, and some others sent to the Czech Convection TNA facility in Brno (CUNI). Some experiment done in the Ilmenau TNA facility till March 2016 where post-process during this third period

In May 2017, an instrumentation paper presenting this probe will be submitted for publication in RSI.

Use of resources:

All declared costs are associated with the development time of the prototypes (drawing new masks, adaptation of fabrication process, time spent at Mimento/Femto-ST facility) and characterization of the sensor at room temperature and at low temperature.

Main contribution of each partner during RP3:

Probe design: JS, FC, PR, ER ; Prototype fabrication: JS ; Mounting design and fabrication: JS, ER ; Room-temperature experiments: JS, FC ; Low-temperature experiments: ER, PR, JS ; Coordination-dissemination: PR, FC

Problems and corrective actions:

none

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 22: Lagrangian measurement of turbulence with strong mean flows

Summary

The aim of the work package 22 is to develop the technologies for 3D Lagrangian particle tracking (LPT) measurements, including calibration and analysis of measurement errors, suitable for turbulence with strong mean flows, which are present in a large number of facilities in EuHIT.

The tasks of WP22 were carried out by three partners of EuHIT: MPIDS, TUIL, and UTWENTE.

The LPT system for the TWT experiment at UTWENTE has been completed, tested. The main error sources were identified and a correction procedure developed to handle the main error source (vertical vibration). 2D tracking has been successfully achieved, but 3D tracking can't yet be done due to the independent vibration of the cameras.

The LPT system for the GTF 1 experiment at MPIDS was built and tested outside of the experiment. Vibrations were measured and the LPT redesigned to reduce them. Installation of the LPT in GTF 1 and testing in-situ have been blocked by the longer than expected vibration testing and ongoing, delayed experimental work in GTF 1. Completion of the subsystems have been delayed in response to delays completing the LPT platform, personnel shortages and major design changes to the illumination subsystem and tunnel floor. The camera alignment and calibration subsystems are complete, waiting for full testing after final installation of the LPT in GTF 1. The feedthroughs and communication/control systems have been completed. The illumination system's design has been finalized and it is just waiting for final manufacture and installation with the LPT.

As was reported in at the end of the second reporting period (months 19-36), at TUIL,

3D-particle tracking techniques were developed and adapted to the large-scale flow of the BOI (Barrel of Ilmenau). A metrology has to be developed to measure the three-dimensional, Lagrangian flow field in thermal convection in air. The metrology should be applied in the Barrel of Ilmenau. The measurement technique described in detail in the report of Deliverable D22.7 was applied successfully at a Rayleigh-Bénard cell of 2.5 m in diameter and 2.5 m in height, slightly smaller than the entire domain in the big Barrel. The system is scalable and can be easily adapted to flows of larger extend. The details of the functioning test are found in this report as well.

List of Deliveries and Milestones

- D22.1: Translation platform at GTF 1
    - Completed after a delay, as reported in the 36 month report.
- D22.2: Completion of the automated alignment, auto-focus and camera calibration system for GTF 1
    - Delayed
- D22.3 Translation platform at TWT
    - Completed
- D22.4: Completion of the movable 3D-LPT system for TWT
    - Completed
- D22.5: Method for calibration and analysis of measurement error of the system
    - Completed at UTWENTE on time and Completed at MPIDS after a Delay
- D22.6 Prototype of the bubble generator for BOI
    - Completed
- D22.7: Test of the large-scale 3D-LPT system at BOI
    - Completed
- MS18 Prototype of the GTF translation platform ready
    - Completed
- MS19: Completion of the translation platform in GTF
    - Delayed
- MS20 Design of the sub-system for the moving LPT in GTF
    - Completed
- MS21: Completion of the sub-systems for the movable LPT in GTF
    - Delayed
- MS22 Functioning of the LPT system at TTF, without translation
    - Completed
- MS23: Functioning of the movable LPT at TTF
    - Completed
- MS24: Identification of main error sources and construction of correction procedure
    - Completed at UTWENTE on time and Completed at MPIDS after a Delay
- MS25 Functioning of the bubble generator for BOI
    - Completed
- MS26: Functioning of the large-scale LPT system for BOI

- Completed

Dissemination Activities

Project meetings

- Göttingen, May 13th, 2013, Kick-off meeting
- Twente, May 12th-13th, 2014, General assembly meeting
- Goettingen, June 16th-18th, 2014, WP7/22 meeting with CNRS-a, MPI-DS
- Lisbon, July 7th-10th 2014, WP7/22 meeting with MPI-DS, UTWENTE and potential users of the BOI
- Ilmenau, July 14th-17th 2014, WP7/22 meeting with potential users of BOI
- Grenoble, May 11th-12th, 2015, General assembly meeting

Publications

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Phys. Rev. Lett. 114, 03450.

Willert, C., du Puits, R. and Resagk, C. 2015
Statistical and Temporal Characterization of Turbulent Rayleigh-Bènard Convection
Boundary Layers Using Time Resolved PIV Measurements
In Progress in wall Turbulence 2: Understanding and Modelling.
Ed. Michel Stanislas, Javier Jimenez and Ivan Marusic
Springer, Cham, Heidelberg, New York, Dordrecht, London 2016

Personnel Statistics:

- Scientific Coordinator
  - Prof. Dr. Eberhard Bodenschatz (m) – MPIDS
  - Prof. Dr. Detlef Lohse (m) – UTWENTE
  - Dr. Ronald du Puits (m) – TUIL
- Work package leaders
  - Prof. Dr. Eberhard Bodenschatz (m) – MPIDS
  - Dr. Chao Sun (m) – UTWENTE
  - Dr. Ronald du Puits (m) – TUIL
- Experienced researchers

- Dr. Greg Bewley (m), Dr. Garrett Good (m), Dr. Xiaozhou He (m), Dr. John Lawson (m), Dr. Jan Molacek (m), Dr. Freja Nordsiek (f), Dr. Haitao Xu (m) – MPIDS
- Dr. Chao Sun (m), Dr. Elise Almeras (f), Dr. Dennis van Gils (m), Dr. Erwin P. van der Poel (m) – UTWENTE
- Dr. Ronald du Puits (m), Dr. Christian Resagk (m), and Dr. Robert Kaiser (m) – TUIL

- PhD students
  - Michael Shinhuber (m) – MPIDS
  - Sander Huisman (m), Roeland van der Veen (m), Varghese Mathai (m), Biljana Gvozdić (f), Ruben Verschoof (m), Dennis Bakhuis, Erwin P. van der Poel (m) – UTWENTE
  - Natalie Schemet (f) – TUIL
- Masters students
  - Jon Brons (m) and Matthijs W.M. Neut (m) – UTWENTE
  - Jakob Stuprich (m), Vivien Chandra (f), Genadi Dimov (m) , Stefanie Rudolf (f), and Alice Loesch (f) – TUIL
- Engineers and Technicians
  - Dr. Artur Kubitzek (m), Dr. Garrett Good (m), Udo Schminke (m), Andreas Kopp (m), Andreas Renner (m), Marcel Meyer (m) – MPIDS
  - Dr. Dennis van Gils (m), Gert-Wim Bruggert (m), Martin Bos (m), Bas Benschop (m) – UTWENTE
  - Sabine Abawi (f), Vigimantas Mitschunas (m), and Klaus Henschel (m) – TUIL
- Undergraduate students
  - Sven Hillebrand (m), Willi Pose (m), Hauke Hirsch (m), Genadi Dimow (m), Stefanie Rudolf (f), Geovan Rezende (m), Pedro Figueiredo (m), Michael Ritzau-Jost (m), and Daniel Sorokin (m) – TUIL

Task 22.1: Construction of a high-speed moving platform

Responsible partner: MPIDS

Collaborators: None

Objectives of all reporting period (month 1 – 48):

To finish the testing with a prototype translation platform, optimize the design of the translation platform for the GTF 1, finish building the LPT platform for GTF 1, install it in the experiment, and test it in the experiment.

Concise overview:

- The progress on the LPT platform has been delayed due to a redesign required to reduce vibration and ongoing experimental work in the tunnel
- The LPT platform has been extensively tested outside of the experiment and is being prepared for installation into the experiment. The folding floor that will cover the LPT and the LPT sled are shown in Figure 1.
- Feedthroughs and other components for the integration of communication and control systems on the platform are complete, with the exception of camera modules which need repair from the manufacturer for use of the easiest high speed data transfer method (we have a harder system that we have used in the past that works that we can use if they are not ready).
- Installation and testing can begin once ongoing experimental work running in the tunnel is complete. We expect to install the LPT into GTF 1 starting in early 2018 and complete installation mid to late 2018.

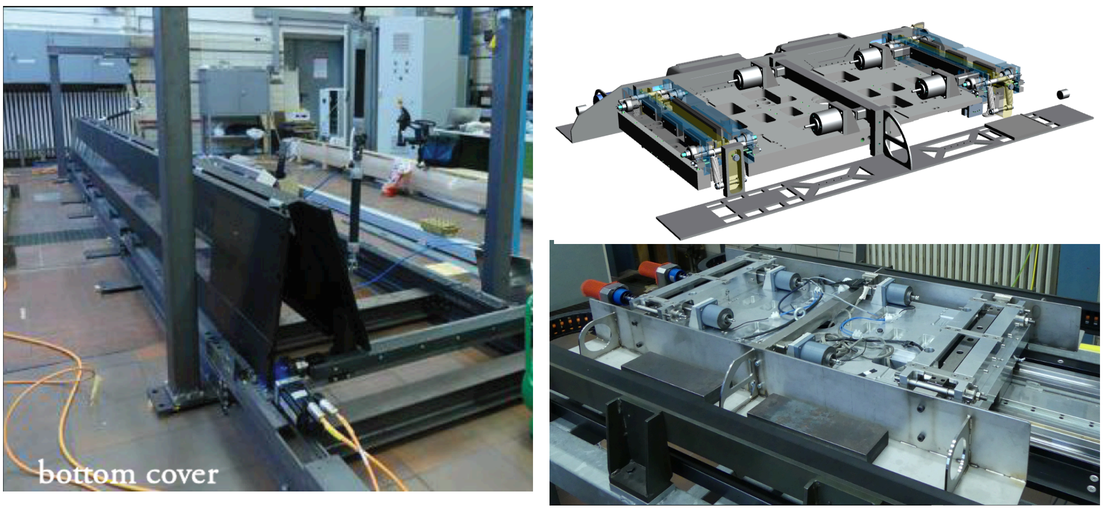

Figure 1: (Left) Photo of a folding test for the wind tunnel floor that will be put into GTF 1 with the LPT. The floor folds from the center and has a long viewing window on each side for the optical components on the LPT sled. **(Top Right)** 3-D CAD view of the specially designed vibration isolation system involving a combination of springs and electromotors. **(Bottom Right)** The vibration isolation system being tested on our prototype translation platform.

Use of resources:

- Experienced researchers
  - Dr. Garrett Good (m)
  - Dr. Jan Molacek (m)
  - Dr. Freja Nordsiek (f)
- Engineers and Technicians
  - Dr. Artur Kubitzek (m)
  - Dr. Garrett Good (m)
  - Udo Schminke (m)
  - Andreas Kopp (m)
  - Andreas Renner (m)
  - Marcel Meyer (m)

Problems and corrective actions:

There have been delays in completing the LPT platform and installing it into the experiment. Testing the platform outside of the experiment and modifying the design to reduce vibration and shocks took longer than expected. This has delayed finishing other components of the platform and installing it in the experiment. Installation of the sled in the tunnel and testing in-situ have been blocked by ongoing, delayed experimental work in the tunnel.

A revised schedule has been drawn up for completion of the LPT platform. The LPT itself and its control system is mostly ready, and are just awaiting the completion of hotwire measurments in GTF 1 and more work on some of the subsystems before installation.

Task 22.2: Design and construction of the subsystem for the moving LPT system

Responsible partner: MPIDS

Collaborators: None

Objectives of all reporting period (month 1 – 48):

Designing, building, and completion of the subsystems for the moving LPT platform in GTF 1. These subsystems handle camera alignment, camera calibration, lens auto-focusing and illumination.

Concise overview:

- Completion has been delayed in response to delays completing the LPT platform, personnel shortages and major design changes to the illumination subsystem and tunnel floor
- Camera alignment is mostly complete, and is waiting for the last parts and full integration and testing with the other systems. The camera focusing subsystems is still in the design and building phase.
- Design of the illumination system is mostly complete. We have Trumpf fiber-coupled laser and calculations show it should provide sufficient illumination. Design of the fiber feedthrough has been completed in collaboration with Trumpf and is awaiting final construction and testing. Design and construction of the co-moving illumination system is ongoing. See Figure 2.
- The camera calibration system has been designed and the key components obtained. It is waiting final installation into GTF 1 with the LPT.
- Installation of the moving illumination subsystem and floor requires substantial modification to GTF 1, which conflicts with the operation of the current hotwire experiments. We expect to install the LPT and these systems starting in early 2018 and finish mid to late 2018.

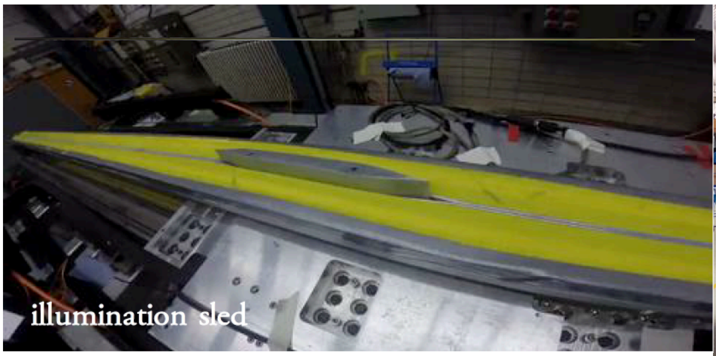

Figure 2: (Left) Picture of the magnetic zipper being tested. The magnetic zipper will be used on the ceiling of GTF 1 to seal around the moving illumination system delivering laser illumination to the test section. **(Right)** Picture of the Trumpf TruMicro 7240 pulse laser (300 W at 515 nm) that will be used to illuminate particles in the test section of GTF 1 when the LPT is

Use of resources:

- Experienced researchers
  - Dr. Garrett Good (m)
  - Dr. John Lawson (m)
  - Dr. Jan Molacek (m)
  - Dr. Freja Nordsiek (f)
- Engineers and Technicians
  - Dr. Artur Kubitzek (m)
  - Dr. Garrett Good (m)
  - Udo Schminke (m)
  - Andreas Kopp (m)
  - Andreas Renner (m)
  - Marcel Meyer (m)

Problems and corrective actions:

There have been delays in completing the LPT subsystems, due to delays in completing the LPT platform itself (Task 22.1) and a shortage of personnel available to work on the task. New experienced researchers (Lawson, Nordsiek) are now working on this task.

A plan for completion of the task has been constructed, which has identified remaining tasks and assigned responsibility for these. Completion of the alignment subsystem is expected by July 2017. The auto-focus subsystem will be completed some time after that.

Task 22.3: Development of sled-based 3D-LPT techniques for particle tracking at TTF

Responsible partner: UTWENTE

Collaborators: None

Objectives of all reporting period (month 1 – 48):

To construct and implement a sled-based movable LPT system for following particles (bubbles or other particles) in the TTF facility, which is capable of reaching speeds up to 0.6m/s. Control of vibrations and achieving uniform illumination of measurement volume.

The task was completed during the second reporting period (19-36 months).

Concise overview:

- A new moveable LPT system has been constructed that can reach speeds of up to 0.4 m/s, which almost matches the maximum mean flow velocity of the TWT measurement section (0.6 cm/s). See Figure 3.

- Vibration effects sufficiently low at speeds below 0.1m/s to allow 3D particle tracking velocimetry. At higher speeds vertical vibrations introduce significant errors.

- We have developed a post-processing technique to reduce errors introduced via platform vibration and used it to obtain first scientific results with the new sled.

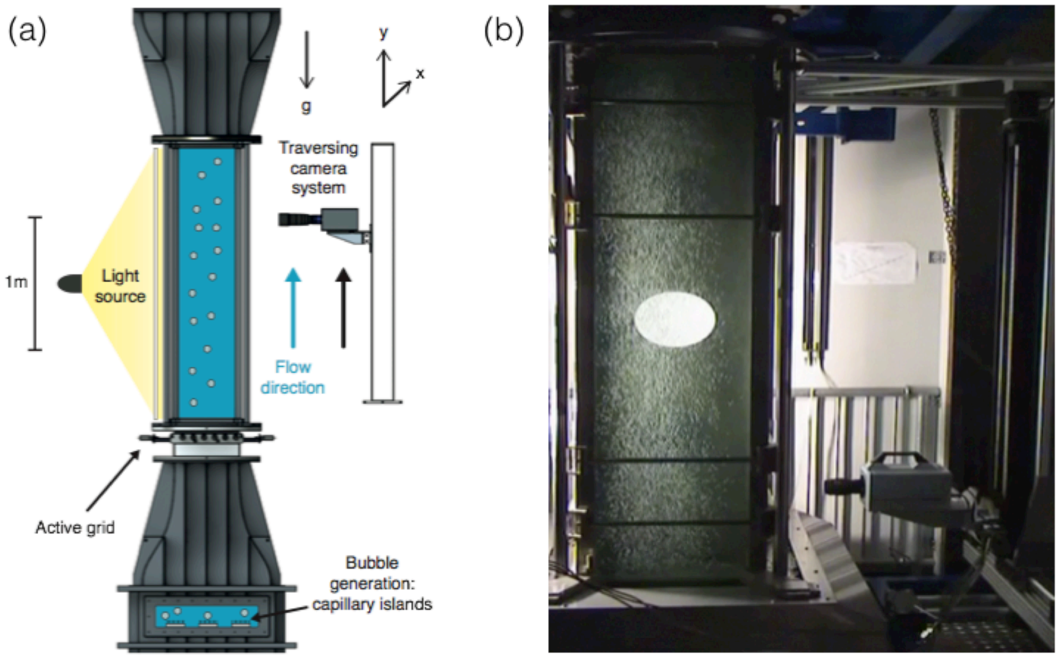

Figure 3: (a) A sketch of the sled system next to the TWT, and **(b)** a photo of the system with one camera

Use of resources:

- Experienced researchers
    - Prof. Detlef Lohse (m)
    - Prof. Andrea Prosperetti (m)
    - Dr. Chao Sun (m)
- PhD students
    - Minori Shirota (m)
    - Varghese Mathai (m)

Problems and corrective actions:

For larger velocities vibrations were difficult to remove. Post-processing technique was developed to mitigate the problem to a large degree.

Task 22.4: Analysis of the measurement errors of the moving LPT system

Responsible partner: MPIDS, UTWENTE

Collaborators: None

Objectives of all reporting period (month 1 – 48):

Calibrate the LPT systems for GTF 1 and TWT, identify the sources of errors and develop correction procedures, test these on the prototype and validate the procedures with numerical simulations.

Concise overview:

- Together with CNRS-a, we drafted a data validation protocol that was discussed at the 2014 annual EuHIT meeting (Twente, May 12-13, 2014).
- UTWENTE
  - This task is complete, though there is some work needed to refine the system. The LPT has been built and installed on the TWT, tested, main sources of errors obtained, correction procedures developed, and initial results obtained.
  - The LPT can go up to 0.4 m/s at the present time. Work is in progress to reach the originally planned 0.6 m/s.
  - Vertical vibration is the major source of error, while horizontal vibration is more minor.
  - A correction procededure has been developed and successively used for the vertical vibration.
  - 2D tracking has been successfully achieved, but 3D tracking can't yet be done due to the independent vibration of the cameras.
  - The first results have been obtained.
- MPIDS
  - The task is complete. We have developed multiple self-calibration routines that have worked on other experiments including the similar moving Lagrangian platform on the Zugspitze. We have developed correction procedures for camera model uncertainty and measurement noise (we are currently preparing publications). The only work that remains will possibly be some small tweaking of our routines after the LPT is installed into GTF 1.
  - We have been simulating particle tracking and assessing error sources for a stationary particle tracking system through our entire image and data processing toolchain using data obtained from collaboration with the Wilczek group.

  - Vibration of the platform has been measured and reduced from extensive testing with the LPT platform outside of the experiment
  - Improvements to the design of the mounts of the optical components on the LPT will reduce errors from relative vibrations in the optical paths of the cameras to an easier to manage level.
  - Analysis of a similar Lagrangian platform on the Zugspitze found that the primary source of error is the bulk movement and vibration of the cameras together, rather than relative movement between the cameras (error less than one pixel).

Use of resources:

- Experienced researchers
  - Prof. Detlef Lohse (m) – UTWENTE
  - Prof. Andrea Prosperetti (m) – UTWENTE
  - Dr. Chao Sun (m) – UTWENTE
  - Dr. Garrett Good (m) – MPIDS
  - Dr. John Lawson (m) – MPIDS
  - Dr. Jan Molacek (m) – MPIDS
- PhD students
  - Minori Shirota (m) – UTWENTE
  - Varghese Mathai (m) – UTWENTE

Problems and corrective actions:

There were delays at MPIDS due to not having the completed LPT system in GTF 1, but work on other experiments and simulations at MPIDS including the similar LPT system on the Zugspitze has allowed the identification of error sources, development of self-calibration and correction routines, and tests of these algorithms without the final installation of the LPT into GTF 1. All that remains will be some final tweaking once the LPT is installed.

Task 22.5: Adapting 3D-particle tracking technique to large scale lows

Responsible partner: TUIL

Collaborators: TAU, MPIDS, CNRS-a

Objectives of all reporting period (month 1 – 48):

Developing an optimized prototype of the bubbles (stubbles) generator for BOI, testing the functionality of the stubbles generator for BOI, developing and building a 3D-LPT system for the BOI, and perform 3D-LPT measurements in the BOI.

The task was completed during the second reporting period (19-36 months), with some additional work on documentation and data archiving done since then.

Unlike most of the other laboratory flow experiments the flow in the experiment "Barrel of Ilmenau" is of very large extent. Presently, there is not any suitable, particle-based technique to probe the 3D field in such large-scale flows. In Work package 22, Task 22.5 the 3D-LPT technique will be adapted to the BOI facility (and to other large-scale facilities in the EuHIT infrastructure network). One problem for such large-scale measurement is the generation of appropriate tracer particles that follow the flow faithfully while still visible on large-scale images. Our idea was to use unbreakable bubbles (commonly referred to as stubbles) of about 3…4 mm size. In order to be overall neutrally buoyant the bubbles are filled with a gas lighter than air. Because of the high viscosity of the bubble fluid, it behaves like a liquid honey, a novel technology has to be developed to generate bubbles. Moreover, a novel volume illumination has to be developed generating sufficient and uniform light intensity in the measurement domain. The third task is to find an appropriate calibration scheme.

Concise overview:

The novel metrology has been applied at a cylindrical convection cell 2.5 m in diameter and 2.5 m in height. The cell was installed in the large facility using the original heating and cooling plates as lower and upper confinement of the air. The cell was made of transparent Perspex and permits a full optical access for the four cameras that were arranged at the inner wall of the large cell. A sketch of the setup is shown in the figure below.

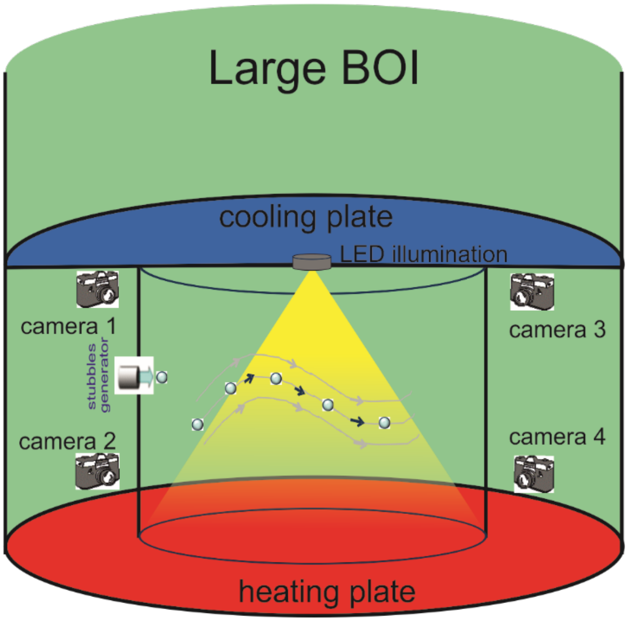

Figure 4: Sketch of the application of the 3D-LPT sytem at the BOI

We used this setup to capture Lagrangian trajectories of the bubbles in turbulent Rayleigh-Bénard convection. The temperature difference between the heating and the cooling plates amounted to $\Delta T = 20K$, resulting in a Rayleigh number of $Ra = 3.6\times10^{10}$. Before a measurement was started, the camera system was calibrated using a swinging dumbbell. A series of 1000 images with a rate of 10 frames per second was taken and the camera parameters required for the reconstruction of the particle positions have been calculated. After the calibration process, the dumbbell was removed and stable bubbles were injected into the airflow. Several short and long-term series of images have been captured to test various settings of the cameras, the illumination and the timing of the system. At the end of those tests a series of 35476 images covering a period of almost one hour was captured

Use of resources:

- Experienced researchers
  - Dr. Ronald du Puits (m)
  - Dr. Robert Kaiser (m)
  - Dr. Christian Resagk (m)
- PhD students
  - Natalie Schemet (f)
- Masters students
  - Jakob Stuprich (m)
  - Vivien Chandra (f)
  - Alice Loesch (f)

- Technicians
    - Sabine Abawi (f)
    - Vigimantas Mitschunas (m)

Problems and corrective actions:

Due to the fact that the project employee Mrs. Natalie Schemet was ill for the period 01/2015 until 09/2015 there was a three month delay in the work. The work has been done by the experienced researchers and some technical issues and the analysis of the flow images were finished by Mrs. Sabine Abawi.

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 23: Advanced Eulerian measurement techniques

Summary

New hot-wire and hot-film sensors for use at high Reynolds numbers shall be designed and fabricated. The probes are smaller than existing probes and the electronics is faster in order to resolve the full range of scales present in high Reynolds number flows. This is of fundamental importance not only for academic research, but also for engineering applications (e.g. friction on aircraft) and turbulence modeling (e.g. wall functions that are still based on the Kármán constant). The WP is organized in the following task:

Task 23.1: Miniature multi-hot-film sensor development

Task 23.2: Calibration of multi-hot-wire and -film sensors

Task 23.3: Numerical simulations of micro-hot-wire probes

Task 23.4: Very high dynamics range hot wire electronics

An extra "Task" has been added in period 36-48 concerning the study of a commodity depth sensor, the Kinect (Microsoft, Redmond WA, USA), in order to assess its application as a water-wave detector and as a tool for the reconstruction of fluid free-surfaces.

List of Deliveries and Milestones (months 1-18)

No deliverables in month (1-18)

MS27 Prototype of single hot-film sensor constructed (status: fulfilled)
MS29 Design of the calibration system for hot-film sensors (status: fulfilled)
MS33 Adaptation of simulation codes (status: fulfilled)

MS34 Very-wide-dynamics-range current sources constructed (status: fulfilled)

List of Deliveries and Milestones (months 18-36)

Deliverables in month (18-36)

D23.1 Single hot-film sensor prototype (status: completed)
D23.3 Calibration system for single probes (status: completed)
D23.5 Simulation of probes in laminar flows (status: completed)

Milestones in months (18-36)

MS28 Prototype of the V-shape hot-film sensor constructed (status: fulfilled)
MS30 Prototype of the single hot-film calibration system (status: fulfilled)
MS31 Prototype of the V-shape hot-film calibration system (status: fulfilled)
MS35 Prototype of cold-wire electronics constructed (status: fulfilled)
MS36 Board design complete (status: fulfilled)

List of Deliveries and Milestones (months 36-48)

Deliverables in month (36-48)

D23.2	V hot-film probe prototype
D23.4	Calibration system for V hot-film probes
D23.5b	Investigation of probe geometry by numerical simulations
D23.5c	Dissipation assessment in wall bounded flow
D23.6	Assessment of probe properties by DNS
D23.7	Prototype of cold-wire electronics
D23.8	K-wave sensor prototype
D23.9	Calibration system
D23.10	Characterization of the sensor

Dissemination Activities

WP23 deals with a research and development activity, which can be disseminated when the end product is completed. This has been done at the end of the project period. For instance, applications of the single hot-film sensor with the corresponding calibration have been successfully employed in the Long Pipe in CICLoPE while the CCA anemometer has been tested at CEA-a and CERN TNA facilities. Scientific communications on these tests are planned in 2017.

Bertinoro (ITALY), September 5th-6th 2016. Workshop Reynolds number turbulent flows. A large-scale infrastructure perspective. Meeting sponsored by EuHIT, with potential users of the developed sensors.

Forlì (ITALY), December 14th 2016. Uno “space day” a forli' – esplorazione spaziale, universita' e internazionalizzazione nel territorio forlivese. Aerospace and Fluid Dynamics activities in the University of Bologna.

Project Meetings

Göttingen, May 13th, 2013, Kick-off meeting

Twente, May 12th-13th, 2014, General assembly meeting

Bertinoro (ITALY), September 21th-24th 2014, meeting with potential users of the developed sensors

Grenoble, May 10th-12th, 2015, General assembly meeting

Bertinoro (ITALY), September 7th-9th 2016, iTi Conference in Turbulence

Goettingen, May 2nd-4th, 2016, General assembly meeting

Publications

A. Talamelli, A. Segalini, R. Orlu, P. Schlatter, P.H. Alfredsson
Correcting hot-wire spatial resolution effects in third- and fourth-order velocity moments in wall-bounded turbulence
Experiments in Fluids, v 54, n 4, April 2013

R. Orlu, F. Malizia, A. Cimarelli, P. Schlatter, A. Talamelli
The influence of temperature fluctuations on hot-wire measurements in wall-bounded turbulence
Experiments in Fluids, v 55, n 7, July 2014

Borisenkov, Y., Kholmyansky, M., Krylov, S., Liberzon, A. and Tsinober, A., 2011. **Super-miniature multi-hot-film probe for sub-Kolmogorov resolution in high-Re turbulence.** Journal of Physics: Conference Series. 318 072004 doi:10.1088/1742-6596/318/7/072004

Borisenkov, Y., Gulitsky, G., Kholmyansky, M., Krylov, S., Liberzon, A. and Tsinober, A., 2015. **Micro-machined super-miniature hot-film multi-array probe for field experiments with sub-Kolmogorov resolution**. Journal of Turbulence. doi: 10.1080/14685248.2015.1014558

Borisenkov, Y., Kholmyansky, M., Krylov, S., Liberzon, A. and Tsinober, A., 2015. **Multiarray Micromachined Probe for Turbulence Measurements Assembled of Suspended Hot-Film Sensors.** IEEE Journal of Microelectromechanical Systems. doi: 10.1109/JMEMS.2015.2417213

European Cryogenics Day 2016, 9-10 June 2016, CERN
"**GReC experiment : probing ultra high-intensity turbulence**" by P.R. (slides:https://indico.cern.ch/event/486602/timetable/?view=standard)

Roche P "**Array of ultra-miniaturized hot-films for high Reynolds number flows**" New Challenges in Wall Turbulence, 14–16 June 2017, Lille, France

Roche P , "**Phénomènes intermittents en Turbulence quantique et classique**" by P.R. (http://neel.cnrs.fr/spip.php?article4519) Institut Néel Monthly Seminar, 16 Dec 2016, Grenoble

Personnel Statistics

- Scientific Coordinator (incl. information m/f)
- Work package leaders
  Prof. Alessandro Talamelli (m)
- Experienced researchers
  Prof. Arkady Tsinober (m)
  Prof. Alex Liberzon (m)
  Prof. Guido Boffetta (m)
  Prof. Miguel Onorato (m)
  Dr. Philippe Roche (m)
  Dr. Michael Kholmyansky (m)
  Dr. Andrea Cimarelli (m)
  Dr. Gabriele Bellani (m)
  Dr. Grigory Gulitski (m)
  F. Toselli (m)
  F. De Lillo (m)
- PhD students (incl. information m/f)
  Mr. Youry Borisenkov (m)
  Mr. Tommaso Fiorini
  Mrs. Lucia Mascotelli
- Other (incl. information m/f)
  Ing. O. Exshaw (m)

Ing. G. Bres (m)
Ing. P. Carecchio (m)

Task 23.1: Miniature multi-hot-film sensor development

Responsible partner: TAU

Objectives of the task:

Objective of this task is to provide micro-hot-film and hot-wire probes for velocity measurements with single and multiple sensors that are one order of magnitude smaller than commercially available hot-wire probes together with a relevant calibration system

Concise overview:

The hot-sensor probes are the central component of the micro-scale turbulence research. In the present project our efforts are concentrated on a new generation of such probes, miniature multi-hot-film sensor ones. The design of the V-probes is naturally based on the one of single probes (MS27, see Fig 1). Such probes were developed, manufactured and successfully tested.

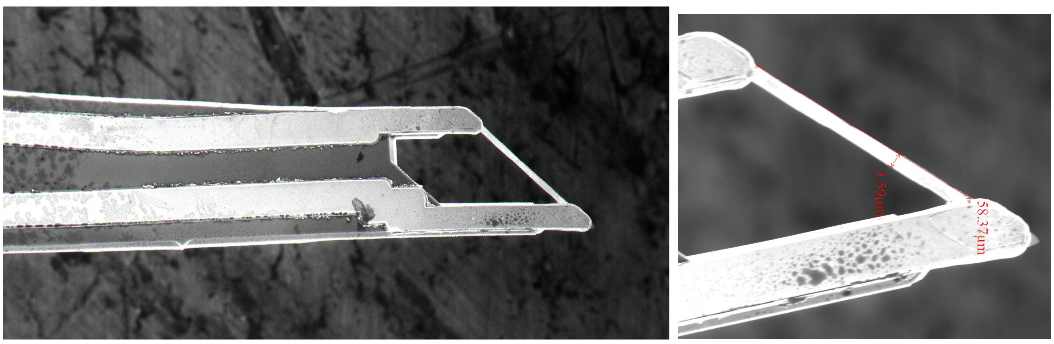

Fig 1. Microphotograph of the tip of the hanging sensor. (right) close-up.

In transferring to the more complicated V-probes, permitting to obtain two components of the velocity vector, a few aspects had to be considered. In addition to miniaturization, there were special requirements to the single sensing element in view of the goal to manufacture a multi-hot-sensor probe, enabling access to all the components of the velocity gradient tensor. In particular, the single sensing element together with its supporting structure had to be compatible with the requirement to minimize not only the interference of its own supporting structure, but also of the neighboring sensing elements. We had to produce an array, consisting of four single sensing elements, which in turn would serve as building blocks for a probe, consisting of five such arrays. For convenience, the first V-probes were produced by MM technology as a unit, with two sensors at the tip, see Fig. 2.

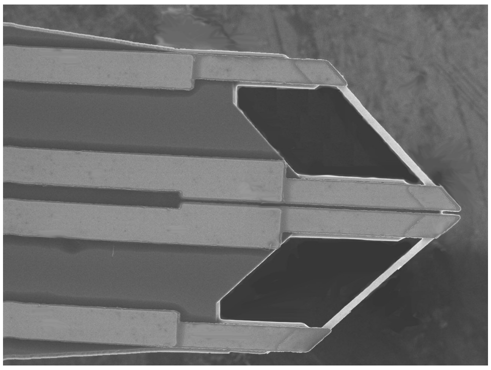

Fig 2. Microphotograph of the tip of the V-shape two-sensor probe manufactured as a unit.

It should be mentioned that this design, convenient for testing, can not be used for building four-sensor arrays. Such arrays have to be assembled of single-sensor elements. The V-shape probes permit simultaneous measurement of two velocity components: longitudinal, oriented along the probe axis, and lateral, in the plane of the probe. Evidently such probes have to be calibrated not only in the flow with variable magnitude, but also with variable angle. We call such calibration two-dimensional. In Fig. 3 we show an example of the angular calibration of the V-probe at fixed velocity magnitude. The plot looks quite reasonable.

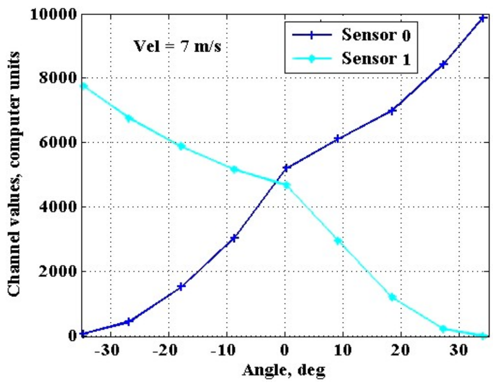

Fig 3. An example of the angular calibration of the sensors of the V-probe at fixed velocity magnitude.

Tests were performed with V-shape probes in a wind tunnel. The tests showed good performance of the probes. As examples we show the time series of two velocity components (see Fig. 4) and their power spectra (see Fig. 5). In conclusion:

1 A single hot-film element with hanging metallic sensor strip was designed and manufactured. It functioned well.

2 Detailed tests were performed. They demonstrated much better spatial and temporal resolution of the new micro-machined sensors, as compared with conventional hot-wire probes. In particular, the MM-probe with sensor length of 60 μ showed that the dissipation rate,

calculated using conventional hot-wire probe, was more than twice underestimated.

3 V-shape probes work properly. Their two-dimensional calibration plots show expected angle dependence. Test measurements in a wind tunnel permitted to obtain two components of velocity. Their time series and power spectra are quite reasonable.

We want to mention that the developments in the framework of the present project represent important contribution to our wider program of high-resolution measurements of turbulent flows at high Reynolds numbers. Among other aspects they made possible our recent experiment, also supported by the European Community, at the CICLOPE laboratory in Predappio, Italy.

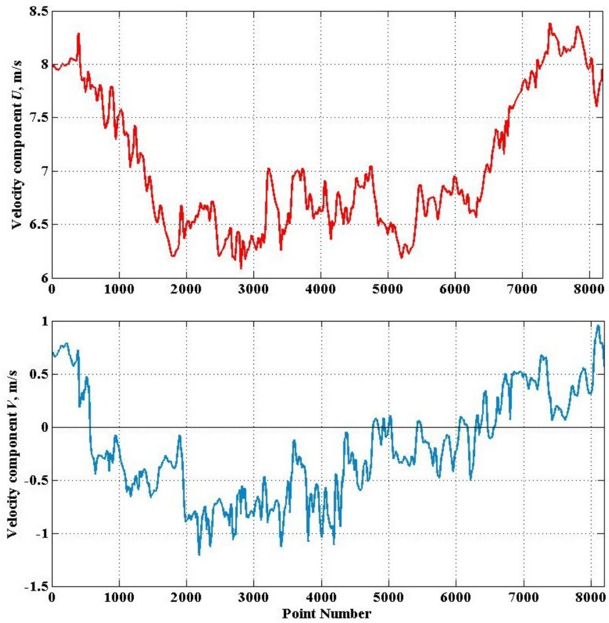

Fig 4. A short fragment of the time series of two velocity components obtained with the V-probe in a wind tunnel.

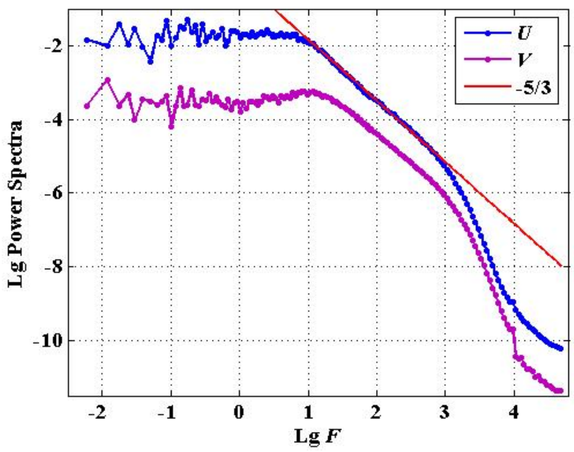

Fig 5. Power spectra of two velocity components obtained with the V-probe in a wind tunnel.

Task 23.2: Calibration of multi-hot-wire and -film sensors

Responsible partners: TAU, UNIBO

Objectives of the task:

It is well-known that the hot-sensor probes have no absolute calibration and must be calibrated using special devices producing the flow of known magnitude and direction. The objective of the task is to design and develop a specific calibration system for the probes developed in task 23.1.

Concise overview:

The calibration of the multi-sensor probe consists of two main steps:

- obtaining calibration data, using the calibration unit, data acquisition equipment and software (field calibration);
- processing the calibration data to calculate calibration coefficients.

Calibration coefficients are used to transform the voltages, recorded in the measurement runs, into physical values, in our case the components of the velocity vector, depending on the type of the probe: a single sensor, V-probe or full multi-sensor probe.

Resistances of hot-sensors are low, therefore small changes of contact resistance in connectors may affect the calibration characteristics and produce errors in measured velocity values. Such errors are especially dangerous because these velocity values, taken at close points within a probe, are used to calculate velocity differences and space derivatives, and even small errors in measured velocities may result in high errors of the differences. To avoid errors of this kind the calibration has to be performed with the probe, connected to its cable in its working position. Another point is that the calibration is sensitive to the temperature of the flow. It is important to provide the temperature of the calibration flow as close as possible to that of the measured flow.

Fig.1 shows the flow in our calibration unit. It is produced by suction, therefore we avoid heating of the air flow by pumping. The calibration flow is a jet formed by a nozzle. When suction is on, the atmospheric air enters the container through a filter, mounted in the air-supplying pipe. From there the flow enters the jet unit that consists of a contractor, a honeycomb and a nozzle. The flow, passing through these elements, forms a jet with uniform velocity profile around its axis and low level of fluctuations. The outlet of the nozzle, where the tip of the probe is located, opens to a suction chamber.

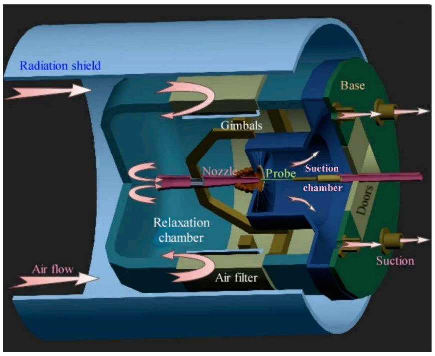

Figure 4. Schematic of the flow in calibration unit.

In order to allow three-dimensional calibration, the jet unit can be rotated around two orthogonal axes: it is mounted on a high precision gimbals mechanism. The rotation of the gimbals is performed by two similar units, each including a motor, a gear assembly and a synchronous resolver that serves for the measurement of the angle of rotation, see Fig. 2. This function is not used in one-dimensional calibration of single-sensor probes. In two-dimensional calibration of V-probes rotation around only one axis is performed.

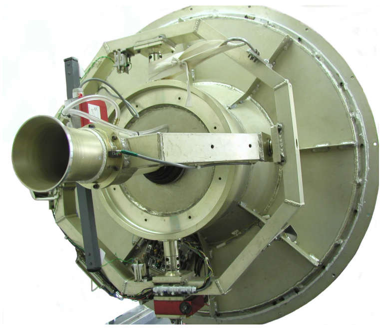

Figure 5. Interior of the calibration unit (container removed).

The value of the velocity magnitude in the jet is obtained by measuring pressure difference at two cross-sections of the nozzle using an electronic differential manometer. The velocity can be calculated using Venturi's formula. The field calibration is controlled by a computer program. It can be performed at 49 angular positions within a spatial angle of up to 35º. At each position the calibration data can be taken, for example, at ten velocities within a specified range. In such case the calibration data will contain 490 samples. The duration of such a calibration is estimated as about 10 min. The sample consists of the values of velocity magnitude, two angles and up to twenty readings of the hot-sensor channels.

The processing of the calibration data to calculate calibration coefficients is performed by least-square approximation of the calibration data by multi-dimensional polynomials of Chebyshev type. The calibration system described above was designed and manufactured in our laboratory and was used in laboratory and field measurements with the old version of our multi-sensor probe based on hot wires. For miniature multi-hot-film sensors that their development is the main purpose of our whole project it was found possible to use the existing calibration unit, performing appropriate modifications in the hardware and software to fit it for the use with the new sensors at each stage of their development. The modifications in the hardware related to the mounting of the sensors in the calibration unit. For each type of the probe (single hot-film sensor probe and V-shape hot-film sensor probe) necessary accessories were designed and tested. The modifications in the software were necessary to implement the one-dimensional and two-dimensional calibration procedures for the work with the types of the probe at various stages of their development. We had to prepare temporary versions of the computer programs for performing both field calibration and calculation of coefficients. Moreover, naturally versions of computer programs for further data processing were also necessary. All such versions of computer programs were prepared and successfully tested. In Fig. 3 below we present an example of a plot of the calibration data section at angle 0. It shows the dependence of the output signal on the velocity magnitude at that angle.

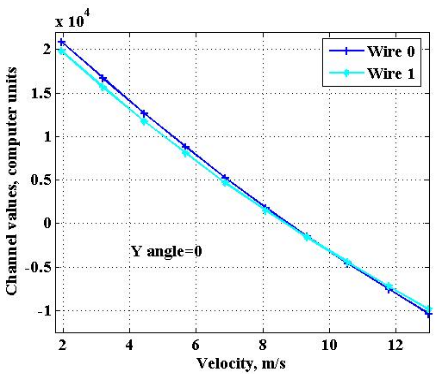

Figure 6. Example of the calibration data section at fixed angle and varying velocity magnitude.

Fig. 4 shows an example of a plot of another calibration data section: at fixed velocity and varying angle. Both plots show reasonable behavior of signals.

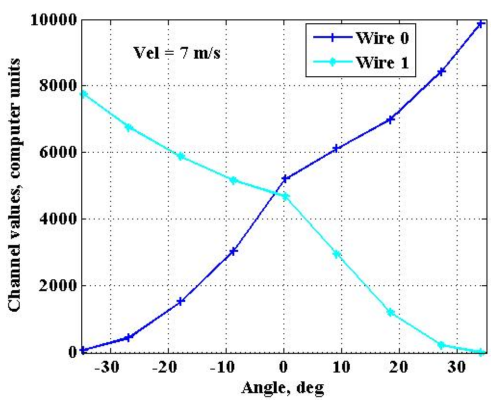

Figure 7. Example of the calibration data section at fixed velocity and varying flow angle.

Task 23.3: Numerical simulations of micro-hot-wire probes

Responsible partners: UNIBO

Collaborators: Dr. Andrea Cimarelli, Dr. Gabriele Bellani, Prof. Philipp Schlatter (Royal Institute of Technology), Dr. Ramis Orlu (Royal Institute of Technology), Dr. Tommaso Fiorini, Mrs. Lucia Mascotelli

Objectives of the task:

Aim of the task is the assessment of measurements techniques for the study of turbulent flows and in particular with the numerical simulation of the response of hot-wire (HW) measurement technique.

Concise overview:

To fully understand the response of a probe, numerical simulations are an invaluable tool which allows to identify, quantify and compensate the deviation of the anemometry response from the actual velocity field. There are many possible sources of measurement errors using hot-wire anemometry. The leading ones are related to
spatial and temporal resolution;
positioning and alignment of the probe;
inhomogeneous thermal conditions of the experiment;
perturbation of the flow induced by the sensor itself;
The first three points have been the subject of research activities performed within the first period of the EuHIT project, while the last point has been addressed in the second and third period accordingly with deliverables 23.5.
By means of direct numerical simulation data of turbulent channel flow, it is possible to evaluate the response of hot-wire probes and to identify and quantify the different measurement errors. The accuracy of these kind of data allows us to evaluate the response of hot-wire probes by considering separately the role of spatial resolution, probe alignment and inhomogeneous thermal conditions. Spatial resolution has been simulated by performing a spatial average of the velocity field over the length of the wire. Based on these results, we have been able to propose practically feasible correction methods. The same technique of simulation of the response of hot-wire probes has been used to assess the role of misalignment errors. In this case the spatial average of the direct numerical simulation data is performed over the wire length inclined with different angles with respect the wall. Direct numerical simulation data of a turbulent channel flow have been also used to assess the effect of the presence of a mean temperature gradient in the flow field on the HW response.
To fully understand the response of a probe it is also necessary to study the flow distortion caused by the presence of subwire fluctuations and by the geometry of the probe itself. In principle, it should be possible ideally to implement an exact simulation of a full detailed probe geometry immersed in a

turbulent flow. However, this approach is very challenging due to numerical stability and resolution requirements. For this reason, the problem has been approached by considering a more simple configuration but at the same time aiming at gaining the same information of the complete approach.
By means of a manageable finite volume code (OpenFoam), a simulation of the velocity and thermal field around a simple hot cylinder representing the wire, see figure 1, has been set up. By means of ad-hoc inlet velocity field fluctuating in the spanwise direction and time, we have been able to mimic the inhomogeneous cooling of the wire sensor given by the presence of turbulent fluctuations occurring at subwire length. The analysis of these data allowed us to quantify this measurement error and to develop correction technique to be applied in the different region of the flow once the ratio between the wire length and the Kolmogorov length scale was provided. Indeed, by changing the characteristic length of the inlet velocity we are able to quantify how the heat exchange varies as a function of the fluctuations length.

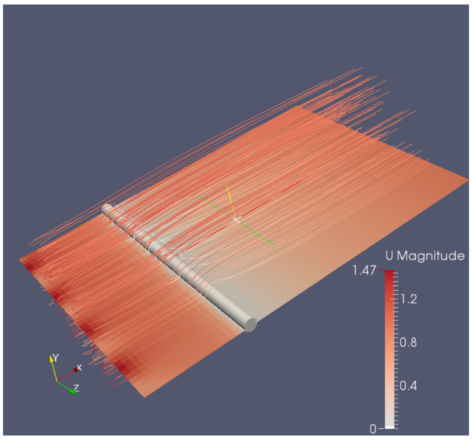

Fig 1. Direct Numerical Simulation of a laminar flow around an hot cylinder. The unsteadyness and inhomogeneity of the inflow conditions are used to mimic the presence of turbulent fluctuations at subwire length.

In order to account also for the velocity disturbances induced by the probe itself on the wire sensor, we developed also a simulation (again using the versatility of OpenFoam) of the entire probe geometry interfering with the wall, see Fig. 2. This approach allows us to quantify the effective mass flow cooling the wire and hence the measured velocity with respect the exact one. Indeed, the presence of the prongs as a support of the wire sensor leads to an aerodynamic interaction with the flow field and the wall thus corrupting the measured velocity. A challenging issue in simulating the behavior of hot-wire probes in turbulent flows is the simulation of the turbulent flow itself impinging the wire. In this set of simulations we do not simulate a real turbulent flow but a laminar one with unsteady and non-homogenous inlet velocity.

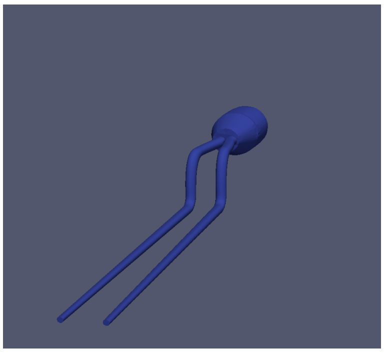

Fig 2. Direct Numerical Simulation of a flow around a hot-wire probe. Geometry of the probe considered.

By means of the versatility of finite volume numerical codes we have been able to adapt an open source code (OpenFoam) to simulate how the distortion of the flow caused by the probe itself and the presence of a wall, affect hot-wire measurements. The results show a clear disturbing effect caused by prongs geometry over measured velocity field not only near the prongs but in the middle wire-line region that cover almost 60% of the wire lenght (90% of input velocity module) considering lastly also numerical error tolerance by Openfoam code.

Finally, a specific analysis aimed at exploring the possibility to estimate the dissipation in high Reynolds number wall bounded flow has been performed. The exact measurement of dissipation is indeed very challenging since it requires the knowledge of the entire gradient tensor.

By means of a single hot-wire, only one component of the velocity gradient tensor can be measured by considering the so-called Taylor hypothesis of frozen turbulence. In this case the measure is exact only for homogeneous isotropic turbulence. However, this simplified relation for dissipation is known to fail in inhomogeneous anisotropic flows especially in the vicinity of walls (see Fig. 3)

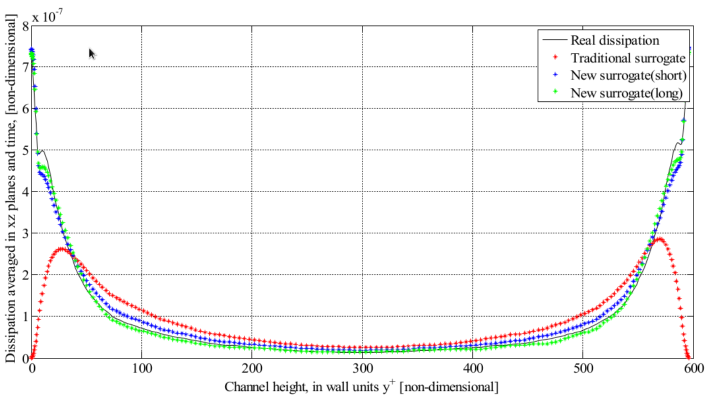

Fig. 3: Wall-normal profiles of turbulent dissipation in a turbulent channel flow. The solid black line reports the behaviour of the exact definition of dissipation. The red symbols denote the prediction of dissipation given by the

classical isotropic model. The blue and green symbols report the behaviour of the proposed new model for dissipation based on measurement given by two single and X wires, respectively.

In order to improve the ability of experiments in wall-bounded flows commonly performed by means of hot-wire probes, we used Direct Numerical Simulation DNS data of a turbulent channel to assess the errors and to develop simplified models for dissipation that can be measured in experiments. First, we investigated the possibility of using two hot-wires mounted in a single probe and slightly displaced in the wall-normal direction in experiments. Indeed, these settings would allow to use simplified expressions for dissipation which involve both streamwise and wall-normal gradient. In this way it is possible to build up a surrogate for dissipation, which significantly improves the prediction of actual dissipation. This improvement is strong in the near-wall region where the isotropic model is completely out of its assumptions but is significant also in the bulk of the flow. To further improve the prediction, we investigate also the possibility of using an X-wire aligned to the x-z plane in experiments thus allowing to measure also the streamwise gradients of the vertical and spanwise velocity, v and w respectively.

Task 23.4: Very high dynamic range hot-wire electronics

Responsible partners: CNRS-c

Collaborators: O. Exshaw, G. Bres, P. Carecchio, P.-E. Roche

Objectives of the task:

The purpose of the task is to develop flexible and programmable hot-wire electronics that performs well enough to resolve the full range of fluctuations present in the flows at the TNA facilities. As an intermediate objective cold wire electronics with similar performance shall be prototyped. It shall feature an alternating driving current with programmable amplitude from a few milliamperes down to a few tens of picoamperes, 5 kHz bandwidth and 20 bits resolution. At the lowest currents, no commercial products exist. The last objective is to implement a field programmable gate array (FPGA) to drive the probe current.

Concise overview:

The outcome of the project consists in different electronic prototypes for hot wire anemometry and cold wire thermometry. All versions can perform cold wire thermometry and constant-current anemometry (CCA), and two can also perform constant-temperature anemometry (CTA). As reported in D23.7, some were operated in TNA facilities (CERN/GReC, CEA/HeJet, Max Planck/SF6 tunnel) to identify sources of improvements.

As a first objective, a cold-wire / CCA electronics with wide-current range was designed and prototyped (MS35). A demonstration of its operation over the full range (10pA-10mA) was successfully performed at the Euhit General Meeting in Grenoble (11-12th May 2015). The defect of this first prototype (no trigger output, use of a demonstration board for the digital functions, some routing tracks needing correction) were corrected in a second version. Specifications and pictures of both versions are provided in D23.7.

A second objective was a CTA electronics controlled by a FPGA. Like for the CCA electronics above, it appeared wise to develop two versions to ease the developments stages. The first version was targeting the minimum specifications of the initial project (400–kHz-bandwidth) and the second version is going far beyond (>1-MHz-bandwidth). Specifications and pictures of both versions are provided in D23.7 and the RP3 report. In short, the first version is build around an commercial Arty FPGA development board along with PMOD ADC & DAC. PID control was programmed with anti-windup, bumpless transfer, current or resistance limiters and filtered derivative. CTA operation was validated with a virtual how-wire, simulated by a dedicated FGPA card specially developed. The second high-end version is based on a home-designed multi-layers board, with Kintex7 FPGA and daughter boards for ADC and DAC. The output of the data is done through an LAN.

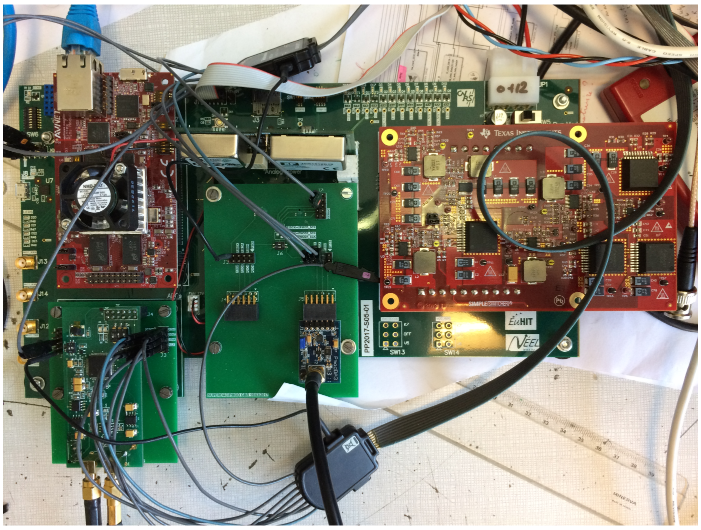

Fig. : Home-designed CTA electronic board (see Euhit logo)

Use of resources:

The four person who worked on this project over the last 4 years had specialised contributions: hardware development (G.B.), FPGA programs (P.C.), specifications and testing (P.R.) and coordination of electronics developments (O.E.). A number of other persons have joined the effort, from one Master student (V. Chandra) to a retired Engineer (J.-L. Bret) but their time contribution was “free of charge” for the project.

G.B.	7.81 p.m. (RP3)	21.8 p.m (RP1+RP2+RP3)
P.C.	5.72 p.m. (RP3)	10.1 p.m (RP1+RP2+RP3)
O.E.	0.33 p.m. (RP3)	4.2 p.m (RP1+RP2+RP3)
P.R.	0.97 p.m. (RP3)	4.3 p.m (RP1+RP2+RP3)

Direct cost. The routing of the electronics circuits was done in-house but the fabrications of the corresponding integrated circuits were outsourced. Other direct costs included buying development boards, PMOD cards, power-supply card for the FPGA and dedicated components.

Problems and corrective actions:

The project has requiring significantly more time resources than expected (40 p.m instead of 17 p.m) but the laboratory has been able to continue to allocate the extra resources needed.

Task 23.5: K-wave sensor system

Responsible partners: UNITO

Collaborators: G. Boffetta, M. Onorato, F. De Lillo, F. Toselli

Objectives of the task:

The purpose of this task is to show that this device can be used as a low-cost, high-resolution imaging camera system in application areas such as 3D mapping or field reconstruction. In detail, we explore its viability for the reconstruction of surface flows and the propagation of surface gravity waves.

Concise overview:

1) K-wave sensor prototype
   In addition to a RGB camera, a three-axis accelerometer and four microphones, the Kinect also contains a structured infrared (IR) light emitter and an IR sensor: the pattern projected by the emitter and diffused by objects is captured by the IR sensor and processed by the internal electronics to give a "depth image", i.e. a 2D field providing for each point in the field of view its distance from the plane of the device.
   In the first part of the work we investigated the principal intrinsic characteristics of the sensor (such as horizontal-vertical resolution, field of view, noise, optimal sensing range etc.).
   Moreover, in collaboration with the Technical University of Eindhoven (TUE) we developed the acquisition software to use the Kinect as a surface wave detector.
2) Calibration system
   The second part of our work concerned the calibration of the sensor.
   The calibration was divided in two steps: in the first step we performed a vertical calibration finding a linear relation between the real distance of points on a flat surface and the depth values from the sensor. As a second step we estimated possible systematic errors due to spherical aberration from the lens and found them to be negligible. Further details about the calibration can be found in the specific section D23_9.
3) Characterization of the sensor
   We investigated the sensor's capability to detect fluid surfaces and to reconstruct the propagation of surface waves from their depth images.
   This experimental characterization was implemented at TurLab in Turin generating water waves (with different lengths wave and amplitudes) in a linear tank. We analyzed different signals also validating the measurements with data acquired with capacitive wave gauges: we obtained promising results and were able to detect wave amplitudes as small as 4 mm.
   Finally, we decided to test the sensor's viability in physical studies by reconstructing the dispersion relation of surface gravity waves in water: we found a good agreement between data acquired with K-Wave and the theoretical prediction (see specific section D23_10).

In conclusion, the results achieved during this project show that the Kinect sensor, thanks to its low-cost and its resolution and precision is a promising instrument for the reconstruction of free-surface dynamics (e.g. surface waves).

EuHIT – European High-Performance Infrastructures in Turbulence funded by the European Commission under the 7th Framework Programme

Grant Agreement Number 312778

Work Package 24: Quality assessment of data and models

Summary

This report summarizes the achievements of the Work Package 24 during the 4 years of the EuHIT project.

The aim of the WP 24 was to confront the results obtained by facilities and numerical work, with the aim of providing means to control the quality of the data, of assessing the validity of the working hypotheses, and identifying the limits of our current understanding, and giving recommendations where further research is needed.

The teams involved in this project were MPI-DS, UTWENTE and CNRS (Lyon).

The work was organized in 4 tasks, and the present report reviews the work done to achieve the goals of these tasks. Explicit reference will be made to the three previous reports, as well as to the contractual documents (Milestones and Deliverables) already provided.

Task 1

The aim of this task was to coordinate numerical and experimental activity. One of the objectives to this end was to make available some of the top-class data obtained in particular at the MPI-DS. Some of the preliminary steps towards the achievement of this goal have been documented in the milestone MS40 and Deliverable D24.1 (data coming from high-quality particle tracking properly documented in the Deliverable D24.4, which explains in details how the data has been cross-validated with results of direct numerical simulations). The ultimate aim of Task 1 was to contribute to making available some of the top-class data available. The success of this enterprise can be judged by the amount and the quality of data now available on the database

"TurBase", available online at:
https://turbase.cineca.it/init/routes/#/logging/search_dataset/tabcate.
As explained in the deliverable D24.6 (which was added to the list, following a readjustment of the allocated funds), a wide range of data has now been added to TurBase. The wealth and the significance of this data speaks for itself.

Task 2

The objective of this task was to develop a set of recommendations to validate the data. The first draft (MS41), elaborated by CNRS in close collaboration with MPI-DS, was first presented and discussed with the other members of the consortium during the meeting in Twente (May 2014). The experience from the team in Lille, who had prior experience with making the data from their own facility available, has been particularly useful in this respect. The final document, Deliverable 24.2, provided details on the procedures discussed. The recommendations have been fully implemented with Turbase. The activities related to this task have been carried out essentially during the first reporting part of the contract.

Task 3

This task consisted in working on a set of cross validation studies between numerical and experimental data. The project listed specifically two particular cases: turbulent Taylor-Couette flow, studied both experimentally and numerically by the team in Twente, and Lagrangian data, obtained from von Karman flows in Göttingen, compared with numerical results from CNRS (Lyon). The work has been satisfactorily carried out, and the Milestone MS42, as well as Deliverables D24.3 and D24.4 have been submitted on time. Further studies were carried out, in particular between MPI-DS and CNRS (Lyon). Some of the work has benefited in particular of the possibility to use numerical data at extremely high Reynolds number resolution ($R_\lambda = 1300$). More collaborative work is still under way.

Task 4

Having invested time and effort in producing top experimental, the aim of Task 4 was to summarize recent efforts in the theoretical and modelling of turbulent flows. The work of MPI-DS and CNRS has stressed the limitations of previous approaches to the description of particle motions in turbulence, on the relation between lagrangian and eulerian properties of the motion of particles in a turbulent flow, as well as the understanding of the small-scale anisotropy in channel flows. The Deliverable D24.5, submitted after 48 months, reviewed some of the available theoretical and modelling knowledge, relevant to the understanding of some of the broad classes of flows.

An extra deliverable, D24.7, consisted in uploading to TurBase some lagrangian data from numerical simulations of turbulent geostrophic flows, in the presence of rotation and stratification. This data is expected to be helpful in understanding some of the very elementary properties of transport in a geophysical context.

List of Deliveries and Milestones

- MS41: Draft document specifying the data validation procedure: achieved on time (delivered on time; 12 months).
- D24.2: A document that defines the validation procedures: achieved on time (delivered on time; 18 months).
- MS40: Data accessible to all participating teams: achieved on time (delivered on time; 24 months)
- MS42: Comparison between experiments and simulations of Taylor-Couette flow, von Karman swirling flows. Achieved on time (delivered on time; 24 months).
- D24.3: Report “Turbulent TC flow: direct comparisons between experiments and direct numerical simulations”: achieved on time (delivered on time; 30 months).
- D24.4: Report “Comparisons Lagrangian measurements and their numerical counterparts”: achieved on time (delivered on time; 30 months).
- MS44: WP24 workshop.
- Deliverable D24.5: A report on properties of various flows widely used in experiments and the strength and limitations of their theoretical descriptions (delivered on time; 48 months).
- Deliverable D24.6: Document describing the data uploaded in the turbulence database. The report will discuss both the scientific achievements as they are recorded in the database, and also the quality of the uploaded data (48 months, delivered on time)
- Deliverable D24.7: Uploading Lagrangian particle trajectories in flows with rotation and stratification (48 months; delivered on time)

Dissemination Activities

The work resulting from the activities of Task 3 (comparison between numerical and experimental data from Taylor-Couette flows and Lagrangian data in turbulent von Karman flows) or Task 4 (model elaborations) has been presented in some of the key meetings of the community, including the Division of Fluid Mechanics of the American Physical Society (San Francisco 2014 and Boston 2015, USA), and at the European Turbulence Conference in Delft, Holland, in 2015; further presentations will be made at the meeting in Stockholm in Aug. 2017). These international meetings are highly visible by the entire scientific community.

The possibility to write an article to review the capabilities and content of the database TurBase is currently explored with the colleagues in charge of WP4.

Project meetings

The elaboration of the ideas of Task 2 has been the subject of presentations during the meeting in Twente (May 2014), and also in Grenoble (May 2015).

Some of the results of Task 3 were also discussed during the meeting in Grenoble.

Publications

J. Jucha, H. Xu, A. Pumir and E. Bodenschatz , *Time-symmetry breaking in turbulence*, Physical Review Letters, **113**, 054501 (2014).

J. Jucha, Time-symmetry breaking in Turbulent Multi-Particle Dispersion, PhD thesis, University of Göttingen (2014). Published in the series Springer Theses (2015).

A. Pumir, E. Bodenschatz and H. Xu, *Tetrahedron deformation and alignment of perceived vorticity and strain in a turbulent flow*, Phys. Fluids **25**, 035101 (2013).

A. Pumir, H. Xu, G. Boffetta, G. Falkovich and E. Bodenschatz , *Redistribution of kinetic energy in turbulent flows*, Phys. Rev. X **4**, 041006 (2014).

A. Pumir, H. Xu, E. Bodenschatz and R. Grauer, Single-particle motion and vortex stretching in three-dimensional turbulent flows, Phys. Rev. Lett., **116**, 124502 (2016).

H. Xu, A. Pumir, G. Falkovich, E. Bodenschatz, M. Shatz, H. Xia, Francois and G. Boffetta, *Flight-crash events in turbulence*, Proceedings of the National Academy of Sciences, **111**, 7558-7563 (2014)

H. Xu, A. Pumir and E. Bodenschatz , *Lagrangian view of time irreversibility of fluid turbulence*, Science China, **59**, 614702 (2016).

R. Ostilla-Mónico, E. P. van der Poel, R. Verzicco, S. Grossmann and D. Lohse, *Exploring the phase diagram of fully turbulent Taylor-Couette flow,* Journal of Fluid Mech., 761, 1-26 (2014).

R. Ostilla-Mónico, R. Verzicco, S. Grossman and D. Lohse*, The near-wall region of highly turbulent Taylor-Couette flows,* Journal of Fluid Mech. 788, 95-117, (2016).

R. Ostilla-Mónico, R. Verzicco and D. Lohse*, Turbulent Taylor-Couette flow with stationary inner cylinder,* arXiv:1604.00673 (2016).

M. Brenner, S. Hormoz and A. Pumir, *Potential singularity mechanism for the Euler equations*, Phys, Rev. Fluids 1, 084503 (2016).

A. Pumir, *Structure of the velocity gradient tensor in turbulent shear flows*, submitted (2017).

Personnel Statistics:

CNRS:

- Alain Pumir (m, scientific leader; 8.5PM).
- Jennifer Jucha (f, postdoc, paid with a Humboldt Fellowship after April 2015 3.25PM)
- Dhawal Buaria (m, postdoc, June 2016 – Jan 2017 6.5PM)
- Vishwanath Shukla (m, postdoc, May 2016- April 2017)

MPI-DS:

- Eberhard Bodenschatz (m, scientific leader)
- Haitao Xu (m, PI)
- Jennifer Jucha (f, student, until April 2015)
- Freja Nordsiek (f, postdoc since January 2016)
- John Lawson (m, postdoc)

UTWENTE

- Detlef Lohse (m, scientific leader, 3PM)
- Chao Sun (m, PI, 0.9PM)
- Rodolfo Ostilla Monico (PhD student)
- Minori Shirota (PhD student, 0.2 PM)

Task 24.1: Coordination of numerical and experimental analysis

Responsible partner: CNRSa

Collaborators: MPI-DS

Use of resources:

This task has involved permanent personnel from CNRS (4 person month) and MPI-DS (9 person months). In addition a young researcher financed by the EuHIT project has worked for 6 months in Lyon, and 1 month at MPIDS).

Task 24.2: Development of validation protocols

Responsible partner: CNRSa

Collaborators: MPI-DS

Use of resources:

This task has involved mostly permanent personnel from CNRS and MPI-DS, for an amount of approximately 4 person-months for each team.

Task 24.3: Detailed study of test cases

Responsible partner: CNRSa

Collaborators: MPI-DS, UTWENTE

Use of resources:

This task has involved mostly permanent personnel from CNRS and MPI-DS, for approximately 10 person-months for each team, and approximately 5 months of person-months in TWENTE. A young scientist has been working on the project for 6.5 months in Lyon, and 2.5 at MPI-DS.

Task 24.4: Model development

Responsible partner: CNRSa

Collaborators: MPI-DS

Use of resources:

This task has involved mostly permanent personnel from CNRS and MPI-DS, for approximately 8 person-months for each team. In addition, the success of this Task has been made possible thanks to the work of young scientists (2.5 person-months at MPI-DS and 5 at CNRS Lyon).

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Work Package 25: Particles and Fields

Summary

- Summary

WP25 aims at developing experimental methods extending the reach of Lagrangian techniques in EuHIT TNAs in order to improve possible connections with Eulerian methods and to address questions related to fundamental aspects of turbulence, mixing, turbulence-particles interactions, etc... The Work Package is structured around four main tasks and involves four laboratories in three European nations (France, Danemark and The Netherlands). The four tasks of this work-package aim at

- Developing a PT system that improves the SNR by following particle shadows instead of scattered light from the particles (task 25.1).
- Developing an ultrasonic probe that performs both vorticity measurements and three dimensional (3D) acoustic particle tracking (task 25.2).
- Developing a technique to measure simultaneously the motions of objects carried by a turbulent flow, and the surrounding flow field itself, by using a combination of 3D-PT and tomographic particle image velocimetry (task 25.3).
- Developing a reliable technique for distinguishing and tracking overlapping finite-size bubbles (task 25.4).

After two internal calls within EuHIT, additional funding was redistributed to WP25, with two additional deliverables :

- Coupled diagnosis of PTV/PIV with finite size, overlapping particles, tested with data acquired at TTF - UTWENTE.
- Protocol to 3D print an operational bubble generating nozzle

The table below gives a summarized portray of WP25.

Task	Partner	Main goals	Aimed TNAs	Milestones and Deliverables up to 36 months	Fulfilled
Shadow PT	20 DTU Risoe (Denmark)	High resolution particle tracking with shadow imaging.	GTF1& 3	**MS45** (12m) : Testing of SPT technique in atmospheric flows	✓
				MS46 (18m) : Adaptaton of SPT to GTF3	Abandoned
				D25.1 (24m) : SPT apparatus demonstrated at the MPI-DS	Abandoned
Acoustic PT	8b CNRS - LEGI (France)	Acoustic particle tracking in cryogenic and SF6 flows.	GTF1, SHREK, HeJet	**MS47** (12m) : Functioning of acoustic transducers in cryogenic conditions	✓
				MS48 (24m) : Testing of particle seeding in cryogenic flows for acoustical tracking	✓
				D25.2 (36m) : Apparatus for APT and vorticity measurement tested under cryogenic conditions at CEA-a	✓
Combined TomoPIV/PT	8a CNRS - ENS-Lyon (France)	Particle tracking with simultaneous resolution of carrier flow velocity field.	Coriolis	**MS49**(18m) : Functioning of Tomo-PIV	✓
				MS50 (24m) : Coupling Tomo-PIV with PTV	✓
				D25.3 (36m) : Apparatus for simultaneouss T-PIV/SPT tested at CNRS-b	✓

Tracking of finite size bubbles	U-Twente (The Netherlands)	Detect and track finite size overlapping bubbles.	TTF	**MS51** (24m) : Algorithms for detection and tracking of overlapped bubbles developed	✓
				D25.4 (24m) : Tracking of large overlapping bubbles implemented at Twente	✓
Coupled PTV/PIV diagnoses	CNRS - ENS de Lyon / U-Twenter	Track overlapping bubbles while resolving the flow around	TTF	D25.25 (48m)	✓
3D printing bubble generating nozzles	CNRS - ENS de Lyon & LEGI	Develop a protocol to massively 3D print bubble generators to seed large infrastructures	Wind-tunnels	D25.6 (48m)	✓

- List of Deliveries and Milestones

Milestones :

The table below recalls all the milestones of WP25. Those in light green are milestones reached during first reporting period ; those in green are milestones reached during second reporting period ; those in light orange : Milestones delayed.

Milestone number	Milestone name	Work package(s) involved	Expected date	Means of verification
MS45	Testing of SPT technique in atmospheric flows	25, task 1	12	SPT technique developed, proper operation demonstrated, performance evaluated.
MS46	Adaptation of SPT to GTF3 conditions	25, task 1	18	SPT system modified and installed in GTF3, functionality demonstrated.
MS47	Functioning of acoustic transducers under cryogenic conditions	25, task 2	12	Sensors developed, installed in appropriate facilities, and proper functioning demonstrated.

MS48	Testing of particle seeding in cryogenic flows for acoustical tracking	25, task 2	24	Seeding technique developed, tested optical probes.
MS49	Functioning of the Tomo-PIV system	25, task 3	18	The Tomo-PIV system constructed and proper operation demonstrated.
MS50	Coupling Tomo-PIV with PTV	25, task 3	24	Coupled Tomo-PIV/PTV system constructed and proper operation demonstrated.
MS51	Algorithms for detection and tracking of overlapped bubbles developed	25, task 4	24	Algorithm developed and tested at appropriate facilities, functionality demonstrated.

Deliverables :

D25.1 : SPT apparatus demonstrated at the MPI-DS: [month 24]

D25.2 : Apparatus for APT and vorticity measurement tested under cryogenic conditions at CEA-a: [month 36]

D25.3 : Apparatus for simultaneous T-PIV/SPT tested at CNRS-b: [month 36]

D25.4 : Tracking of large overlapping bubbles implemented at UTWENTE: [month 24]

Deliverable number	Deliverable name	Work package(s) involved	Expected date	Means of verification
D25.1	SPT apparatus demonstrated at the MPI-DS	25, task 1	24	Report on SPT apparatus demonstrated at the MPI-DS.
D25.2	Apparatus for APT and vorticity measurement tested under cryogenic	25, task 2	36	Report on apparatus for APT and vorticity measurement tested under cryogenic conditions.

	conditions at CEA-a			
D25.3	Apparatus for simultaneous T-PIV/SPT tested at CNRS-b	25, task 3	36	Report on simultaneous T-PIV/SPT.
D25.4	Tracking of large overlapping bubbles implemented at UTWENTE	25, task 4	24	Report on tracking of large overlapping bubbles.
D25.5	Tracking of overlapping particles + PIV of the flow around	25, task 5	48	Report on experiemtns carried in TTF - UTwente
D25.6	3D printing of bubble generating nozzles to seed large facilities	25, task 6	48	Report on the protocol to manufacture and assemble 3D printed nozzles

- Project Meetings
  - Partners meet once a year (during the annual meeting of EuHIT) to discuss progresses of their task.
- Publications

- "Multiple states in highly turbulent Taylor-Couette flow", S.G. Huisman, R.C.A. van der Veen, C. Sun, and D. Lohse, Nat. Commun. **5** (2014)
- "Stochastic dynamics of particles trapped in turbulent flows N. Machicoane, M. López-Caballero, L. Fiabane, J.-F. Pinton, M. Bourgoin, J. Burguete, and R. Volk, Phys. Rev. E **93**, 023118 (2016)

- 4 articles related to WP25 are in preparation.

- Personnel Statistics
    - Experienced researchers (incl. information m/f): 9 (m)
    - PhD students (incl. information m/f): 6 (m)
    - Other (incl. information m/f): 3 postdocs (m)

Task 25.1: Shadow Particle Tracking (SPT)

Responsible partner: DTU – Risoe, Denmark (partner 20)

Objectives :

Main objectives for this task over the first period concern the achievement of milsestones 45 and 46 :

- MS45 (month 12) : Proof of concept of SPT from tests in atmospheric flows.

- MS46 (month 18) : Adapt SPT to GTF3.

Concise overview:

As detailed in the report of the first period, the proof of concept of Shadow Particle Tracking (SPT) has been demonstrated. However the group in Risoe did not succeed in building a functional bubble generator required to seed the flow as originally planned for real scale tests of the SPT. Such tests were mandatory in order to adapt the system for a later implementation in GTF3. The lack of local resources did not allow to find a solution to this problem in the timeframe of the project. Milestone MS46 and deliverable D25.1 have been abandoned.

Use of Resources :

Only "person-months" were requested for this task which implicated for this first period 2 permanent researchers.

Task 25.2: Acoustics Particle Tracking

Responsible partner: CNRS/LEGI – Grenoble, France (partner 8b)

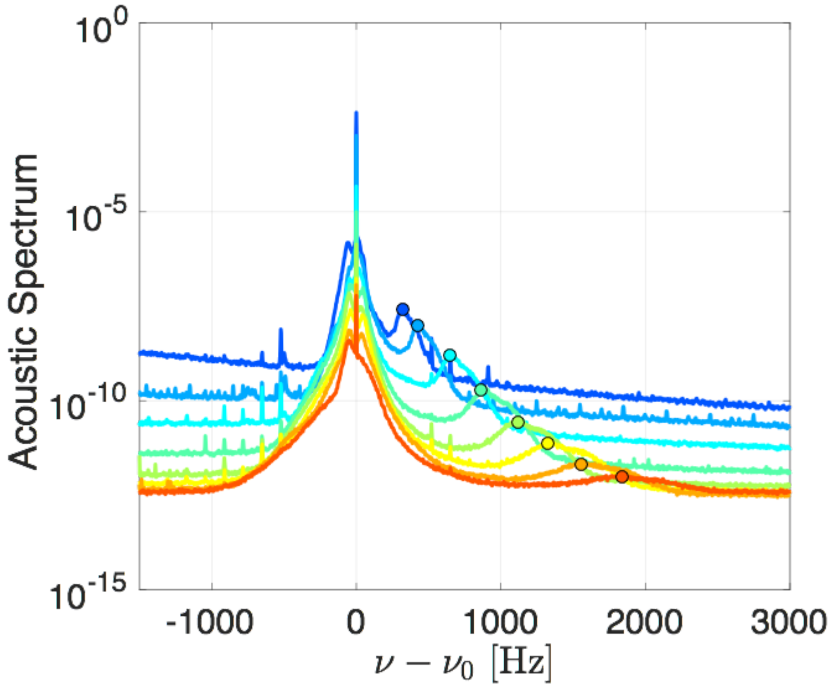
Objectives :

Main objectives for this task over the second period concern the implementation of acoustic measurements in EuHIT TNAs and testing seeding strategies for cryogenic flows :

- MS48 (month 24) : Testing of particle seeding in cryogenic flows for acoustical tracking.
- D25.2 (month 36) : Apparatus for APT and vorticity measurement tested under cryogenic conditions at CEA-a.

Concise overview:

Ultrasonic Sell-type transducers, usually used by partner 8b (CNRS / LEGI) in classical air flows to perform Acoustical Particle Tracking (APT) have been successfully tested in liquid Helium at CEA/SBT (partner 2a), both in normal fluid and superfluid. The response of the transducers indicates that they behave in the same way as in usual fluids. During previous reporting period first particle tracking measurements have also been achieved (ahead with the original schedule) in the simple configuration of



Acoustic spectrum recorded in GTF1. Different colors correspond to different mean velocity. The frequency shift of peak of the Doppler shift evolves with the mean velocity, while the amplitude of the shape of the Doppler

millimetric free falling spheres in cryogenic flows. During the second reporting period, acoustic transducers have been successfully implemented in two EuHIT TNAs : SHREK (CEA-a) and GTF1 (MPI-DS). In both facilities, acoustical signals of turbulence vorticity were successfully recorded (the fig. shows an example of spectrum of acoustic signal recorded in GTF1, the Doppler signal, in which vorticity is encoded is clearly observable). In addition, possible strategies to seed cryogenic flows using small hollow spheres (with diameter below 100 micrometers) matching the density of fluid and superfluid helium have been successfully tested.

Therefore, **MS48 has been reached and D25.2 achieved** (see corresponding reports).

<u>Use of Resources</u> :

Only "person-months" were requested for this task which has been carried by 3 permanent researcher at LEGI funded by EuHIT.

Task 25.3: Combined Tomographic PIV and Particle Tracking

Responsible partner: CNRS/ENS-Lyon – Lyon, France (partner 8a)

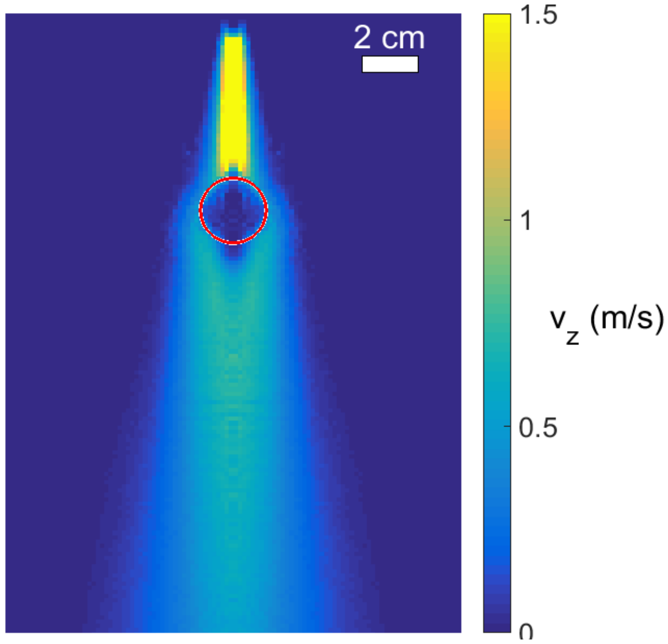
Objectives :

The main objective for this task over the first period concerns the development and the implementation at CNRS/ENS-Lyon of a Tomographic PIV technique, which could be easily coupled in the future to conventional Particle Tracking methods :

- MS50 (month 24) : Coupling Tomo-PIV with PTV.
- D25.3 (month 36) : Apparatus for simultaneous T-PIV/SPT tested at CNRS-b.

Concise overview:

During the previous reporting period partner 8a (CNRS / ENS-Lyon) has developed Tomo-PIV technique based on a short term 3D particle tracking method and a new versatile and more precise (compared to usual methods) calibration method for 3D particle stereo-matching. During these developments have been implemented, simultaneously with 3D shadow particle velocimetry (3DSPT). Tomo-PIV has been used to measure the flow (seeded with small tracers particles) around a large sphere tracked with 3D SPT transported by turbulence in a jet flow. The figure below illustrates the reconstruction of the mean flow around the sphere. This proves the concept of the coupled T-PIV/3DSPT method (see report on D25.3).



Reconstruction of the mean flow around a light sphere trapped in a downward turbulent jet. The red circle indicates the average position of the sphere.

Therefore, **MS50 has been reached on time and D25.3 achieved** (see corresponding reports).

Resources :

Only "person-months" were requested for this task which has been carried out by 2 permanent researchers at ENS-Lyon and one post-doc funded by EuHIT (one year of postdoc has been funded so far).

Task 25.4: Tracking of finite size bubbles

Responsible partner: UTwente – Enschede, The Netherlands (partner 4)

Objectives :

The objective is to detect overlapping bubbles and particles in moderately dense particle-laden flows. Since bubbles are highly deformable (see Fig. below), a prototype case of rigid light particles in a channel flow is considered in order to test different algorithms :

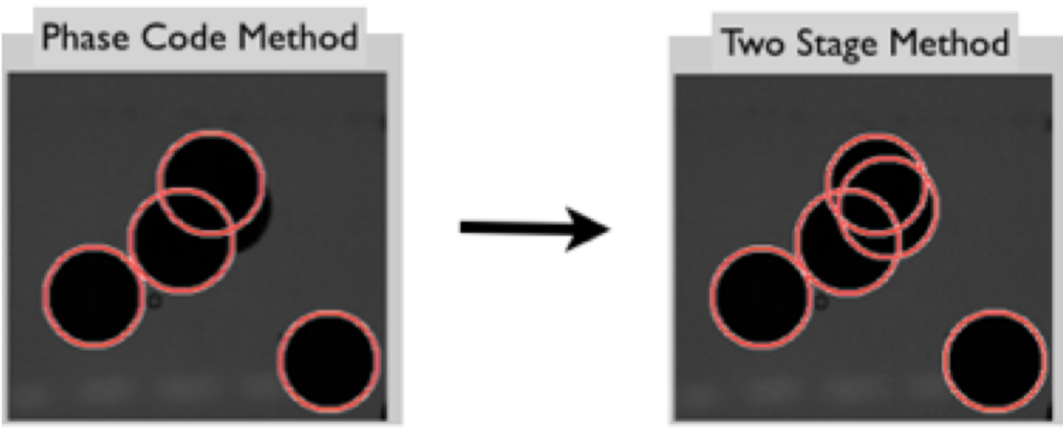
- MS51 (month 24) : Algorithms for detection and tracking of overlapped bubbles developed.

- D25.4 (month 24) : Tracking of large overlapping bubbles implemented at UTWENTE.

Concise overview:

A method for the detection of overlapping spheres has been developped. This was used in two studies on the tracking of buoyant and large spherical particles in the Twente Water Tunnel. The bubble detection method was successfully implemented by V. Prakash (*Light particles in turbulence*, University of Twente, PhD thesis, doi: 10.3990/1.9789036507240).

The future plan is to extend the method to other regular shapes (ellipses) in an overlapping situation, and finally to finite-size deformable bubbles. Besides, task 25.5 (see below) also benefited from advances from tasks 25.4 and 25.3.



Detection of overlapping particles using regular Hough-Transform (left) and with the improved two stage method (right).

Therefore, **MS51 and D25.4 are fulfilled**.

Resources :

Only "person-months" were requested for this task which has implicated 1 permanent researcher and 2 PhD students.

Task 25.5: Tracking of finite size bubbles combined to PIV of the surrounding flow

Responsible partner: CNRS - ENS de Lyon – Lyon, France (partner 8a)

Objectives :

This task aims at pushing further the deliverables of WP25 by combining two previous tasks (D25.3 and D25.4) in order to set up a metrology capable to resolve the velocity field surrounding finite size particles in turbulence, in regimes of increasing seeding concentration of particles, where particles image overlap becomes an issue.

- D25.5 (month 24) : Tracking of large overlapping bubbles combined to flow reconstruction implemented at UTWENTE.

Concise overview:

We have carried a set of experiments in the water channel (TWT) at U-Twente, in order to test the possibility to combine the PIV and detection (plus tracking) of finite-size (eventually non-spherical) overlapping particles.

The experiment was carried using the active grid in TWT to generate turbulence. The flow was seeded with two different sort of particles : (i) Small and mono disperse air bubbles with a diameter of the ordre of 1mm were massively seeded ; (ii) large poly-disperse, deformable bubbles, less massively seeded. In spite of the lower seeding of the big particles, there large dimension results in frequent an significant overlap. PIV was successfully performed on the small particles while PTV was carried on the large

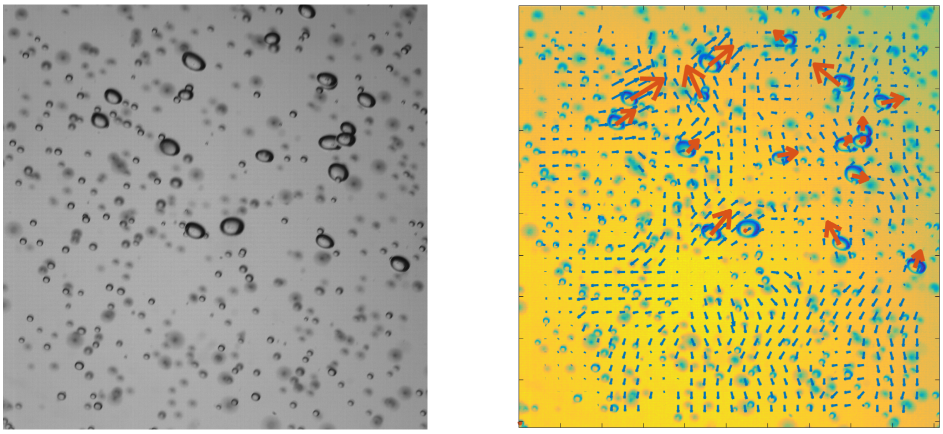


Fig. Right: Sample image of the large overlapping bubbles and small bubbles. Left: Red arrows show the Lagrangian velocity of the large bubbles, from PTV. Blue

overlapping particles (see Fig. below).

Therefore, **D25.5 is fulfilled**.

Resources :

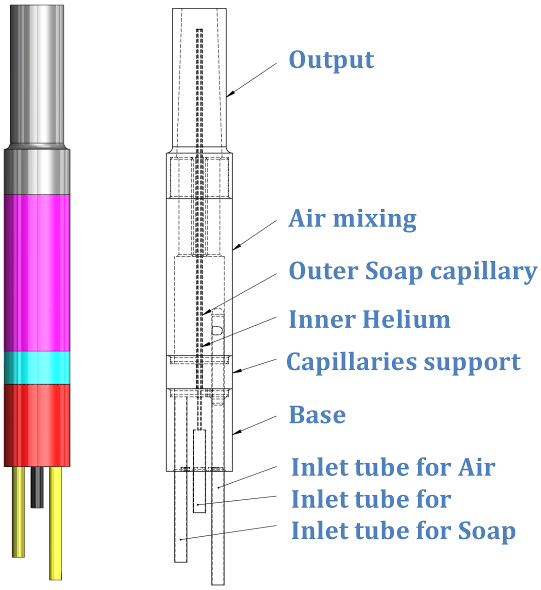
Only "person-months" were requested for this task which has implicated 2 permanent researcher and 1 Post-Doc and 2 PhD students.

Task 25.6: 3D Printing of bubble generators to seed large infrastructures

Objectives : This task aims at providing a versatile particle seeding system for a variety of flows (primarily in air, but possibly also in other gases, as SF6), by means of a generator of soap bubbles with adjustable size, density and production rate.

Concise overview:

Soap bubbles have been used by several groups involved in EuHIT, and in particular by LEGI (Grenoble, CNRS partner 8b) who designed such a nozzle, capable to produce highly mono-disperse bubbles (filled with any gas, in particular with Helium, for neutrally buoyant particles), with adjustable diameter and density, and high production rate. However, manufacturing the bubble generating nozzle requires complex and sophisticated machining, what limits both, the quantity of nozzles which can be reasonably manufactured and our capacity to test different nozzle designs to better tune the range of accessible sizes, densities, bubble generation rate, etc.. In this project we want to take benefit of new 3D printing technologies to systematically design and produce bubble generating nozzles. The use of 3D printing technology will make the systematic production of the nozzles simple and affordable, hence allowing to customize the geometry of the nozzle and also allowing to easily produce numerous identical nozzles, in order to make arrays of nozzles, for a better control of seeding concentration and homogeneity. Aimed TNAs of this task are all the facilities where such bubbles could be used to seed/trace the flow (Lille wind-tunnel, Cyclope, Ilmenau barrel, possibly Gottingen SF6 wind-tunnel).



Drawing of the developed 3D printed soap bubble

We have developed a protocol for 3D printing such nozzles. Due to limitations of the spatial resolution of 3D printers, hybrid nozzles were printed, with main body actually 3D printed into which small metallic capillaries (carrying the soap and the inflating gas) are inserted. Fig. below shows the final design of the nozzle. The full protocol description is provided in a separate report.

The developed nozzle produces bubbles with diameter adjustable between 2 and 6mm. The design can be downsized (within printing resolution limits) to produce smaller bubbles. The shape of the main body and geometry of inlets can also be customized for specific usage. The production cost of the nozzle is marginal (a few tens of euros).