Proposal full title

European High-performance Infrastructures in Turbulence

Proposal acronym

EuHIT

Type of funding scheme:
Combination of Collaborative Projects and Coordination and Support Actions for Integrating Activities

Work programme topics addressed:
INFRA-2012-1.1.20
Infrastructures for studying turbulence phenomena and applications.

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1 Scientific and/or technical quality, relevant to the topics addressed by the call

1.1 Concept and objectives

Advances in key economical and societal issues facing Europe, like ground-, air- and sea-transport, energy generation and delivery, processing in chemical industries, marine biosphere management, climate change impact, atmospheric and marine pollution prediction, and carbon capture and storage processes are obstructed by the lack of understanding of turbulence. The reason lies in the fact that turbulent flows underlie all macroscopic natural and technological flows as soon as mass transport is large.

Turbulence has been a topic of deep scientific inquiry since the first half of the 20th century, when Burgers (NL), Eiffel (F), Prandtl (D), Richardson (UK), Reynolds (UK), Taylor (UK), von Kàrmàn (D, USA), Dryden (USA), Weizsäcker (D) and many others began to realize the importance of turbulence inception, turbulent mass and momentum transport, and turbulent structure formation. It was understood that without the detailed knowledge of turbulence with its cascade of instabilities and large fluctuations, it is hopeless to capture the full dynamics of geophysical, astrophysical, and technological phenomena. It was realized that engineering requires the optimal use of turbulence for process efficiency and control.

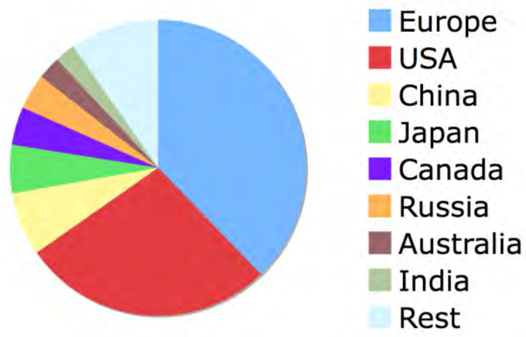


Figure 1: Contribution of countries to the ISI recorded publications that have "turbulence" or "turbulent" as topic (from 2000-2011 total 80,599 hits).

Progress has been disappointingly slow. To a great extend this belies the fact that the full resolution measurements of the 3D flow fields, concentration fields, temperature fields, etc. has been impossible until very recently. Technological breakthroughs over the past 10 years in CMOS imaging, high-power lasers and LEDs, electronic integration, computing, data handling, electronic control, and nano-fabrication have for the first time enabled the creation of world-leading turbulence infrastructures that provide the tools that researchers could not even have imagined 15 years ago.

Analysis shows that Europe is leading the world in turbulence research. In the past 10 years it has surpassed all other nations in research output and development of national infrastructures. However, due to a lack of European wide integration it has not reached its full potential for innovation in the sciences and technologies. The creation of the **European High-performance Infrastructures in Turbulence (EuHIT)** shall overcome these limitations and shall very significantly advance the competitive edge of European turbulence research with special focus on providing the knowledge for technological innovation and for addressing grand societal challenges.

Turbulence occurs whenever fluid viscous forces are small compared to the dominant driving forces in the fluid. Mixing and transport in fluids is dominated by the huge fluctuations of turbulence ranging from the scale where energy is injected (which could be hundreds of meters) to the scale where energy is dissipated by viscosity (which could be microns). Statistical theories and first principle numerical simulations are successful in capturing some general and idealized properties of turbulence. Nevertheless, our knowledge remains insufficient for solving real-world turbulence problems. Research and development still needs to rely on trial and error techniques and experience, rather than on true process engineering, design and quantitative understanding. Experiments constitute for years to come the main tool in the quantitative investigation of real-world turbulent flows. The flow complexity of natural, environmental and technical flows is by orders of magnitude higher than the capacity of the most advanced first principle computations.

What are the main ideas that led us to propose the integrated activity EuHIT?

For the first time in history, it is now possible to measure with high resolution from the largest to the smallest scales not only the spatial, but also the temporal properties of highly turbulent flows. It is becoming common for experimental runs to produce terabytes of raw data, which need to be stored and analyzed. This requires huge investments in both the measurement equipment and the associated computational resources often reaching M€s.

The need for a better understanding of turbulence has led several European countries to found new large-scale turbulence infrastructures, unsurpassed in flow properties and measurement technologies. To achieve the suitable flows with appropriate velocities and temperature differences and the associated ranges of spatial and temporal scales, these facilities use cryogenic He, pressurized gases, and water. Currently these are not easily accessible to the larger European scientific community; in fact, most of them are only accessible within university programs or national research institutions. End of 2006 the International Collaboration for Turbulence Research (ITCR.eu) was created and now has partners from all around the world. It was born out of the realization that the much-needed progress in turbulence requires going beyond the financial, technical, and personnel capabilities of a single researcher, a single research group, and single nation. Already then it was clear that progress in turbulence and its many applications warrants a joint, cross-disciplinary, approach both in attacking the science, but also in optimizing the investment into human and infrastructure resources. Partners from ICTR have published in the past 5 years under its affiliation more than 80 publications in the leading journals of the field. ICTR and a prior proposal to the I3 competition were the nucleus for the COST Action MP0806 “Particles in Turbulence” (19/05/2009-18/05/2013). MP0806 has 22 participating European States and four non-COST institutions from the USA, Russia and India. With its 190 members it has become a very important tool to advance turbulence research on particles.

As a result of these initiatives across Europe a vibrant turbulence community of young and senior investigators from Engineering, Physics, and Mathematics has been established. Overall, according to ISI 80,599 papers with topic “turbulence” or “turbulent” were published from 2000-2011. Figure 1 shows their geographic distribution. Measured by involvement into the scientific innovation, as measured by publications, Europe is leading the world. This has been accomplished mostly by huge national investment. We shall argue here that the true potential for a leadership role in the innovation of turbulence as it applies to science and technology can only be optimised and sustained by an integrated approach that brings together the key European facilities addressing the turbulence phenomena in various areas of science and technology. The consistent world-class eco-system of research infrastructures proposed here will enable researchers with the much needed fundamental knowledge to create innovative products, processes and services in ground-, air- and sea-transport, energy generation and delivery, industrial processing in chemical industries, marine biosphere management, climate change impact, atmospheric and marine pollution prediction, and carbon capture and storage processes. Please let us emphasize this proposal can provide the first-ever, integrated infrastructure and approach to turbulence research and its applications.

What is the concept of EuHIT?

The creation of the **European High-performance Infrastructure in Turbulence (EuHIT)** has it’s origins in the foundation of ICTR, the subsequent creation of the COST action, and now as a next step in this proposal. In 2008, our earlier I3-proposal was the first-ever international initiative to take an integrated approach towards Research Infrastructures (RI). The proposal received high marks, but was not successful due to limited funding capacities of the EU and some minor issues that are fully addressed here. In the 3 years since submission, turbulence research in Europe has significantly strengthened. This is documented by the additional 6 cutting edge infrastructures proposed here. This EuHIT proposal answers all aspects of the current call:

INFRA-2012-1.1.20. Infrastructures for studying turbulence phenomena and applications. *There is a need for detailed understanding of turbulence phenomena. A project under this topic should aim at bringing together key facilities addressing the turbulence phenomena in various areas of science and technology. A combination of modelling and experimental in situ testing is needed.*

In a competitive process that was advertised all over Europe fourteen key research facilities in various areas of science and technology were selected to provide the ideal foundation for experimental in situ testing of modelling results. The thirteen research infrastructures and one service activity open their facilities for trans-national access to the large European community of researchers from the fields of aerospace (1), chemical (2), biological (3), environmental (4), mechanical (5), and electrical engineering (6), meteorology (7), atmospheric sciences (8), oceanography (9), and astro- (10), condensed matter (11), geo- (12), and plasma physics (13).

The RIs are to provide access to turbulence infrastructures equipped with the best research tools for the investigation of

- boundary layer flows, transition to turbulence and fully developed turbulence. (1-6,10,11,13)
- statistical properties as a function of turbulence level. (1-13)
- turbulent convection and heat transport. (2-13)
- mixing and dispersion in turbulent flows. (1-12)
- rotating flows. (1-10,12,13)
- inertial and large particle dynamics in turbulent flows. (2-4,7-13)
- turbulence in multiphase flows and complex fluids. (1,2,4-13)
- quantum turbulence. (6,10,11)

To foster a culture of co-operation inside of EuHIT and with the community of European turbulence researchers from academia and industry a **networking program (Net)** is proposed. Net will optimize the efficient use of resources, provide common databases and dissemination of knowledge, define good practices, train researchers in the most modern equipment and data analysis techniques, ensure innovation through integration of researchers from industries, and promote long-term sustainability. EuHIT is made complete by **joint research activities (JRA)** that will innovate, explore, and improve the technologies, and thereby will optimize the Research Infrastructures (RIs) for the users. Important deliverables are the development of innovative measurement techniques together with industry, implementation of controlled turbulence generation, creation of much needed sensors for cryogenic applications, development of innovative optical particle tracking technologies, fabrication of nano-machined sensors. A very important component is the assessment of the quality of data and models by in situ testing. With its advanced measurement technologies, the associated collective know-how, and its links to companies that drive innovation, EuHIT promises a large impact on the future of R&D in Europe and the world.

What are in detail the overall and quantifiable objectives of EuHIT?

Objective	Success Indicators	Relation to call
Increase the relevance of world-class turbulence RIs to enable ground-breaking research and innovation; optimize, ease, and foster access for researchers from academia and industry; bring the RIs to the attention of users.	# of user requests and access provided; quality ratings of proposals; # of training units given; evaluations from academic and industrial users; Scientific Advisory Board (SAB) evaluations.	Increase the potential for innovation of RI; optimize the use of existing RIs; support regional and EU economic development; boost EU research potential; reinforce EU research communities.

Provide free access to the knowledgebase for turbulence data (turBase); ensure stable and highest quality service; provide knowledge support, optimal data use, download, and upload capabilities, ensure editorial process of the knowledge-base.	# of knowledge-sets, logins, data access, data porting, consulting units; geographical distribution; user evaluations; hits to turBase; up/download statistics; SAB evaluations.	RI operation; transfer of knowledge; harmonise and organise the continuous flux of data collected or produced by the RIs, efficient curation, preservation and provision of access to the data, internal and external user interaction;
Provide a networking structure fostering a culture of co-op through science management, comm. tools, diss. of knowledge, good practice, training, human resource dev; provide harmonised and enhanced interfaces.	workshop participant # and evaluations; internal report review; quality and # publications.; # of invited talks; geographical distribution; personnel exchanges; SAB evaluations.	Foster the culture of cooperation; service enhancement; internal and external dissemination; exploitation of results, building a community of users.
Innovate in enabling technologies and though integration; partnering with industry in instrument development; attract industry to the RIs and the turBase; ensure advice by innovation leaders; connect to leading industries.	Joined instrument development; # of patents; add. funds for RI development; # of workshop and training participation by industrial researchers; industry particioation in SAB.	Bring together research and innovation to address major challenges; construction of an efficient research and innovation environment; integration into a virtual community.
Enable the evaluation of data qulaity; innovative instrumentation for the joint use at the RIs,also portable to general R&D, implementation of controlled turbulence generation, develop a quality assessment for data and models; enabling instrumentation; opening new directions.	Level of standardization; novel cryo- or nano sensors, progress in optical particle tracking techniques; novel active grids for turbulence generation; establishment of a quality assessment, new vision tools; intelligent particles; quality assessment to models.	Optimise the use and development of existing RIs; development of advanced technologies; improved services; optimization of resources, higher performance methodologies, protocols and instrumentation.

State-of-the-art

Natural and technical turbulent flows can cover about 5 orders of magnitude of fluid motions (for example for laboratory flows from micro-meters to meters and from fractions of milliseconds to 10s of minutes). Since the days of Reynolds and Rayleigh fluid mechanics, engineers, mathematicians, and physicists laboured on understanding the many aspects of turbulence as they appear in nature and in engineering applications. Seminal approaches (pioneered by Prandtl, von Kármán, Kolmogorov, Onsager, von Weizsäcker, Heisenberg, Obukhov, Yaglom, Taylor, Batchelor, Kraichnan and others) have classified these motions into dissipative scales (smallest), inertial range (where self-similarity laws are expected to hold) and integral scales (largest, where the details of the flow generation are prominent). It was understood that the nonlinearities of fluid mechanics tend to isotropize the flow as the scale of observation becomes smaller. This supported the idealized assumption of statistically homogeneous and isotropic turbulence that is at the basis of impressive theoretical progress. However, this approach does not do justice to the true physics of real-world turbulence that includes shear, difference in turbulence generation mechanisms, and other issues involving anisotropy and inhomogeneity. The situation is even more complex for multiphase and particle-laden flows and flows in complex and quantum fluids. These issues become prevalent in fundamental and very applied situations.

Recent progress in the field shows that the century old *Ansatz* of scale separation may not be sufficient to describe the relevant properties of real turbulence at the various levels observed on

Earth and elsewhere. Indeed, the non-locality of the pressure gradient term in the fluid dynamics equations implies that in principle all scales of fluid motions need to be treated as a whole. Over the past five years, these issues have become an area of very active theoretical and experimental research, as is evidenced by recent reviews in Annual Reviews of Fluid Mechanics (***2011*****:** 1. G. Boffetta & R. Ecke; 2. T. Mullin; 3. C. Meneveau; 4. A. Smits et al. ***2010:*** *1.* S. Balachandar & J. Eaton; 2. J. Wallace & P. Vukoslavčević; 3. D. Lohse & K. Xia; 4. A. Woods; 5. R. Klein; 6. M. Miesch & J. Toomre. ***2009:*** 1. F. Toschi & E. Bodenschatz; 2. J. Salazar & L. Collins. A. Guha et al. (**2008**), B. Eckhardt et al. (**2007**), H. Pitsch (**2006**)).

Thus, a thorough understanding of the coupling between scales and of the exact role of the intense fluctuations observed is a major challenge in turbulence research. To simulate large-scale flows in practical applications (like wind power, or aircraft wing design), numerical schemes have been devised, in which the small scales are replaced by so-called sub-grid models. However, they fail to capture many decisive features of turbulence found in experiment and applications, the separation of a turbulent boundary layer over a wind-turbine blade being just one example. At the same time, for the years to come *ab initio* (direct) numerical simulations will not be able to simulate the full complexity of real turbulent flows and experiments will remain the most important tool at higher turbulence levels to test theoretical models and parameterizations.

The experimental techniques have rapidly progressed and they now begin to allow a scale resolving and integrated approach to study the evolution of quantities that are carried by fluid flows, e.g., dispersion, mixing, transport, particle fluid interaction as applied for example to cloud micro dynamics or other complex mixing flows or geophysical flows in oceans. This new development has led national research institutions in Europe to invest M€s into the building of the infrastructures that are to be the foundations of EuHIT. Extremely high Reynolds and Rayleigh number flows and flows tailored for specific tasks are now available. Hence, the state-of-the-art of turbulence research is represented by high-level infrastructures that span from ideal turbulence over inhomogeneous anisotropic conditions that one meets in natural or engineering situations to turbulence in multiphase flows, quantum liquids, and rotating flows found in geo- and astrophysical situations. Finally, data analysis tools are coming of age and allow direct confrontation of experiments and simulations with models from the rapidly advancing field of theoretical analysis.

1.2 Progress beyond the state-of-the-art

The progress beyond state-of-the-art lies in a strategic, targeted, cross-disciplinary approach to solving the issues laid down above. This can only be achieved by breaking down national and institutional barriers and by opening the best and complimentary infrastructures and their tools to all researchers in Europe and associated states. The call by the European Union for the establishment of infrastructures networks has given the international community of researchers the opportunity to join efforts, to collaboratively design and select, and to create in a democratic and collaborative manner a consortium providing the much needed trans-national access to European turbulence researchers. The present state-of-the art provides all necessary pieces that individually are useful, but only effective when conducted in concert and supported by common aims, tools and networking. The pieces need to be matched and glued together. Only this provides an optimal environment for turbulence research in Europe– **this is EuHIT**. The individual pieces of EuHIT are the 14 cutting-edge infrastructures providing trans-national access, the data service activity, the 7 joint research activities with 27 research laboratories and 2 industrial partners developing novel measurement technology, and the three networking activities providing the glue, i.e., synergy development, culture building, training and teaching, innovation enablement through integration, and knowledge-base creation.

To illustrate what the impact of EuHIT could be, we give here an exemplary illustration in the field of meteorology (more, see chapter 3). Any adaptation and mitigation strategies for climate-change impacts, including both long-term trends and short-term effects, will depend crucially on our ability to predict changes within the hydrological cycle, including the very difficult area of quantitative precipitation forecasting. This places clear emphasis on the necessity to develop first-principles-based, quantitative models for cloud and precipitation development, to replace the semi-empirical methods currently in use. As described by Bodenschatz et al. in Science 327(2010) the physical processes in the turbulent atmospheric boundary layer occurring below the scales currently simulated (<100 m) must be captured in the form of relatively simple physics-based models in order to be incorporated into efficient cloud-scale computational models. Processes to understand include (i) the impact of turbulence on particle sedimentation, particle collision, and particle pair dispersion, (ii) turbulent thermal convection, (iii) turbulent boundary layer flows and their impact on aerosol transport, (iv) turbulent mixing and entrainment, (v) turbulent multiphase flows, and (vi) impact of coherent structures. Until very recently, laboratory experiments did not achieve atmospheric turbulence levels nor did the necessary measurement tools exist. For the first time in history, the combination of trans-national access activities and service offered by EuHIT will provide the necessary infrastructure for researchers from meteorology to address these issues. It shall be further enhanced, for example, by the proposed technological imaging innovation developed by Vision Research Inc. Europe.

Below we first summarize the networking program. We then describe the Research Infrastructures (RIs), and close with explaining how the Joint Research Activities (JRAs) are necessary to ensure innovation in technology at the research infrastructures and other applications in the technology market.

1.2.1 Networking activities

Networking – synergy – communication – integration - innovation

The three work-packages of the EuHIT networking actions are the main bonding agents between the programs of trans-national access to infrastructures, the technology development by the Joint Research Activities, and inclusion of and communication between academia and industry. They are designed to ensure synergy development, partner building inside and with industry, innovation through integration, knowledge transfer and knowledge/data capture, as well as improved performance and access to the trans-national access infrastructures.

WP2a: Synergy and communication provides the structuring elements necessary for an effective communication and dissemination within and outside of EuHIT. It shall establish a stable, tightly integrated community by providing through a web-portal a combination of modern communication tools adapted to favor the stabilization of a culture of synergic cooperation and an effective communication with the users of the trans-national access infrastructures. The web-portal will include the knowledge-base turBase that combines high quality data with the knowledge from ScholarTurb. WP2a will provide rapid and efficient communication and dissemination of all matters of science and technology within EuHIT. WP2a will structure and support the communications between different activities and between the potential users from academia and industry, and the funders. It will also provide the information gathering and reporting necessary to trigger timely actions of the governing bodies of EuHIT and the specific actions of scientific and external dissemination. An important task of WP2a is the management of the optimized trans-national access to the EuHIT infrastructures.

WP2b: Innovation through Integration has the fundamental task of creating a vibrant and sustainable community of European turbulence researchers by integrating industrial R&D through outreach, communication, training, workshops, and schools and thus instigating innovation in industries employing aerospace, chemical, biological, environmental, mechanical, and electrical engineering. It will integrate all stakeholders (from industry, academia, and government) in the optimal use of the Europe-wide turbulence facilities. Through setting up a user friendly high level "webpedia" on turbulence (**ScholarTurb**) within the web-portal, it will provide online, up to date and reliable information on the most recent developments in turbulence theory, modelling and experiment. We expect the impact of ScholarTurb to extend well beyond the lifetime of EuHIT.

WP3: TurBase: Establishing a virtual turbulence research community. The development of a culture of cooperation between research infrastructures in the turbulence research community will be further fostered through the creation of **TurBase**, an easily accessible knowledge-base infrastructure for high quality turbulence data. TurBase will require 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 will be the backbone of the EuHIT integrated activity, which is going to greatly facilitate the scientific objectives of the research infrastructures, as well as their mutual interactions. The activity will produce 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 will contribute 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 practises' and deployment of standardized data will promote clustering of new research initiatives helping the growth of a wider community in the European area. We expect the impact of TurBase to extend well beyond the lifetime of EuHIT.

1.2.2 Transnational access activities and/or service activities

EuHIT establishes the first ever trans-national access to turbulence infrastructures in Europe. It has a total of 14 trans-national access research infrastructures (TNA) and one service activity providing user access in support of the main issues in turbulence described in 1.1. The research infrastructures and the turbulence database service are summarized briefly:

Infrastructure	Description	Uniqueness
Göttingen Turbulence Facilities (GTF), Göttingen, DE, since Feb 2008.	GTF1: Turbulence tunnel 1.8 m dia. 18 m long, very high Re ~$5x10^7$ with active grid. GTF2: Thermal convection Ra ~ 10^{15}, versatile for modified inserts. SF_6 or other gasses at 19 bar – adjustable properties. GTF3: Karman Swirling flow using water or complex fluids. Instruments: 3D Particle Tracking, Tomo PIV, LDV, PDPA, nano fabricated hotwires, oil particle generators, active grid, high power pulsed lasers, temperature sensors.	Free stream turbulence in closed flows. Ideal for study of turbulence at very high Re and Ra. Particle dynamics in simple and complex fluids. Highest Re and Ra at room temperature. Versatile installations possible. Accessible down to 1mbar for astrophysics applications.
Grenoble Helium Infrastructures (GHI), Geneva, CERN, since 2009.	SHREK: He cryostat at 1.6 K, pipe with Re~$2x10^7$ von Karman mixer up to Re~10^8, HeJet: He jet at 1.6 K, Re~$4x10^5$, Instrumentation: temperature sensors, miniature Pitot tubes, second sound probes.	Jet and pipe flows with ultra high Re, both superfluid and normal turbulence measurements possible in the same experiment.
Barrel of Ilmenau (BOI), Ilmenau, DE, since 2001.	Turbulent thermal convection in air (7.0m x 6.3m). Instruments: LDV, PIV, PTV, ultra-small temperature probes, infrared camera.	Rayleigh-Bènard experiment with unrivalled spatial and temporal resolution.
Twente Turbulence facility (TTF), Enschede, NL, TWT: since 2007. T3C: since 2010.	TWT: Active grid generated high Re turbulence for bubbly and light particle flows T3C: Single and two-phase turbulent Taylor-Couette flows Instruments: 3D PTV, 3D-PIV, LDA, optical probes, hot-film anemometry.	Two-phase flow, active grid generated turbulence, TC flow in an unexplored parameter range at very high Re.

CICLoPE Bologna, IT, starting Jan. 2014.	Precision long pipe (0.9 m⌀, 120 m long) devised to study boundary ("naturally") generated turbulence at high Reynolds numbers. All turbulent scales fully resolvable.	Long Pipe. Ideal for the investigation of transition to turbulence and boundary driven turbulence.
High Rayleigh number Cryogenic facility (HRCF) Trieste, IT, since Dec. 2003.	Cryogenic He at 4-6 K. Convection with world-record Ra ~ 10^{17}. Rotation up to 60 rpm Ta ~ 10^{15}. Instruments: liquid helium PIV, non-intrusive light scattering and fluorescence techniques	Convective turbulence with highest Ra with and without rotation. Low temperature PIV and optical access.
CERN Cryogenic Turbulence facility (GReC), Geneva, CERN, since 2000.	Axisymmetric jet with Re~$2x10^7$ Instruments: movable, fast response, hot and cold wire anemometry, acoustic scattering.	Jet flow with ultra high Re, movable, fast response, hot and cold wire anemometry to resolve Kolmogorov length.
CORIOLIS rotating platform Grenoble, FR, starting mid 2013.	Rotating platform with a tank 13 m in diameter and 1.2 m in height, Instruments: time-resolved PIV, ultrasonic velocimeter, temperature and salinity sensors	Unique installation for the study of turbulence influenced by rotation and/or density stratification,
LML boundary layer wind tunnel Lille, FR, since 1993.	Wind tunnel 20m long, transparent test section, 5 m long, up to 10m/s free stream velocity, Re~$4x10^5$ Instruments: stereo and Tomo PIV, hot-wire anemometry	High Re number turbulent boundary layer, resolvable over all scales, unique optical access
Czech Cryogenic Turbulence Facility (CCTF) Prague, CZ, since 2011.	CCTF 1: low temperature He cryostat at 1.1 K with opt access for PIV/PTV measurement CCTF 2: He II quantum turbulence facility CCTF 3: He cryostat for Rayleigh-Bénard convection, Ra~10^{15}	Liquid and superfluidic Helium flows can be studied, Rayleig-Bénard convection under Boussinesq-conditions
Refractive Index Matched Tunnel (RIMT) Nürnberg, D, since 2000.	Index matched tunnel, 0.6 m x 0.45 m x 2.5 m, Flow speed: 0-4.8 m/s, Turb. intensity:<0.1%, Instruments: 3 component LDA, PIV, Stereo PIV, hot-film sensors	Near wall measurements with optical measurement technique are possible, inserted structures and be invisible,
Cottbus Geophysics Experiments (CoGeoF) Cottbus, D, since 2004.	CoGeoF1: Baroclinic Wave Tank,10^4<Ta<10^{11} CoGeoF2: Inertial wave tank, CoGeoF3: Taylor-Couette-System CoLaPipeF: highly turbulent pipe flow, Re~10^6	Various rotating turbulence experiments in fluids, one pipe flow experiment, full set of flow measurement technique for geophysical flows.

Turin Rotating Platform (TurLab) Torino, IT, since 2005.	Rotating platform 5 m diameter and 1 m depth, rotation rate up to $0.3s^{-1}$, can be filled with water and density stratified Instruments: PIV, PTV	Study of turbulence in presence of rotation and stratification. Ideal for oceanographic studies.
CINECA-DLTD Bologna, IT, since 2006.	World's largest databases freely available to the European turbulence community, easily accessible through communication networks.	Turbulence database service

1.2.3 Joint research activities

Improvements of services at the infrastructures and innovative technologies

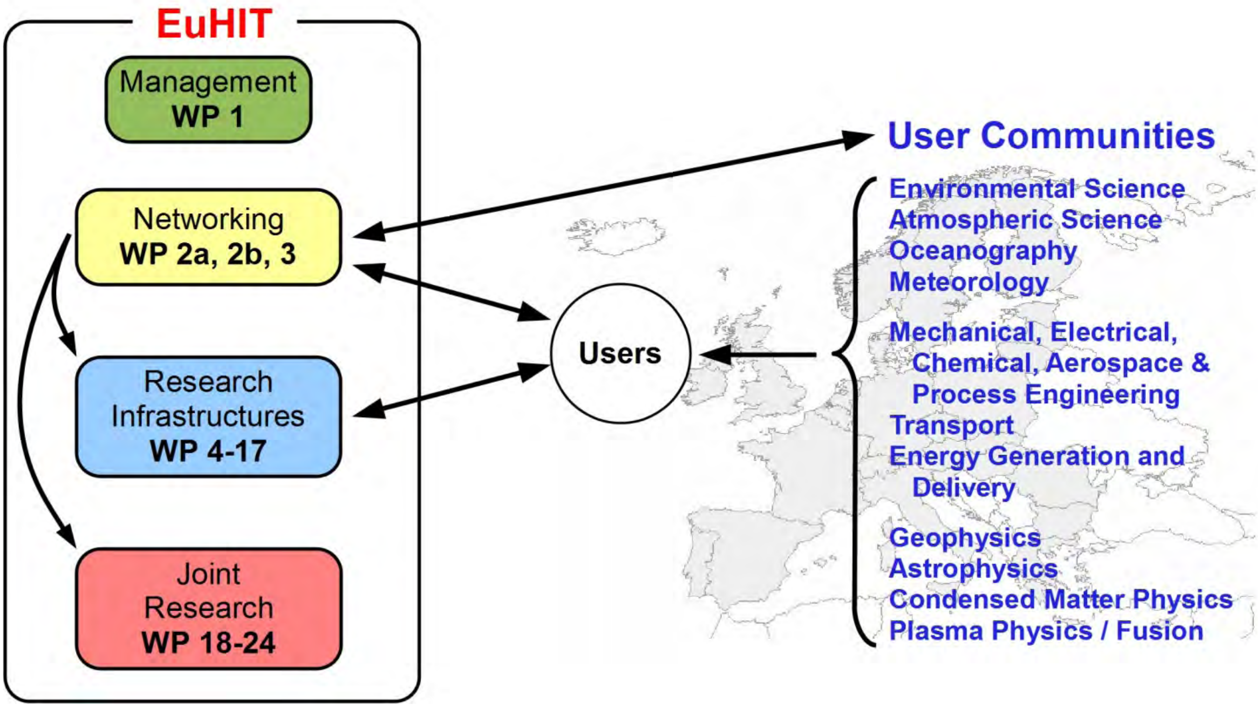
The joint research activities will provide the trans-national access infrastructures with the most advanced technological innovations. They will optimize access and service and thus ensure the technological advantage for European innovation in turbulence and its applications. They are summarized below:

Activity	Objective	Means	Service
W18 Next generation innovative instrumentation	Develop innovative research instrumentation for EuHIT facilities and R&D departments worldwide by teaming commercial R&D with academic participants.	Develop electronics to allow real-time processing of images. Develop a smart particle that is carried by the flow and measures fluid and flow properties. Develop a laser-cantilever probe to measure 3D fluid velocities at high resolution.	GTF, GHI, BOI, TTF, CCICLoPE, HRCF, GReC, Coriolis, LML,CCTF, RINT, CoGeoF, TurLab.
W19 Turbulence generation	Improve the means turbulence is generated and controlled at the facilities to replicate flows found in nature and industrial settings.	Develop new algorithms for active grids for high Re, large-scale intermittency, and flow around objects. Develop multi-scale fractal grids and propellers for high Re and desired mean flow profiles	GTF, GHI, RINT.
W20 Cryogenic measurement technologies	Develop customizable velocity and temp. probes. Support users in the customization of cold and hot wire probes. Develop anemometer array to probe I velocity correlations in super-fluid flows.	Production of end-user-customizable millimeter-resolution Pitot tubes and thermometers. Develop thin-film thermometry by nanofabrication. Develop a heat-flux advection probe for convection experiments. Develop cantilever array for measurements of flow velocities in superfluids.	GTF, GHI, BOI HRCF, GReC, CCTF.

W21 Lagrangian measurement of turbulence with strong mean flows	Develop 3D particle tracking systems for measurements in situations with fast mean-flows.	Develop systems that translate the particle tracking units; for automated alignment / focusing / calibration; for data/storage; illumination. Develop calibration and error analysis software.	GTF, BOI, TTF, CCICLoPE, Coriolis, LML, RINT.
W22 Advanced Eulerian measurement techniques	Develop nanofabricated probes for velocity measurements and electronics with high dynamic range. Provide PIV/LIF system for stratified flows.	Develop hot-film sensor, micro-fabrication, calibration mythology, and testing. Conduct simulations of the flow around the sensors for probe assessment. Develop high fidelity electronics. Build PIV/LIF system for stratified flows.	GTF, GHI, BOI, TTF, CCICLoPE, HRCF, GReC, Coriolis, LML, RINT, CoGeoF, TurLab.
W23 Quality assessment of data and models	To confront systematically experimental data with numerical and modelling results. Develop quality control and quantifiers. Indentify limits of current understanding.	Develop working groups for fast exchanges between facilities and groups specialized in simulation and modelling. Develop validation protocols for critical comparison of data with modelling results and predictions. Develop joint numerical and theoretical effort to respond to unexpected experimental results.	All research infrastructures.
W24 Particles and Fields	Advance Lagrangian measurement technology. Develop simultaneous Eulerian and Lagrangian measurement system. Improve ultrasonic vorticity and particle tracking measurement system.	Increase SNR of particle tracking systems by shadow imaging. Combine 3D-PTV with tomographic PIV. Develop identification technique for tracking overlapping finite-size bubbles. Advance realtime processing PTV-system. Develop 3D ultrasonic vortcity/particle tracking.	GTF, GHI, BOI, TTF, GReC, Coriolis, LML, RINT, CoGeoF, TurLab.

1.3 S/T methodology and associated work plan

1.3.1 Overall strategy of the work plan



As shown schematically in Figure 2, the S/T methodology and the associated work plan are strategically integrated through four types of activity: (i) management (WP1), (ii) the trans-national access to research Infrastructures (WP4-17), (iii) joint research (WP 18-24) and (iv) networking (WP2a,b,3).

The responsibility of the research infrastructures and of the management is to guarantee that EuHIT provides efficient and optimal access and service to the user communities depicted in Figure 2. WP 2 (a: Synergy and communication and b: Innovation through Integration) is the structuring work package for setting up a truly integrated network and to provide it with standardized and up-to-date tools via the EuHIT Web-portal that integrates knowledge and data through ScholarTurb and TurBase. The latter is developed by WP3. The Joint Research Activities explore innovative technologies and provide new measurement and analysis tools for the RIs (WP18-24) and promise to innovate R&D well beyond this project.

When designing the management structure of EuHIT great care was taken to leave the responsibilities for each WP with the respective leaders. Checks and balances are put into place, which enable a transparent science management at all levels. Yearly meetings of the Consortium partners including a site visit of the Scientific Advisory Board will optimize the communication within the project. Workshops, schools and other services will establish and strengthen the interaction of EuHIT with the community of potential users. The Steering Committee (SC) will guarantee the execution of the project as a whole. To this end, well-defined milestones at strategic positions and the list of deliverables are provided (described in detail under risk management at the end of Section 1.3).

Work package 1: Management of the Consortium

Work package number	1	**Start date or starting event:**	Month 1
Work package title	Management of the Consortium		
Activity Type	MGT		
Participant number	**1**		
Participant short name	**MPG**		
Person-months per participant:	**60**		

Objectives

- The management is designed to generate a simple, flexible and efficient instrument to ensure that the aims of this large-scale project will be achieved. In the view of this objective, the management team will place special focus on the specific management requirements of the complex project structure – involving scientific work as well as innovation instruments – and its multi-disciplinary approach.
- It will guarantee that the contractual duties of the grant agreements and its annexes as well as the consortium agreement are fulfilled. Special attention will be paid to the management of intellectual property issues in relation to the planned exploitation activities.
- It will provide a transparent and professional financial management.
- A web-portal as communication infrastructure, including an online management software tool will be provided. It will offer an overview over the entire project, the individual tasks per partner as well as a download section where all relevant documents of the project can be easily found.
- It will supervise and control the scientific progress of the project work, will promote publications, dissemination and exploitation activities.
- It will coordinate all meetings of the Steering Committee, the Innovation Panel and the Scientific Advisory Board.
- It helps coordinate all scientific meetings of EuHIT.

Description of work

The Project Office located in Göttingen is in charge of the overall project management and provides an interface and help desk for all EuHIT partners. The Project Office is organized according to the description of the project management in section 2.1. A full-time project manager, supported by a part-time assistant- will perform the administrative project management in support of the Coordinator.

The main goal is the coordination of all technical activities of the project at consortium level. This will include the overall legal, contractual, financial and administrative management of the consortium as well as preparing, updating and managing the consortium agreement between the participants. The overall performance of the project will be monitored, ensuring the correct progress of the work so that the results of the project adhere to the contract. Adequate collaboration between the teams working on different work packages will also be ensured. Funds will be distributed to the EuHIT partners, and project resources administered to cope with unexpected occurrence. Project management will keep track of the financial status of the project at any given time.

<u>Task 1.1 Contract and IP management</u>

- 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 rights issues in accordance with provisions of the grant agreement and consortium agreement.

Task 1.2 Financial management

- Monitoring of budget and expenditures.
- Distribution of the EC payments to the partners
- Provision of advice for all partners regarding financial issues (e.g. eligibility of costs).

Task 1.3: Preparing the financial reports for the EU

- The Project Office will collect the financial reports as well as the Form Cs and Audit Certificates from the partners and compile the entire financial report, ensuring consistency with the scientific report and compliance with the reporting guidelines and the reporting deadlines.

Task 1.4: Communication Infrastructure

- Provide web-portal as communication infrastructure.
- Include an online management software tool.
- Develop evaluation infrastructure.

Task 1.5: Communication management and meeting coordination

- On behalf of the coordinator, the project office will communicate with the EU concerning administrative matters (e.g. financial issues grant agreement amendments, reporting).
- The project office will make 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 general assembly meetings taking place annually.
- It will coordinate all meetings of the Steering Committee, the Innovation Panel and the Scientific Advisory board.
- It helps coordinate all scientific meetings of EuHIT.

Task 1.6 Innovation Panel

- Establishment of an Innovation Panel to stimulate dynamics and innovations within the consortium during the funding period and to prepare continuation of the collaboration of the consortium after the end of EU funding.
- Develop and support the innovation potential of EuHIT.
- Prepare recommendations to the Steering Committee.
- Evaluate progress with respect to deliverables and milestones and recommend stopping a particular work package if necessary.
- Recommend inclusion of new techniques not yet available to the consortium.
- Develop ideas to allow continuation of the collaboration of the consortium after funding of the EU is finished. These activities include development of fund raising strategies with private institutions as well as national funding institutions.

Task 1.7 Gender Equality

- The coordinator shall ensure gender equality in all aspects of EuHIT.

Deliverables			
Del. No.	**Content**	**Del. Month**	**Partner**
D 1	Periodic reports to the Commission	**12, 24, 36, 48**	P1
D 1.4	Setup of project website	**3**	P1
D 1.5	Activity description of site monitoring	**12,24,36**	P1

Work package 2a: Synergy and communication

Work package number:	2a	**Start date or starting event:**			Month 1	
Work package title:	Synergy and communication					
Activity Type:	COORD					
Participant number:	18	1				
Participant short name:	**UWAR**	MPIDS				
Person-months per participant:	86	6				

Objectives

- to broaden the use of the EuHIT facilities, especially by including other research communities,
- to create a forum to facilitate communication between researchers in turbulence from both industry and academia,
- to foster a culture of cooperation among the partners of EuHIT,
- to publicise within EuHIT the progress of the consortium,
- to ensure broad dissemination of scientific results achieved by the EuHIT consortium,
- to enable the next generation of researchers to exploit the scientific opportunities available in the turbulence community,

Means

- 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,
- Advertising the EuHIT facilities and their capabilities to potential users in order to optimize their productivity,
- Establishing an equitable selection procedure for users of the TNAs,
- Organizing four annual meetings, of which the final one will be part of an international EuHIT conference,
- Communicating the opportunities offered by the EuHIT infrastructures to other research communities,
- Organizing a workshop for young researchers,

Description of work

The fundamental objective of integration of the research infrastrucurtres is to enhance the synergy between the research capabilities, thus creating added value. This can be achieved only when good communications and exchange of information is established among the partners who are operating most of the top-level turbulence research in universities and research institutions in Europe. The enhanced potential for innovation of the research infrastructures resulting from integration can be realised only when the research infrastructures become visible to external researchers, convincingly advertise the opportunities they offer and, ultimately, demonstrate in practice their ability to accommodate external research projects.

Reflecting these three aspects, this work package, based on networking, is organized around three tasks on internal project communication and synergy (T2a.1-3), three tasks on external communication and outreach (T2a.5-7) and one task (T2a.4) which strengthens important coordination support to the central objective of the entire EuHIT project, i.e., transnational access to turbulence research facilities.

Task 2a.1 Establishment and maintenance of the EuHIT Web Portal (UWAR):

The EuHIT COMMUNICATION & OUTREACH WEB INTERFACE (web-portal) will be the entry point to EuHIT, and will act as the main source of all official information. It provides an overview of the project and its objectives to the research community and it gives a detailed description of the Consortium together with the expected results and benefits. It will inform the researchers not directly participating in the project about its activities, broadcast recent developments and scientific achievements. Last, it will support internal networking activities of EuHIT. It will advertise new developments in networking tools and integrate in a seamless manner the "local" websites of the research infrastructures, of the joint research activities, and the partners of EuHIT. The portal will also support activities like scientific dissemination and outreach. The web-portal will be maintained by the web manager and publishing editor. It will provide, among other things:

- EuHIT descriptions, user information, application forms, news, etc.,
- Open access repository of EuHIT technical communications,
- Webpedia ScholarTurb developed in WP2b,
- Multi-point video conferencing (e.g. Adobe Acrobat Connect Professional or WebEx).

Channelled through the EuHIT Web Portal we will launch the EuHIT Virtual Help Desk Service (VHDS) providing general guidance, advice and information thus providing a contact point for new entrants to the EuHIT activities. On more general scientific aspects the EuHIT users will be directed to the relevant sources of information. The VHDS will also seek, on behalf of the EuHIT users, advice from the senior researchers participating in the EuHIT project. This will gradually build a set of generic guidelines and instructions (including Frequently Asked Questions) to be published on the Web Portal. We expect the outcome of this activity to provide valuable information on the needs and interests of turbulence research community, especially its younger members. The EuHIT web-portal, by using up-to-date networking tools, is expected to have a long lasting impact in terms of a modern internal communication and dissemination, which should extend well beyond the lifespan of the project.

Task 2a.2 Networking tools (UWAR):

Networking tools are needed to ensure an efficient and reliable networking between the scientists involved in EuHIT. These tools will be used to build a shared platform enabling efficient communication among the partners, as well as simple and interactive scheduling and organization of events of all types and safe and well-structured handling of all documentation produced (including storage, easy retrieval, notification, approval and distribution). The work will consist of:

- Setting up the networking tools,
- Advertising and establishing their use throughout the collaboration,
- Providing basic training and assistance to the users,
- Ensuring the maintenance and adoption of the tools,
- Adapting regularly the tools to the needs of the users.

Adobe Acrobat Connect Professional and WebEx will be candidates for the EuHIT networking tools, but we will explore other available tools and options and make a comparative assessment. We will set up a system of discussion groups, mailing lists, electronic document management system and a database of users.

Task 2a.3 Internal project communication (UW):

The EuHIT Partners will be constantly kept fully informed about the advancement of the project. The information will be suitably edited and, subject to Intellectual Property Rights, will be made available through the EuHIT web-portal and other appropriate EuHIT publication channels. The results coming from the JRA's will be communicated to the entire community through the EuHIT web-portal. Periodic reports will be provided upon the implementation of the results at the research infrastructures and their internal and external dissemination. A database of the hardware and software available at the different TNAs and the research groups will be progressively created and maintained EuHIT Portal. This will facilitate sharing of instrumentation, hardware and software between the participants and thus will serve the pooling of the distributed resources.

Task 2a.4 Management of access provision (UWAR):

We aim to raise awareness of the role of turbulence research, to advertise existing opportunities and available infrastructures and to induce interest in them among young scientists working on fundamental as well as directly applicable problems involving turbulent flows. The outreach to new users not only in the field of turbulence research, but also in associated fields of science and engineering is one of the central tasks of the proposed Networking Activity. We will specifically target potentially new users from the research groups currently outside EuHIT through the EuHIT web-portal and through all the external communication activities (EuHIT Workshops, EuHIT Schools, EuHIT Annual Meetings, EuHIT Conference). Many of these users belong to groups involved in the currently running MP0806 COST Action ‘Particles in Turbulence’ in which all members of the EuHIT Steering Committee, leaders of the proposed JRAs and most TNA research groups are also active.

The formal procedure of granting access to TNAs will be developed. There will be an open call for applications on the EuHIT Web Portal and potential users will be encouraged to apply at any time. The web-based applications will be first assessed by the research infrastructures who will rank them in order of quality and give their recommendations. The applications eligible for funding will then be subject to the assessment of independent reviewers. The final decision will then be taken by the EuHIT Steering Committee (SC) subject to the financial approval of the Coordinator. Priority will be given to users who have not previously used the infrastructure and are working in countries where no such research infrastructures exist. After the access the users will be asked to evaluate their research stay and the quality of the services provided. Their detailed reports, subject to the Intellectual Property Rights, will be published on the EuHIT web-portal. As part of this task assistance in the two-way communication between the users and the Research Facilities will be provided.

Task 2a.5 Workshop for young researchers (MPI-DS):

The Workshop for Young Researchers will be organised during the first half of the EuHIT project. This will be a major event aimed at promoting innovative turbulence research, involving experimental methods and state-of-the-art instrumentation. The participants will be informed about the EuHIT facilities in general, including the most recent facilities launched at the MPI-DS in Göttingen. This Workshop is expected to lead to new applications for transnational access to the EuHIT research infrastructure at the time when, after the period of initial integration, they should be ready to accommodate new projects.

Task 2a.6 Annual meetings (MPI-DS):

Three Annual 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 will 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, will be invited. One of the aims will be 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 annual meeting a committee will be appointed, subject to the approval of the EuHIT Steering Committee. The committee will prepare the programme of the Meeting. Participation will be by invitation only but the events will be well publicised to ensure good representation of expertise covering the entire field of turbulence research, The EuHIT Industry Liaison Person will ensure the participation of industrial researchers and R&D representatives. Efforts will be made to ensure broad representation of the public bodies funding and operating the Research Infrastructures.

Task 2a.7 The EuHIT conference (MPI-DS):

At the end of the EuHIT project, a EuHIT CONFERENCE will be organised. It may safely be assumed that by the time of the conference all EuHIT combined activities will make considerable contribution to the advancement of turbulence research. Judging from the past performance of the participants and anticipating the boost given by networking, the EuHIT project is expected to yield a large number of significant scientific results, which will motivate an international conference of broad interest. The Conference will 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, will be at least partially sponsored. Conference Proceedings will be published. Representatives of the industrial R&D groups involved in turbulence research and officials from the research infrastrucure operating institutions will be invited to participate. The conference will aim 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 Annual 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.

Deliverables			
Del. No.	**Content**	**Month**	**Participant**
D2a.1a	Launch of the EuHIT Help Desk and EuHIT Electronic User Discussion Group	**6**	UW
D2a.1b	Full release of the EuHIT Web Portal	**12**	UW
D2a.2	Set-up of the EuHIT networking tools	**10**	UW
D2a.5	EuHIT Workshop for Young Researchers (including Report by month 30)	**30**	MPI-DS
D2a.6a	Kick-off Meeting	**1**	MPI-DS
D2a.6b	Annual Meeting	**11**	MPI-DS
D2a.6c	Annual Meeting	**24**	MPI-DS
D2a.6d	Annual Meeting	**36**	MPI-DS
D2a.7	Final meeting held in conjunction with the EuHIT Conference	**48**	MPI-DS

Work package 2b: Innovation Through Integration

Work package number:	2b	**Start date or starting event:**		Month 1				
Work package title:	Innovation Through Integration							
Activity Type:	COORD							
Participant number:	**1**	18	2a	3	4	5	6	7
Participant short name:	**MPI-DS**	UWAR	CEA-a	TUIL	UTWENTE	UNIBO	ICTP	CERN
Person-months per participant:	13	10	1	1	1	1	1	1
Participant number:	8b	8d	9	10	11	12	13	
Participant short name:	CNRS-b	CNRS-d	CUNI	FAU	BTU	UNITO	CINECA	
Person-months per participant:	1	20	1	1	1	1	1	

Objectives

- To create a vibrant and sustainable European research turbulence community, reaching out to industrial R&D through communication, training, workshops, and schools. The aim is to foster innovation in all industrial activities where turbulence plays a role, including ground transportation and aerospace, energy and process engineering,
- To offer to all scientists, from European laboratoris in industry, academia, and government the optimal use of the Europe-wide turbulence facilities.

Means

- to provide training and consultancy to parties interested in the Research Infrastructures, including new users, both, from industry and academia,
- to keep track of technological innovations by setting a private wiki for the consortium to share the technical information in an informal, easy and efficient way,
- to advertise EuHIT research and workshops in trade journals,
- to draw a road map for future fundamental and applied turbulence investigations,
- to propose new research facilities motivated by engineering challenges,
- to set-up ScholarTurb a user friendly high level webpedia on turbulence which will provide online up to date and reliable information on the most recent developments in turbulence theory, modelling and experiment. It will be wiki-based but with a peer review access for updating the site,
- to provide direct access to the best technical expertise on problems of interest to the actual and potential industrial partners through the ScholarTurb interface.

Description of work

The aim of WP2b 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. The networking tools necessary for the planned outreach and dissemination will be provided. WP2a will integrate the ScholarTurb webpedia and thus provide a broad knowledge base on turbulence research in the EuHIT web-portal.

Task 2b.1 Outreach to industry (MPI-DS):

The EuHIT Industry Liaison Person (ILP) will be responsible for establishing and maintaining partnership of the EuHIT RIs with the industry. The ILP will create and maintain a database of the industrial R&D representatives and researchers in the companies involved in turbulence-related activity. Those representatives will be regularly informed about the developments in the EuHIT project and will be invited to participate in the EuHIT events. Industrial R&D community will be encouraged to use the EuHIT web-portal and the Virtual Help Desk Service. Every effort will 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. First, the industrial researchers will be kept informed about cutting-edge experimental research establishments, and given an opportunity to identify methods and techniques of potential application in the industrial processes. Second, the EuHIT research groups will be exposed to the challenges faced by the high-technology industrial research. To support this, based on the success of the PIVNET European network experience, a few specific one day workshops will be organized, targeted specially toward industry management, in order to demonstrate them the possibilities offered by the consortium to solve their particular problems.

Task 2b.2 Dissemination and exploitation of project results (UW):

Maintaining a database of publications by the EuHIT Partners and making them available on the web-portal will optimize external dissemination of knowledge. The Partners will be provided with the EuHIT information packs to be distributed at the non-EuHIT conferences and other appropriate events. Partners will be required to acknowledge the role of the research infrastructures they used when publishing their research work.

Task 2b.3 Liaisons with other consortia (UW):

The EuHIT Steering Committee made every effort to include in this initiative most large European infrastructures involved in turbulence research, in physics and in engineering. In this spirit, part of the networking activities will be to identify other groups doing experimental work in this area and to establish closer cooperation, with the aim of extending the integration efforts in the future. We will also approach other Integrated Infrastructures Initiative projects in order to improve our own model of integration and sharing of the research infrastructures. The aim will be to identify common difficulties and formulate general suggestions for possible policy change concerning the efficient use of large European research facilities. Common issues are likely to emerge in the integration initiatives concerning related research areas, like atmospheric physics, geophysics or space science, but also more distant disciplines.

Task 2b.4 Workshops at the facilities (MPI-DS, CEA-a,b, TUIL, UTWENTE, UNIBO, ICTP, CERN, CNRS-a-e, CUNI, FAU, UNITO, CINECA):

Fourteen scientific workshops will be organised on sites of the infrastructures participating in the EuHIT project. The workshops will be aimed at future users of the experimental facilities. Scientists with a project proposal already approved by the EuHIT Steering Committee will be able, on site, to familiarize themselves with the environment in which they will be performing their experiments, to discuss technical details with the scientists and technical personnel responsible for running the facility. Scientists who consider submitting a project proposal to EuHIT will be able to find out about the experimental opportunities and limitations and to assess the scale of necessary preparations. Representatives of the EuHIT facilities other than the host facility may participate in order to advertise their installations and to learn about common users' queries and expectations. EuHIT industrial Partners and non-EuHIT industrial R&D representatives will be encouraged to take this opportunity to inspect the research potential of the leading European facilities. The workshops will be organised by local committees subject to the approval of the EuHIT Steering Committee. Participants will be invited after a selection procedure following open calls for applications. The events will be well publicised to ensure good representation of expertise covering the entire field of turbulence research. For some of them, a special day will be targeted at industrial management and R&D deciders in order to demonstrate them the potential of the consortium expertise to solve their specific problems. They will have the opportunity to see a real experiment working and to have a good hint of the kind of results and accuracy they can expect. Potential fields are: Turbulent mixing for process engineering, turbulence enhancement for combustion, turbulent drag and noise reduction for ground transport.

Embedded within workshops organised by the research infrastructures will be training sessions for the new users who already had their research projects approved by the Steering Committee. The workshop organisers will publish the prerequisites and learning materials on the EuHIT web-portal.

Task 2b.5 Summer schools on experimental methods and techniques (UWAR):

Four topical summer schools will be organised. The two target groups of participants will be young researchers (especially actual and potential EuHIT users) and industry representatives interested in the R&D involving the investigation of turbulence. The schools will focus on general experimental methods and techniques in turbulence research with specific reference to those kinds of measurements that can be taken at the experimental facilities participating in the EuHIT project. Techniques and methods of numerical data analysis may also be included. The EuHIT Industry Liaison Person will ensure that the schools will be a fertile ground for knowledge transfer between academic research and the industrial engineering communities. Our hope is that during summer schools, the scientists of the RIs will contribute to broaden the horizons of the application-driven research.

Task 2b.6 Development of ScholarTurb (CNRS-d):

Internet is now an indispensable and universally used mean of information. It is of prime importance that scientific information be provided in a clear, attractive and reliable manner. For that purpose, the best specialists have to contribute and peer reviewing is mandatory. Based on the quality of the EuHIT consortium and on the amount of knowledge which will be assembled and produced during the four years of the project, a key issue will be to diffuse largely the accumulated knowledge on one of the main riddles of modern physics, in a didactic and trustable manner. This will foster the development of new ideas, attract bright young people to the subject and contribute to the collective memory of science. On the technical point of view, this webpedia will be based on wiki for which LML has already a good experience. A platform will be developed in parallel to TurBase from WP3 and with a compatible architecture. This platform will permit us to post both detailed scientific contributions and articles targeted to a broader public, conveying a good idea about the success stories and open questions in the field of turbulence. Three levels will be aimed: general public, public with a scientific background and specialized public. From the organizational point of view, an editorial board will be formed at the beginning of the project, in order to define the rules and practices to publish on ScholarTurb. The first contributions will be posted after one year. The reporting from the different work packages will be organized so that most of the produced material by EuHIT can be made available on ScholarTurb, either as major scientific contributions or as broad public articles. During the last three years of the project, the shape and content of the webpedia will be improved. Editorial board and contribution will be opened to the whole scientific community. At the end of the project, ScholarTurb should be a living entity, complementing the WP3 TurBase and contributing to a better knowledge of the turbulence phenomenon, of its understanding and of its impact on human activity.

Deliverables

Del. No.	Content	Month	Participant
D2b.1	Database of industrial researchers and R&D representatives	**6**	MPI-DS
D2b.2	Establishing database of EuHIT publications	**9**	UWAR
D2b.3	EuHIT information pack	**6**	UWAR

	D2b.4a	RI workshop at MPI-DS (including report)	**42**	MPI-DS	
	D2b.4b	RI workshop at CEA (including report)	**42**	CEA-a	
	D2b.4c	RI workshop at TUIL (including report)	**42**	TUIL	
	D2b.4d	RI workshop at UTWENTE (including report)	**42**	UTWENTE	
	D2b.4e	RI workshop at UNIBO (including report)	**42**	UNIBO	
	D2b.4f	RI workshop at ICTP (including report)	**42**	ICTP	
	D2b.4g	RI workshop at CERN (including report)	**42**	CERN	
	D2b.4h	RI workshop at CNRS-b (including report)	**42**	CNRS-b	
	D2b.4i	RI workshop at CNRS-d (including report)	**42**	CNRS-d	
	D2b.4j	RI workshop at CUNI (including report)	**42**	CUNI	
	D2b.4k	RI workshop at FAU (including report)	**42**	FAU	
	D2b.4l	RI workshop at BTU (including report)	**42**	BTU	
	D2b.4m	RI workshop at UNIBO (including report)	**42**	UNITO	
	D2b.4n	RI workshop at CINECA (including report)	**42**	CINECA	
	D2b.5a	Summer school year 1	**12**	UWAR	
	D2b.5b	Summer school year 2	**24**	UWAR	
	D2b.5c	Summer school year 3	**36**	UWAR	
	D2b.5d	Summer school year 4	**48**	UWAR	
	D2b.6	Evaluation report	**48**	MPI-DS	
	D2b.7a	ScholarTurb wiki operating	**6**	CNRS-d	
	D2b.7b	ScholarTurb fully operational	**48**	CNRS-d	

Work package 3: TurBase: Establishing a virtual turbulence research community

Work package number:	3	**Start date or starting event:**		Month 1		
Work package title:	TurBase: Establishing a virtual turbulence research community					
Activity Type:	COLL					
Participant number:	16	13	17	8a		
Participant short name:	**UTOV**	CINECA	TUE	CNRS-a		
Person-months per participant:	49	20	34	6		

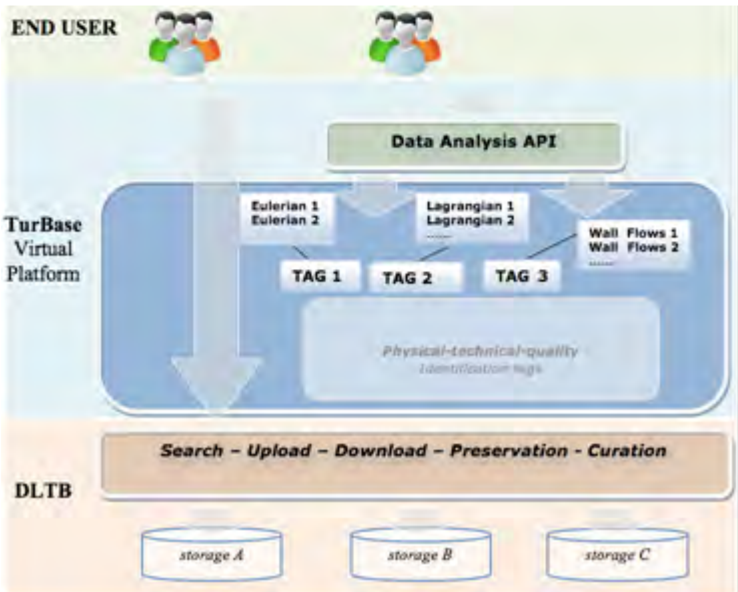
Objectives

Contribute to the development of the turbulence research community through the creation of TurBase, a freely accessible living knowledgebase for high quality turbulence data. TurBase shall provide easy access to experimental and numerical data, as well as data derived from theoretical models. TurBase shall foster the use and deployment of standards and efficiently curate, preserve and provide access to the data and metadata collected or produced by EuHIT in particular and the turbulence community in general.

Means:

- Development of a set of requirements for data, metadata, data access and data processing,
- Development of a common meta-data scheme for describing content, structure, and quality,
- Development of tools for easy interaction with the knowledgebase,
- Development of tools for interactive data visualizations and data exploration,
- Establishment of the TurBase knowledge base,
- Integration of TurBase into the EuHIT dissemination activities including the EuHIT web-portal.

Description of work



The main task of this WP is to develop TurBase, a freely accessible, highly interactive and evolving knowledge-base for high quality turbulence data. It shall foster a culture of cooperation between research infrastructures in Europe and shall establish a virtual environment for an integrated community from academia and industry. We envision TurBase to become the major resource for innovation in fluid dynamics applications in technology. TurBase shall go well beyond the state of the art that has shown that interactive and passive databases provide essential tools for research. Developing TurBase will require a considerable Networking activity to identify the needs of the community, to establish common standards, to develop Application Programming Interface to interact with data, and to disseminate the knowledge acquired within the TNAs and to the outer community. This networking activity will be supervised by scientists from three of the nodes participating in this WP (Rome, Eindhoven, Lyon), in tight collaboration with the CINECA staff.

State of the art: Numerous scientific initiatives around the world have led to the creation of database and data warehouse. During the last decade, scientists and infrastructures belonging to this WP have pioneered the use of scientific database in the turbulence community at CINECA (http://cfd.cineca.it). The success of this first attempt, in terms of popularity (30000 page visits in the last two years) is a clear indication about the need and the added value of a common repository where data can be stored, cured and quality assessed. A similar initiative has been since developed in the US (http://turbulence.pha.jhu.edu/) and extended to provide also on-the-fly analysis on restricted set of turbulent data. Similarly, in other fields, it is now common practice to make data available on the web, to be easily downloaded via ftp. This is the case, for example, for space missions (http://ulysses-ops.jpl.esa.int/ulysses/archive/). Our vision here is to go beyond these data repository cases, developing something never tried before in our community, i.e. an interface where: (i) data from different labs and groups on a wide list of different turbulent systems are integrated together; (ii) making the repository 'alive' by continuous exchange between data providers, data managers and data users; (iii) leaving a legacy of knowledge on how to federate different datasets and how to develop software and middleware to interface with data. The development of TurBase at CINECA will be facilitated and consolidated by the participation in several state-of-the-art EU-funded activities. CINECA is hosting member in PRACE (www.prace-project.eu), member of EUDAT, the European data Infrastructure (www.eudat.eu) and coordinates HPC-Europa, the Transnational HPC Access program (www.hpc-europa.eu). CINECA actually operates as a Tier 1 system in PRACE and will install a Tier 0 system in 2012.

To reach the above objectives, we have to address the following issues.

- *Defining common standards for the data*: Data coming from different labs and fields, originally prepared in several formats, will need to be stored, reshaped, homogenised (common standards). Their quality will also have to be checked and quantifiers reported. Input from the academic and industrial community will be essential for collecting the needs and requirements. The objective is to generate a well-structured knowledge-base that includes sets of experimental, numerical, as well as data derived from theoretical models indexed and classified according their technical and physical contents. The meta-data must include not only a set of standards based on common integrated inputs, and quality, but also descriptors that give the necessary gray literature describing the data.
- *Development of a proper user-friendly interface:* Usability will be enhanced in order to reach the whole knowledge-based community by developing Application Programming Interface (API) for search and analysis and protocols and interoperability through the design of metadata and metadata access. This step, which will require networking in an essential way, will be achieved through the adoption of meta-data queries, data mining and visualization on-the-fly. Sharing data and resources from different sources will have a leverage effects concerning, benchmarking, validation and spreading of best practises for all users in the community
- *Technical documentation describing the data*: As in any scientific activity involving the manipulation of large dataset, an important concern for any potential user is to be able to properly use the data. Knowing what the strength and possible limitations of a set of data is an obvious concern. Also, knowing what a particular dataset means, in relation with previously accumulated knowledge, possible deviations from expected behaviour are crucial when for anyone using the data. To address this problem, we intend to make available on-line a description of the data, produced first by the users, in relation with the quality management effort (WP23), and with the possibility offered to future users to further annotate, or provide information on the scientific status of the data.

TurBase will be the backbone of the EuHIT integrated activity, and it is going to greatly facilitate the scientific objectives of the TNAs, as well as their mutual interactions. The work of this WP will rest on networking activity, in close collaboration with the service provided by CINECA. The aim is to guarantee that the data repository evolves in a coherent and sustainable way. To reach this objective, we intend to include functionality to assist with data input, to maintain formatting standards, and to facilitate the development of a new unified 'storing language' for the whole community, associating meta-data to stored data sets. The activity will produce the fundamental specifications necessary for the development of the library components and the access tools. The activity will contribute to strengthen and expand 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. To this end, an important objective will be to disseminate and integrate the developed knowledge between the TNAs and the outer knowledge-based community.

The development of the project is expected to proceed in five steps. First we shall collect information by developing networking between TNAs, and by gathering inputs and data from the community. Second, clear and well-defined sets of technical and "physical" tags will be identified to organize the database. Third, data will be homogenised and standardized according to the requirements identified by the potential users. Fourth, a user-friendly Application Program Interface (API) tool will be developed and benchmarked in order to improve the 'usability' of data and to reach a wider scientific community. Fifth, a library of best practises and manual for users and administrators will be delivered. The WP will participate, at all levels, in the development and posting of technical and scientific information concerning the data. Aside from technical aspects of software development, which will be dealt with through consultation with the future users, the scientific aspect of this activity will involve discussions and consultations with the various scientific groups, and will be closely associated with WP23 on "Quality assessment of data and model". This structure is reflected in the breaking of the WP in tasks, described below.

Task 3.1 Networking activity aimed at identifying fundamental classes of turbulent data:

This work package aims to identify fundamental classes of turbulent data that will require individual characterization (data scouting at the raw TurBase level). This task will allow defining the "data alphabet" out of which to build the TurBase language and syntax. We will pool the community to select a wide set of heterogeneous data sets, available and future, which needs to be classified and disseminated among the community., D3.1.

Task 3.2 Specification of the data model for identification, indexing and search in the TurBase database:

The goal is to define simple and effective data models able to describe the classes of problems relevant for the project (identified in Task 3.0). The logical data model will be characterized by a restricted set of parameters (metadata) facilitating the integration of data from different communities for specific problems (Lagrangian turbulence, thermal convection, cryogenic turbulence, boundary layer, etc.) and of different type (numerical, experimental, etc.) This will also include specifications on data description (spatial and temporal resolution, accuracy, boundary conditions, etc. which are as important as the data for the end user) D3.1

Task 3.3 Identification and proposal of a minimal set of input file formats for storing data in the library:

In order to make the tool flexible and user-friendly, we need to identify the easiest and the most efficient standards to simplify the use of the data. Standards will evolve throughout the networking activity, through interaction between TurBase and the users. The standard will be disseminated and updated during the duration of the project. D3.1, D3.2.

Task 3.4 Development of recommendation and of a minimal set of Application Programming Interface for delivering data in client/user applications:

Dissemination of the recommendation and software adapters. The network will contribute to further develop the software adapters for the benefit of the end users who may be able to access data formats on the fly. Development of visualization tools to facilitate dissemination and improve data comparison, data analysis and validation. A final goal of the WP will be to make TurBase easily accessible, provide manuals, and recommendation for users and administrators D3.3, D3.4, D3.5.

Task 3.5 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. To this end, one of the aims will be to provide information concerning the quality of the data, to develop ‘best practices’ and to establish the proper connection with the modelling effort. This work will be carried out in close collaboration with the “quality assessment” WP23. D3.1, D3.5.

Risk Assessment: TurBase will have to deal with highly heterogeneous sets of data. There is a risk that the proposed tagging is i) too simplistic thus not allowing accurate search, ii) too sophisticated thus making it not practical and discouraging data providers. While we will try to find the optimal compromise the fact that the tagging is extensible will alleviate the risk. A possible lack of synchronization between data from different TNAs may lead to a delayed availability of the data in TurBase.

<u>WP Management:</u>

The technical side of the work will rest on the competence of CINECA, who has developed an important expertise in the storage and management of large data set, and on a concerted networking activity of several participants in the project, who will aim to define the proper standards and protocols, with the explicit objective to make TurBase an efficient tool for turbulence research. The scientific duties will be under the responsibility of the groups of scientists at the nodes involved in the WP providing the professional knowledge on the numerical and experimental landscape in Europe. Such global vision is needed to ensure the right integration of tools and the exhaustive coverage of data existing in the European area. The coordination activity between data-provider and data-users, together with the development of software and middleware interface with the IT aspects at CINECA will demand an important involvement of scientific personnel, due to the need of continuous exchange of information and feedbacks from people working on TurBase and the outer community all along the duration of the project. Collaboration with the activity detailed in the WP on “Quality assessment of data and models” will also be crucial to identify different data sets on a usability reference scale. Synergies will also be developed with the development of a ScholarTub webpage within the WP2b dedicated to integration and innovation.

Deliverables

Del. No.	Content	Month	Participant
D3.1a	Formalization of TurBase data model consistent with requirements capable to represent data content/structure/quality	**12**	Tu/e
D3.2	Beta version TurBase operational. Available data are converted and tagged for content/structure/quality	**24**	CINECA
D3.3	First version of API operating on numerical and experimental data	**36**	CINECA
D3.4b	TurBase fully operational	**48**	CINECA
D3.5	Final report: manual of TurBase for users and administrators delivered.	**48**	UTOV

Work package 4: Access to Göttingen High-Turbulence Facility (GTF)

Work package number	4	**Start date or starting event:**		Month 1		
Work package title	Access to Göttingen High-Turbulence Facilities (GTF)					
Activity Type	SUPP					
Participant number	1					
Participant short name	MPI-DS					
Person-months per participant:						

Description of the infrastructure

Name of the infrastructure: *Göttingen High Turbulence Facility*
The GTF comprises three facilities that are all at the same location, right next to each other.

Location (town, country): *Göttingen, Germany*

Web site address: *www.gtf.ds.mpg.de (under construction)*

Legal name of organisation operating the infrastructure: *Max Planck Institute for Dynamics and Self-Organization*

Location of organisation (town, country): Göttingen, Germany

Annual operating costs (excl. investment costs) of the infrastructure (€): 628,018 €
(GTF1: 284,393 €, GTF 2: 297,993 €, GTF 3: 45,632 €)

Description of the infrastructure:

Summary:

- *Highest turbulence levels under well controlled conditions in a pressurized turbulence tunnel with long measurement sections (7m and 9m respectively.) in a 24m^3 pressure vessel using sulphur hexafluoride, and in a sea-water compatible swirling flow apparatus;*
- *Flow resolvable over all scales by current measurement technology;*
- *High-pressure compatible measurement systems: 3D LPT, Tomo PIV, LDV, PDPA, hot-wire.*

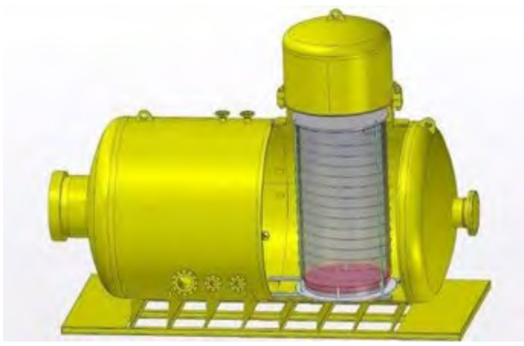
The facilities are exceptional in providing both Eulerian and Lagrangian measurements with the highest technologically realizable speed and resolution. They are versatile and flexible in the installation of other flow generators and instruments.

The Max Planck Society has established the Göttingen High-Turbulence Facilities (GTF) at the Max Planck Institute for Dynamics and Self-Organization. The GTF is equipped with the most advanced measurement technologies (see below). The GTF has become fully operational in February 2008 after 5 years of planning, design, and construction. The investment was 5 Mio € for the experimental hall including offices, 3 Mio € for the experimental facilities, and 2 Mio € for measurement equipment, totalling a 10 Mio € investment into turbulence research. In addition, the Max Planck Society is providing 10 guest apartments and 14 guest rooms in three guesthouses.

The Göttingen Turbulence Tunnel (GTF1) and the Göttingen U-Boot (GTF2) use compressed SF_6 gas or other non-corrosive gases such as air, N_2 or He. The high density of SF_6 allows very intense turbulence to be achieved at pressures as low as 15 bar. GTF1 is a wind tunnel with extra long measurement sections to allow particle tracking of the decaying turbulence behind a turbulence generator like a passive or active grid. GTF2 is used for the investigations in Lagrangian mixers and thermal convection. The Göttingen Von Kármán mixer (GTF3) allows Lagrangian particle tracking in turbulent swirling flows (R_λ up to 1000) in liquids such as pure water, sea water, or liquids with other additives, e.g. polymers. In addition to serving the in-house experimentalists, the GTF provides visitors with the possibility to study phenomena in turbulent flows under very well controlled conditions at high Reynolds and Rayleigh numbers.

In GTF1, Reynolds numbers of up to R_λ ~7000 are possible when filled with SF_6 at 15bar. The tunnel is upright and consists of two measurement sections with a cross-sectional area of $1.9m^2$ and lengths of 9m and 7m, respectively. A passive grid is mounted at the entrance of one measurement section to generate the turbulence (R_λ up to 1700). An active grid has been designed, constructed, and pre-assembled. It will replace the passive grid in order to increase the Reynolds number up to R_λ~7000. The wind tunnel has been designed to contain sleds in each of the measurement sections, carrying up to 350kg and driven by linear motors, which allows measurement devices (e.g. cameras and optics) to be moved with the mean velocity of the circulating gas (up to 5m/s). Appropriate test systems (outside the wind tunnel) and optical benches (inside the wind tunnel) exist. The tunnel is pressure and temperature controlled, and has optical and electrical interfaces. The circulating gas can be filtered to <1μm in order to gurantee the cleanness. Measurement equipment can be installed along the measurement sections. Beside several pressure sensors, nano-fabricated hot-wires from Princeton University have been installed on a 3D traversing system. Other measurement devices to be used in the tunnel are Lagrangian particle tracking systems, LDV/PDPA systems, and cantilever velocimeters. Specifications: Total length 18m, height 6m, measurement section lengthes 9m and 7m, inner diameter 1.8m, pressure range 1mbar-15bar, temperature 20-35°C, mechanical power of the fan 210kW, cooling capacity 280kW, kinematic viscosity of SF_6 at 15bar: $1.5x10^{-7}m^2/s$. Turbulence properties: $\langle u\rangle_{max}$ =5m/s, $u_{rms,max}$=1m/s, L_{max}=0.45m, $R_{\lambda,max}$=7000, ε_{max} =1.2W/kg, η >8μm, τ_η>0.4msec.

GTF2 is a general-purpose pressure vessel. It has been designed to house different experiments. As in the turbulence tunnel, all equipment, from heat transport and PIV to 3D-Langrangian Particle Tracking (LPT), can be used inside the vessel. Experimental inserts available include two turbulent cylindrical Rayleigh-Bénard experiments (diameter 1.1m, height 2.2m and 1.1m respectively) that reach Rayleigh numbers as large as Ra~10^{15}. Specifications: length 5.3m, max. height 4.0m, outer diameter 2.5m, straight cylinder length 4m, dome 1.5m high and 1.2m diameter, pressure range 1mbar-19bar, temperature 20-35°C, cooling power up to 50kW, kinematic viscosity of SF_6 at 15bar: $1.5x10^{-7}m^2/s$. Properties of the Rayleigh-Benard cell: Ra_{max} = $7x10^{14}$ with very weak non-Boussinesq effects; Lagrangian stirrer: $\langle u\rangle_{max}$ =0m/s, $u_{rms,max}$=1m/s, L_{max}=0.1m, $R_{\lambda,max}$=4500, ε_{max} =5.5W/kg, η >5μm, τ_η>0.2msec.



GTF3 generates high Reynolds number turbulent water flows between two counter-rotating baffled disks. Large glass windows provide access for LPT or PIV measurements. The apparatus can be pumped down to reduced-pressure for the study of bubble dynamics. A frequency doubled high-power (50W), high-repetition-rate Nd:YAG laser is devoted to measurements in this apparatus. Specifications: Inner diameter 0.5m, height 0.63m, propeller diameter 0.25m, $u_{rms,max}$=1.4m/s, L_{max}=0.07m, $R_{\lambda,max}$=1200, ε_{max} =10W/kg, η >20μm, τ_η>0.3msec.

Measurement Systems: The facilities include the following equipment: a 3D Lagrangian particle tracking system consisting of 4 phantom V7b cameras (800x600 at 6k fps and 256x256 at 36k fps), a Tomo-PIV system (LaVison) with 4 Phantom cameras (2000x2000 at 500fps), a 3 component LDV system (TSI) with a PDPA for particle sizing, a Dantec hot-wire system, nano-fabricated hot-wires (Princeton). All of the above equipment is compatible with high pressure up to 15 bar. In addition, 2 frequency doubled, high-repetition-rate and high-power Nd:YAG lasers (100kHz and 50W), 2x5W argon-ion lasers, 2 linear optical rails (7m, 9m) with linear motors (capable of driving 350kg at speeds up to 5m/s), optics, data analysis software, and a computing and storage cluster are available.

The facilities are housed in a newly constructed experimental hall that is vibration isolated and temperature stabilized. Safety control systems are installed to support daily use of pressurized gases and high-power lasers. High bandwidth fibre optics links the facilities to a 288-processor data analysis cluster. A 36m^2 class 1000 clean room is available for micro fabrication of sensors. The institute installed a gas liquefaction system in a separate building, where 13 tons of SF_6 gas are stored. The operational pressure of the system ranges from 1mbar to 19bar.

Services currently offered by the infrastructure:

We offer in situ research with a direct access to the facility, where the users come in person and conduct research at our facilities. To these researchers we offer practical guidance as well as assistance from our scientific and/or technical staff, which is necessary due to the high complexity of the facilities. Thoughout the project, the users will work with the facility lead scientist and supervisor, the facility engineer, the manager of the computational support and the facility technician. The accommodation facilities of the MPI-DS, in particular the guesthouse, significantly reduce the organizational effort required for arranging the visits to the GTF facilities.

Description of work

Modality of access under this proposal:

Upon approval of the application from an external user to conduct research at GTF, a preparatory meeting between the user team and the facility management and support team will be held (either in person or per teleconference). Requirements and possible modifications of the experimental system will be defined. At the preparation stage, the technical staff (mechanical, electronic, and electric workshops) at GTF, under the guidance from the scientific team, will carry out necessary modifications of the apparatuses, experimental equipment and measurement systems. During this time, short-term visits of the users are encouraged to ensure proper preparation of the experiments. A typical project from an external user will take at least four weeks. When the users arrive, the first week will be devoted to safety training, the instructions to the experimental and computational facilities, and the installation of the user's measurement system in the appropriate GTF facilities. After testing the functioning of the experimental systems and the facilities reaching steady conditions, which could take several days for GTF1 & 2 at high-pressures, the user will then conduct the planned experiments over the allocated period. During this time, at least one member from the user's research group should stay at MPI-DS. Upon completion of the experiment, extra times are needed to disassemble the user's devices from the facilities. For GTF1 & 2, this can take another two or three days. For GTF3 this time is shorter but could still be one day or even longer depending on the complexity of the installation. The experimental data will be given to the users either in external storages or as shared data on the computing clusters. The users will be able to analyze the data either using the computing facility at GTF or at their home institution. During their stay, office space and full access to the infrastructure of the institute will be provided.

Support offered under this proposal:

As described already above, the facility scientists, engineers, computer specialists, facility technicians and the workshops of the institute will provide support to external users. In addition, the users will be working in a very stimulating research environment. MPI-DS has more than 100 scientific employees with approximately one-third of of them working on turbulence and related areas. Another Max Planck Institute, MPI Biophysical Chemistry, is located on the same campus, which is only 500 m from the Univerisity of Göttingen, and the German Aerospace Center is just a little further away. The MPI campus houses several lecture halls and seminar rooms, a cafeteria, and a well-equipped library. In addition to the MPI-DS guesthouses in the city centre, the guesthouses of the MPI-BPC which are within 50m of GTF, can also be used. MPI-DS will also be part of the node that develops the data infrastructure (see WP 17). The local expertise will help users in the management of their data and the provision of the analysis tools on the local and EuHIT computing infrastructures.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
GTF1	1 day	779	168	24	336	6
GTF2	1 day	816	224	24	336	8
GTF3	1 day	125	120	4	240	2

Unit of Access: The unit of access is defined as one day. For any external project, it is estimated that a minimum stay of four weeks will be needed. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. When the users arrive, the first week will be devoted to safety training, the instructions to the experimental and computational facilities, and the installation of the experimental system inside the facilities. The workload, of course, will vary from experiment to experiment. Before the first test runs are conducted, typically two to three days are needed for the facilities to reach steady conditions. During this time, at least one member from the user's research group should stay at MPI-DS. After the experiments, another one to three days will be needed to disassemble the users' instruments from the facilities.

Work package 5: Access to Grenoble Helium Infrastructures (GHI)

Work package number	5	**Start date or starting event:**				Month 1	
Work package title	Access to Grenoble Helium Infrastructures (GHI)						
Activity Type	SUPP						
Participant number	2a						
Participant short name	CEA-a						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *Grenoble Helium Infrastructures (GHI)*
This infrastructure is made of two installations: SHREK and HeJet, both working with superfluid and normal helium, which are complementary and open independently for external users

Location (town, country): *Grenoble, France*

Web site address: *http://inac.cea.fr/sbt/*

Legal name of organisation operating the infrastructure: *Commissariat à l'Energie Atomique et aux Energies Alternatives*

Location of organisation (town, country): *Paris, France*

Annual operating costs (excl. investment costs) of the infrastructure (€): 477,393 €
(SHREK: 358,073 €; HeJet: 119,320 €)

Description of the infrastructure:

Summary:

- *Very High Reynolds (up to 10^8) He flow production;*
- *High flexibility of flow conditions, due to the large variation of helium properties over the temperature range available (1.6 K to 5 K);*
- *Both superfluid and normal turbulence measurements possible in the same experiment, with adjustable fraction of the superfluid component (from 1.6 to 2.2 K);*
- *Miniature pitot anemometer, second sound probes for superfluid turbulence measurement, miniature pressure sensors, torques and power calorimetric measurement;*
- *Two complementary facilities working with both normal and superfluid helium, one offering high flexibility, the other unsurpassed performance in terms of helium mass flow rate.*

CEA-SBT facilities make particularly use of the phase transition experienced by Helium at 2.2 K, thus allowing to make experiments at very High Reynolds values with normal (above 2.2 K) and superfluid helium (below 2.2 K). It will contribute to the understanding of the fundamental differences between frictionless and normal turbulence.

CEA-SBT in Grenoble has a world-wide recognized expertise in cryogenic engineering. CEA-SBT had built a He refrigerator providing a large refrigeration power over a temperature range of 1.5 to 5 K, for both applied and fundamental studies, in the domain of helium cooling of superconducting magnets for fusion, and also in the domain of superfluid helium cooling of accelerators (LHC project). More fundamental studies of two phase superfluid helium flows have also been performed, and more recently two turbulence experiments have been set up and funded under the French National Agency for Research, to study some specificities of superfluid turbulence. These projects have been made possible by the unique conjunction of a multidisciplinary expertise at CEA and in the geographical area around Grenoble:

- The LEGI (Laboratoire des Ecoulements Géophysiques et Industriels) has a strong theoretical and experimental expertise in fundamental turbulence, usually at room temperature. Its collaboration with Luth in Paris improves its von Karman flow knowledge;
- The CNRS Institute Neel has always been a pioneer in cryogenic turbulence, in the domain of turbulent convection, turbulent jet generation and superfluid turbulence;
- CEA-SBT expertise in large refrigerators and in cryogenic engineering;
- And both theoretical and experimental expertise at CEA/Saclay and ENS-Lyon.

This unique environment has made possible the construction at CEA of a large facility for helium turbulence study, using the large refrigerator available at CEA, together with the expertise in the field of instrumentation of the above mentioned laboratories. CEA opens this facility to external users. Two facilities are made available by CEA: the main facility is the SHREK facility.

The SHREK facility enables to work in superfluid as well as in normal liquid helium. This is a large apparatus connected to the 400 Watt/1.8K refrigerator providing Re in the 10^7 range.

The 400W/1.8K Refrigerator is in operation since 2004, when it achieved its nominal performances, namely 400W at 1.8K. The refrigeration power available ranks from 120W at 1.5K to 800W at 4.5K. All the temperature levels in between have been fully explored, and temperature can be adjusted in the range of 1.5 to 4.5 K continuously. Noisy screw compressors are located in a separate building, while the cold box stays in the main hall at the vicinity of the 26 m^2 control room. Compared to the refrigerators available at CERN for turbulence studies, it offers the possibility to operate below the superfluid transition, down to 1.6K.

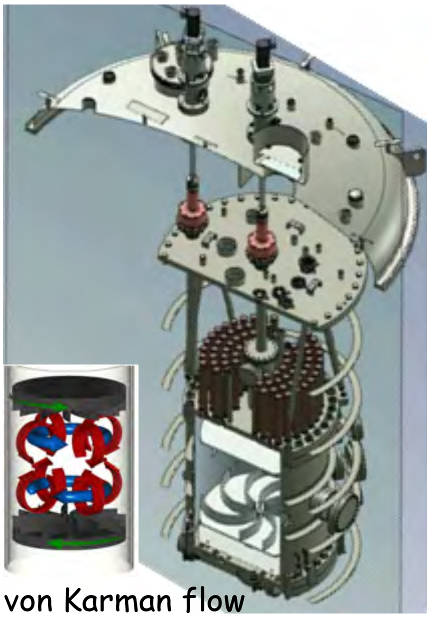
Refrigerator cold box

multitest cryostat

warm compressor station

Reynolds numbers of up to Re ~ $2x10^7$ have been obtained on the previous experiment (test line in the 1.5 m long 30 mm inner diameter pipe with a mean flow velocity of 8 m/s). Stability better than 0.05 K has been maintained over more than one hour. A new multitest cryostat (shown in figure above) has been installed since 2009, offering large dimensions for an experiment totally independent of the refrigerator. The space available in this upgraded SHREK cryostat will roughly fit in a cylinder of 4m in height and 2 m in inner diameter. Lines providing liquid helium (normal or superfluid) and return pumping line and connections to cryogenic circulating pump are located at the bottom of the cryostat, ensuring easy access for assembly of experimental inserts. Our new von Karman cell of unprecedented dimension (0.8m I.D. and 1.2 m in height - 0.7 m between turbines) permits to address either higher Reynolds numbers (Re up to 10^8) or to be able to resolve the dissipative scale for lower Re. It is worth mentioning that our group works on other (past, future) experiments to be installed in the SHREK cryostat. These experiments, when available, could also be used by external users.

Instrumentation to characterize the type of flow (mainly torques at the turbine level) as well as local measurement (microthermometer, miniature Pitot), can be used. Moreover, the potential user can perform modifications to this apparatus, e.g. introducing device as heated grid inside the von Karman cell, or new sensors, etc.



Scheme of SHREK inner parts

The apparatus @ SHREK

The HeJet experiment

The HeJet facility consists of a round inertial jet driven by a centrifugal pump. It is designed to perform comparative studies of the homogeneous turbulence in He I and He II at high Reynolds number (R_λ= 2500). Comparison with classical results is easy since this kind of flow geometry is very well documented. The cylindrical test chamber dimensions are 50 cm high by 20cm in diameter, and sensors can be situated up to a distance x/Dnozzle = 30 (with currently available nozzle). The integral scale is L = 2 cm and the dissipative scale is a few tenth of micron. HeJet can achieve the same pressure and temperature conditions as SHREK so that it is also a very reliable development and test bench for SHREK sensors. The self similarity of the jet flows is very interesting regarding the test of cryogenic sensors: size effects can be tracked simply by changing the distance from the nozzle to the sensor.

<u>Services currently offered by the Grenoble Helium infrastructure:</u>

CEA-SBT offers two kinds of service: (i) direct access to the facility, and (ii) commissioned research. In the first case the user attends the facility and performs himself the experiment. Technical assistance from the permanent staff at CEA/SBT is provided in the following domains:

- Preparation of the experiment, and adaptation of the facility to the user requirements; in some cases it is necessary to plan well in advance the experiment in case a CAD designer from CEA will be needed to make the necessary adaptations;
- Installation of the experiment in the cryostat, together with electrical connections of the sensors;
- The refrigerator will be run by the permanent staff and the flow conditions adjusted according to the user requirements by the permanent staff, as it is a highly technical work.In the case of commissioned research, everything will be installed and run by our permanent staff according to the specifications given by the users.

Description of work

Modality of access under this proposal:

In the building room where facilities are located, a meeting room and a visitor room are available and can be booked during user stay. Furthermore, the control room is equipped with PC (including internet), provided by the infrastructure.The SHREK and HeJet facilities offer substantial manpower for support of external users. As they are cryogenic installations, some special features of these facilities are to be carefully described to users, so that they can get more familiar with cryogenic constraints. While the time scale for SHREK is typically of the order of month, it is reduced to order of week for HeJet. For SHREK, allocated time can be divided in different periods: (i) assembling and cabling of new components/instrumentation, (ii) vacuum and cool-down of the experiment and (iii) running period; (iv) eventually a warm-up period is necessary before removing the experiment from the cryostat. The running period, dedicated to the experiment itself, is usually of the order of few days, which is generally sufficient to acquire lots of data, as using liquid helium (the fluid with the lowest kinematic viscosity) enables a drastic reduction in time scale. The working periods of external users cannot be chosen freely and they are supposed to coordinate with our own research projects. In case the user wishes to insert a new sensor in the SHREK facility, this sensor should be first tested in the HeJet facility for validation.

Support offered under this proposal:

The SBT permanent staff is composed of fifty persons, all working in the field of cryogenics. Various collaborations enable CEA-SBT to take part in national and international projects such as Large Hadron Collider (LHC) at CERN, ITER, Laser Mégajoule (LMJ), HERSCHEL and SHREK. Taking benefit of this large cryogenic team, unexperienced (in cryogenics) external users will receive a one-day training course on cryogenic constraints. Seniors engineers will supervise the access, while technicians will install the experiment. A designer is available when some adaptations are needed.

CEA buildings are located in a vast scientific area with all the infrastructure necessary for scientific work: more than 6000 scientists (from CEA, CNRS, ILL, ESRF) work in this area. CNRS/Institut Neel is located a few meters away from CEA, with the great expertise in cryogenic turbulence, and LEGI is only a few kilometres from CEA.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
SHREK	1 day	1627.6	60	9	120	3-4
HeJet	1 day	668.46	40	12	136	4

Unit of Access: The unit of access given here is the day. However, concerning the SHREK facility, the minimum time for a project is 5 weeks: 1 week for installation (generally the user should be at the infrastructure); 10 days for cool down and test of all the utilities (presence of the user is not necessary); then 2 weeks minimum are dedicated to the experiment itself; then one week for warm up (user not needed); decommissioning lasts typically 3 days. For the HeJet facility the unit of access is again the day, but a minimum stay is 2-3 weeks: one week for preparation of the experiment; then cool down, and the experiment lasts typically one week. Warm up and decommissioning take one additional week.

Work package 6: Access to Barrel of Ilmenau (BOI)

Work package number	6	**Start date or starting event:**			Month 1		
Work package title	Access to Barrel of Ilmenau (BOI)						
Activity Type	SUPP						
Participant number	3						
Participant short name	TUIL						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *Barrel of Ilmenau*

Location (town, country): *Ilmenau, Germany*

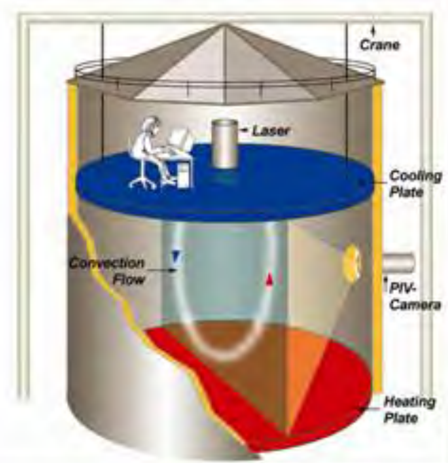
Web site address: www.ilmenauer-fass.de

Legal name of organisation operating the infrastructure: *Technische Universitaet Ilmenau, Institute of Thermodynamics and Fluid Mechanics*

Location of organisation (town, country): *Ilmenau, Germany*

Annual operating costs (excl. investment costs) of the infrastructure (€): 312.761 €

Description of the infrastructure:



Summary:

- *Worldwide largest experiment (7.0 m x 6.3 m) to study highly turbulent convection in air with unrivalled spatial and temporal resolution;*
- *Full measurement access into a very well controlled space of 250 m³ with a regular and easily changeable geometry;*
- *Cutting edge flow measurement techniques: LDA, PIV, PTV, ultra-small temperature probes, infrared camera;*
- *Roughly isotropic turbulence with zero mean velocity in the centre, different from all the wind-tunnel-like facilities.*

The "Barrel of Ilmenau (BOI)" presents a large-scale Rayleigh-Bènard experimental setup to study highly turbulent convection in its pure form, which recently also contributed to more applied research such as testing novel measurement techniques or verifying indoor flow computations.

The fundamental study of convective flows is a very important issue in these days quite relevant to very ongoing questions related to the earth climate, the weather or the properties of the geomagnetic field as well as to a large number of technical applications. Despite of the giant progress in the computational technique it is still quite hard or sometimes even impossible to predict these very complex flows and therefore simplified model experiments are an exclusive way to study their properties. One of the best-known and in the last hundred years intensively explored models is the Rayleigh-Bènard (RB) experiment: an adiabatic box that is heated from below and cooled from above (see figure). The BOI presents such an apparatus in which a turbulent air flow can be investigated up to Rayleigh numbers of $Ra=10^{12}$ ($Ra=\beta*g*\Delta T*H^3/(\nu*\kappa)$). The experimental facility consists of a virtually adiabatic cylinder filled with air and shielded at the sidewall by an active heating system. An electricallly heated plate at the bottom as well as a free hanging cooling plate at the top triggers the convective motion of the air in between. Both plates, with diameters of 7 meters, are carefully designed to maintain a very constant and homogeneous temperature with a deviation below 1 K. A further unique feature of the apparatus is that the distance between the two plates can be varied continuously between 0.05 meters and 6.30 meters by lifting the cooling plate. While experiments using the maximum height are interesting to depict flows with highest complexity and the broadest variation of turbulent structures, the geometry at moderate heights is closer to the geometry of typical geophysical flows. Compared with a similar low-temperature helium facility at ICTP able of achieving higher Rayleigh numbers (up to $Ra=10^{17}$) with rotation, in our facility the access for the measurement of velocity or temperature is very easy and these quantities can be measured with an unrivalled spatial and temporal resolution. The BOI also complements other turbulence facilities like the Göttingen Turbulence Tunnel or the CICLoPE, being basically large wind tunnels, since it enables the user to study thermally driven, highly turbulent flows at very small velocities.

In order to investigate the flow field inside the cell a broad variety of modern flow measurement technique is available: a 3D Laser Doppler anemometer (LDA), a 3D Particle tracking velocimeter (PTV, under development), a 2D Particle image velocimeter (PIV), a 3D hot-wire system, a high resolution infrared camera and a multi-channel system for temperature measurements with temperature probes of the size of 125 µm. The PTV system is planned to be adapted to large measurement volumes within an associated JRA in WP 21. All the experimental data shall be published in a standardized form in the joint database of the EuHIT infrastructure.

<u>Services currently offered by the infrastructure</u>:

Generally we offer two kinds of service in the moment to use the BOI: i) direct access to the facility, and ii) commissioned research. In the first case the user has a direct access to the experiment. Because of the complexity of the technical systems he/she is usually supported by our scientific and/or technical stuff. This is the typical way for experimenters who e.g. want to extend their own measurements into a broader parameter range or who are interested in evaluating novel measurement techniques. In the second case the user simply charge us to perform certain measurements, which then will be done by our own staff. The results are delivered to the user without its personal presence in Ilmenau. This is a typical scenario e.g. for the majority of users dealing in computation and interested in the experimental validation of their numerical results.

Even though access or service activities in this form were not explicitly funded in the past, we already hosted a number of external users including:

- German Aerospace Center Göttingen – Test of a novel 2D-3c PIV system;
- Berlin University of Technology – Validation of a novel numerical code for the prediction of indoor flows;
- Leipzig University – Test of a novel tomographic field measurement system for coherent velocity and temperature measurements;
- Oldenburg University – Test of an ultra-small temperature sensor for boundary layer measurements.

Besides these special applications a broad variety of scientific achievements and conceivable applications can be done, such as the study of Lagrangian turbulence, particle dispersion, mixed convection, reverse RB convection. Alternatively the facility can be used to verify newly developed measurement techniques for the low-temperature helium experiments or to compare numerical simulations with measurements.

Description of work

<u>Modality of access under this proposal:</u>

Once the external user's request is approved, access to BOI can be given in direct or indirect form. Regardless of this form a minimum working period of three weeks will be needed for one stay typically consisting of about one week of preparatory work that includes a training course to introduce the user in the operation of the experiment and the measurement technique, the installation of the set-up and a waiting time of three days to bring the experiment to a steady state. In the second week the measurements can be done and in the third week the user can pre-process his/her data. If measurements at more than one parameter are requested, another full week is needed for each parameter, because of the long settling time of the facility (about three days). A workplace at the experimental facility, about 3 km away from the University campus, and a workplace at our institute with full access to the university infrastructure will be provided during the stay of the external user. Our full stock of measurement technique (listed before) operated by one scientist and one technician will be available to support the experimental work. For the proposed time the complete facility is reserved exclusively for the external user and it does not need to be shared with other working groups.

Support offered under this proposal:

In order to support the external user there is a team of about ten scientists and technicians with longtime experience in experimental and theoretical turbulence research as well as in flow measurement technique. In terms of scientific work (see e.g. du Puits et al. PRL 99, 234504, 2007) and also with respect to the experimental facility and the measurement technique (see paragraph "Description of the infrastructure") the external user will work in a scientific environment presenting the actual state of the art in thermal convection. The experience of previous national collaborations has shown (see paragraph "service currently offered by the infrastructure") that this type of joint-research was always very stimulating for both the external users and the Ilmenau group. In many cases the results have been published in joint papers. Since our institution will also be a node in the development of the data infrastructure (see WP 3), external users will certainly profit from the participation in this network with their own data. They will also be able to use all the options offered by CINECA (see WP 3), e.g. the management of data, the application of standard algorithms or simply the comparison with data from other experiments.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
BOI	1 day	1.489	168	8	224	8

Unit of Access: A unit of access is defined as one day. A typical research project consists of about four weeks. This time covers one week (seven days) of preparatory work including a short training course in which the user will be qualified to operate the experimental facility and the measurement technique. Furthermore, this first week covers the preparation of the measurement set-up and at least three days of waiting time to bring the experiment into a steady state. A period of two weeks of measurement time follows up, typically consisting of some days of measuring and some days of waiting time to adjust different parameters. During the waiting time the data recorded at the measurements will be pre-analyzed. The fourth week finishes the stay in which the measurement set-up is dismantled and the data are implemented into the joint database. The minimum duration of one stay should not remain under three weeks, whereas the maximum duration should not exceed eight weeks.

During the stay our institution offers the user a workplace with phone, fax and Internet and, upon request, a personal computer. For travel and accommodation the user will be funded with 500 € per trip and 100 € per day. This costs will be covered by the European Commission.

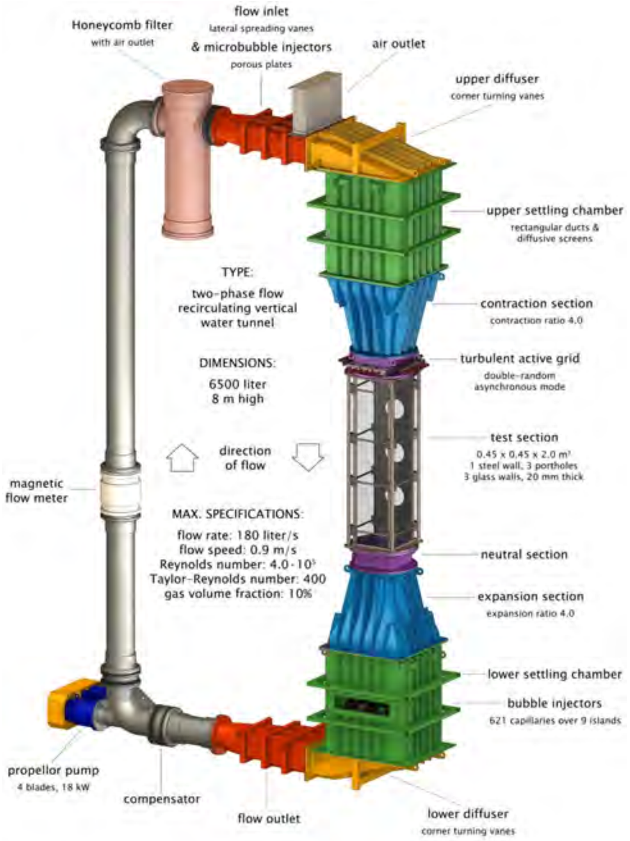
Work package 7: Access to Twente Turbulence Facilities (TTF)

Work package number	7	**Start date or starting event:**			Month 1		
Work package title	Access to Twente Turbulence Facilities (TTF)						
Activity Type	SUPP						
Participant number	4						
Participant short name	UTWE NTE						
Person-months per participant:							

Description of the infrastructure
Name of the infrastructure: *Twente Turbulence Facilities (TTF)* *The TTF consists of two facilities (TWT and T3C), both located in the same building.*
Location (town, country): *Enschede, the Netherlands*
Web site address: *http://pof.tnw.utwente.nl//*
Legal name of organisation operating the infrastructure: *Physics of Fluids Group, University of Twente*
Location of organisation (town, country): *Enschede, the Netherlands*
Annual operating costs (excl. investment costs) of the infrastructure (€): 453,146 € (TWT: 218,441 €; T3C: 234,705 €)
Description of the infrastructure: ***Summary***: • *Two-phase flow system with strong turbulence generated by an active grid (TWT);* • *Unique bubbly and light particle flow regimes (TWT);* • *Single and two-phase turbulent Taylor-Couette flows in an unexplored parameter space (T3C);* • *Advanced measurement techniques: 3D-PTV, 3D-PIV, LDV, optical probes, high-precision torque sensors, hot-film anemometry (phase-sensitive), and outstanding expertise in the field of two-phase flow.* *Two facilities will be included in this work package: Twente Water Tunnel (TWT) and Twente Turbulent Taylor-Couette (T3C). The facilities are equipped with cutting-edge modern measurement techniques: 3D-PTV, 3D-PIV, LDV, torque sensors, optical probes, hot-film anemometry.* The Twente Water Tunnel is an 8m high facility in which strong turbulence (up to a Taylor-Reynolds number of 300) can be created thanks to an active grid. Light particles including bubbles (from now on all called particles) can be injected into the turbulent flow with a concentration up to 10%. The size of the mono-disperse particles can be varied. These light particles rise with the flow and can be observed and followed in the measuring section. The instrumentation includes 3D Particle Tracking Velocimetry, hot-film anemometry, and optical probes. A traverse system enables the movement of the cameras (up to 30 kg) and other devices with the operated mean flow. The control parameters in the TWT are the density ratio between particles and water, the particle size and concentration, and the Reynolds number. The questions that we address with the TWT facility are the Lagrangian particle dynamics in the flow and in particular particle clustering, velocity

and acceleration statistics, effect of particles on spectra and collision rates, average rise/sink velocity of particles, further Lagrangian aspects, and finally also bubbly drag reduction.

The TWT is a unique facility for two-phase turbulence studies. The bubble and light particle regime of the phase space: relative particle density vs. Stokes number is only accessible in the TWT. For these reasons, the TWT should be made accessible to a broader turbulence community.



The Twente Turbulent Taylor-Couette system consisting of two independently rotating cylinders has been operational since 2010. The gap in between the cylinders has a height of 0.927 m, an inner radius of 0.200 m and a variable outer radius (from 0.279 m to 0.220). The maximum angular rotation rates of the inner and outer cylinder are respectively 20 Hz and 10 Hz, resulting in Reynolds numbers up to 3.4 x 10^6 with water as working fluid. With this Taylor-Couette system, the parameter space (Re_i, Re_o, η) can be pushed to (2.0 x 10^6, ±1.4 x 10^6, 0.716 - 0.909). The system is equipped with bubble injectors, temperature control, skin-friction drag sensors, and several local sensors for studying turbulent single-phase and two-phase flows. The inner cylinder is able to sense the skin-friction drag by means of measuring the cylinder's torque with load cells. The dynamics of the liquid flow and the dispersed phase (bubbles, particles, fibers etc.) inside the gap can be investigated with specialized local sensors and nonintrusive optical imaging techniques, enabled by the clear acrylic outer cylinder. The system allows for studying Taylor-Couette flow in high Reynolds number regime and the mechanisms behind skin-friction drag alterations due to bubble injection, polymer injection, and surface hydrophobicity and roughness. Various liquids (including FC-liquids) will be used for the experiments.

We provide the following measurement equipment in the facilities: a 3D-PIV/PTV system consisting of 4 Photron cameras (1k x 1k at 1 kHz). A Dantec LDV system, a Dantec hot-film velocimetry and shear stress system, a Nd-YLF laser with a repetition rate of 20 kHz and high power 100W, a computer cluster for data analysis.

Services currently offered by the infrastructure:

Twente offers adequate support by local technicians and scientists. We offer two types of services: i) in situ research with a direct access to the facilities, and ii) commissioned research with measurements to be performed by our scientists at our facility without the users being present in Twente.

Description of work

Modality of access under this proposal:

For in situ research projects: users should stay in Twente at least 4 weeks to prepare and perform the experiments. The experiments should be done together with our local scientific and technical staff. The users have full access to the facilities and the measurement devices. For commissioned research projects: users are encouraged to stay in Twente at least 1 week to familiarize themselves with the experimental facilities and limitations. The research progress on the collaborations can be communicated through teleconferences.

Support offered under this proposal:

Twente offers adequate support by local technicians and scientists. The physics of fluids group (PoF) is chaired by Prof. Detlef Lohse. The group has 9 scientific staff, about 10 postdoc fellows, more than 30 PhD and master students. The PoF group has outstanding expertise in the field of two-phase flow. The university has its own guest hotel on the campus.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
TWT	1 day	840.16	160	10	336	4
T3C	1 day	902.71	160	10	336	4

Unit of Access: A unit of access is defined as one day. The workload will vary depending on the experiments to be conducted. However, the preparation of experiments usually takes at least 1 week. We require that the users should stay at least 4 weeks to perform experiments using our facilities for the in situ projects (mentioned above). Short-term visits of the users are encouraged to exchange data and intermediate results. The PoF group provides accommodation in the university hotel, office space, and access to the full infrastructure resources for the duration of the stay.

Work package 8: Access to CICLoPE

Work package number	8	**Start date or starting event:**			Month 1		
Work package title	Access to CICloPE						
Activity Type	SUPP						
Participant number	5						
Participant short name	UNIBO						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: CICLoPE (Center for International Cooperation in Long Pipe Experiments)

Location (town, country): *Predappio, Forli', ITALY*

Web site address: *www.ciclope.unibo.it*

Legal name of organisation operating the infrastructure*: Interdepartmental Centre for Industrial Research "Aeronautics" (CIRI Aeronautica), Alma Mater Studiorum, University of Bologna, ITALY*

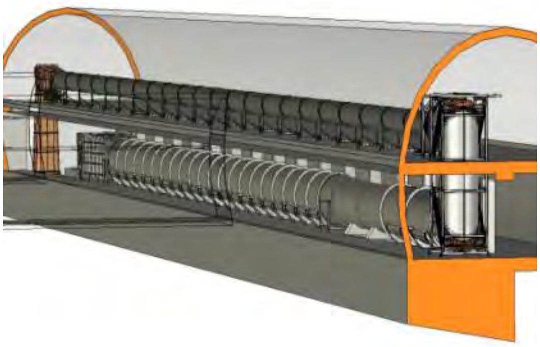
Location of organisation (town, country): Forlì, ITALY

Annual operating costs (excl. investment costs) of the infrastructure (€): 224,304 €

Description of the infrastructure:

***Summary*:**

- *Large scale wind tunnel (0.9m in diameter) to generate turbulent scales fully resolvable with currently available measurement techniques;*
- *High Reynolds number;*
- *Fully developed turbulence in a "naturally" generated flow (120m long, L/D > 110);*
- *Possibility to insert generating "passive" or "active" grids;*
- *Full and easy access to the test section, and to several other places along the pipe development;*
- *Highly controlled environmental conditions (no background noise, stable temperature and humidity).*



The infrastructure allows the worldwide best space and time resolved measurements in turbulent pipe flows. The moderately high Reynolds number is obtained by keeping a large pipe diameter and is sufficiently high to reproduce "real" applications. Since the test section is at ambient pressure the facility is perfectly suited for testing and optimizing novel measurement techniques and may be easily adopted to study various aspects of turbulent flows, e.g. pressure gradients, wall roughness and friction control.

The Centre for International Cooperation in Long Pipe Experiments (CICLoPE) is a research laboratory which allows high resolution turbulent-fluctuation and detailed flow structure measurements. The laboratory is operated with the idea of gathering world-leading scientists in the field of turbulence research to make decisive breakthroughs in the fundamental issues of high Reynolds number turbulence.

The centre was founded and is presently lead by a group of different Universities and research Centres: the University of Bologna, the International Centre of Theoretical Physics in Trieste, the Royal Institute of Technology, Illinois Institute of Technology and Ecole Polytechnique Fédérale de Lausanne, the University of Rome “La Sapienza” and the Princeton University.

Photos of the tunnels which will host the “Long Pipe"

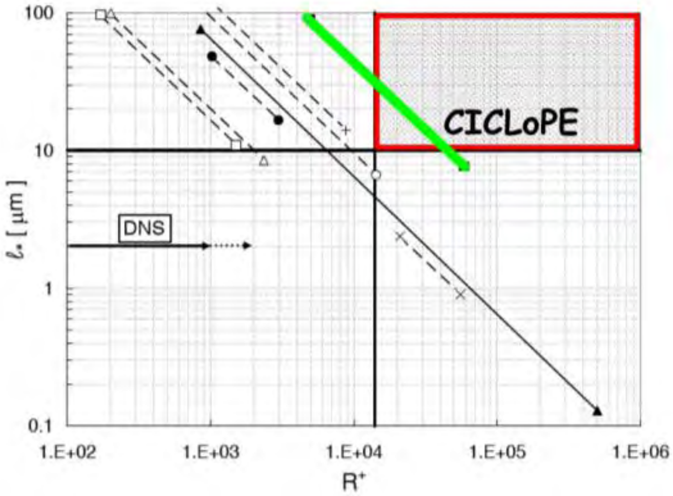
The laboratory is located beside the old factory of the Caproni Industry, which is basically a tunnel complex excavated. In 2006 the tunnels were given by the Air Force to the University of Bologna specifically for turbulence studies. The complex comprises two 130 m long tunnels with a diameter of about 9 m each. The stability of the ambient conditions, viz. temperature, humidity; the complete absence of any background noise (vibration, electrical noise, etc.) are the characteristics making Predappio an ideal site for this laboratory.

The main facility that will be used (the “Long Pipe”, LP) is basically a closed loop wind tunnel operating with air at atmospheric pressure. A closed loop has been chosen since it will allow the flow characteristics to be accurately controlled in terms of velocity, temperature and humidity. The layout resembles an ordinary wind tunnel where the main difference is the long test section which gives most of the friction losses. Many of the various aerodynamic components are the same as those for an ordinary wind tunnel (diffusers, screens, contraction, etc.). The long pipe consists of a 115 m long tube with an inner diameter of 0.9 m and will be made of 5 m long carbon fibre modules held by precision positioning elements.

The definition of the Reynolds number shows that various possibilities exist to obtain high Re: the velocity (U) should be high (but not so high that compressibility effects come into play), the density can be increased (by for instance pressurizing an air flow facility) or the physical dimensions (L) should be large. On the other hand, for the type of studies aimed at, it is necessary to have a facility where the spatial size of the smallest scale is sufficiently large to be resolvable by available measurement techniques. A measure of the smallest scale is the viscous length scale, l^*, and it can be easily shown that for a pipe flow experiment with high Reynolds number, in order to keep large (and measurable) scales, l^*, the diameter of the facility should be chosen as large as possible. Concerning the geometry to be used in the experiment, a unique advantage of the pipe flow compared to all the other canonical cases is that the wall shear stress can be determined directly from the pressure drop along the pipe, which can be measured accurately.

Over the years, there have been a number of pipe flow experiments reported in the literature, but they are mainly at low Reynolds numbers and do not fulfil the criteria above. In the Princeton “superpipe” the high Reynolds number is obtained through highly pressurizing the air used, reaching Reynolds numbers $R+$ of up to 500000. Although the achievable Reynolds numbers in the “superpipe” are extremely high for a laboratory experiment it is at the expense of a very small viscous length scale, i.e., for $R+=500000$ the viscous length l^* is only slightly above 0.1 μm. The scientific results from the “superpipe” include measurements of the mean velocity distribution and new information on the skin friction variation for both smooth and rough surfaces. However, due to the spatial resolution limitations, few reliable turbulence data have been published.

In the figure below the range of various pipe experiments in terms of the viscous length scale as function of the Reynolds number is plotted. The experiments include air, compressed air and water as flow medium. As can be seen, most experiments are for low Reynolds numbers. The "superpipe" covers a wide range of Reynolds numbers but does not satisfy both parameters simultaneously. Although the Long Pipe in CICLoPE has a much smaller Reynolds number range than the "superpipe" it is designed such that the scales within that range will be large enough to be reasonably well resolved by present measurement techniques and therefore it will offer the scientific users the possibility to fully characterize the flow characteristics and the physical phenomena involved.



Range of parameters that can be reached by CICLoPE compared with other from international facilities

(Vertical black line represent minimum Reynolds number with adequate extent of the "overlap" region, horizontal black line represent the minimum turbulence scales length for sufficient spatial resolution)

The Long Pipe is designed to provide a test rig for at least twenty years of basic research in this field. It will also offer the external users the possibility for extensions with more direct impact on applications, such as the study of the effect of non-smooth walls or non-isothermal conditions, the evolution of various non-equilibrium flows, and of flows with some particulates.

The laboratory is presently under construction. Ventilation, electrical and mechanical systems will be positioned and tested before the end of this year. Most of the "Long Pipe" elements have been ready to be installed afterwards. The "Long carbon fibre Pipe" is on the process to be acquired through European Competition. We estimate to be able to place the order before the end of this year. The facility is going to be completed and assembled by the end of year 2012. The classic configuration should guarantee standard time for the set-up and flow quality assessment. The access will be available to external users by January 2014.

Services currently offered by the infrastructure:

The facility is presently under construction and will be available to external users not later than January 2014. Thanks to the different international research groups involved and to the peculiar characteristics of the facility, CICLoPE represent an "ideal" infrastructure open to a large transnational access. Many different research groups, coming from different European and non-European countries have already shown an interest to conduct research in Ciclope. For the purpose of a better coordination, an advisory board has been established in 2011, formed by representatives of the different research groups.

The infrastructure may offer two type of services. The personnel involved may guarantee a direct access to the facility providing all the necessary technical support and the assistance to run the apparatus (this requires some training). Moreover, with the direct involvement of the scientific personnel of CICLoPE, the infrastructure can provide a commissioned research on demand from external groups.

Description of work

Modality of access under this proposal:

There are two different types of access. In case the user requires only the provision of a remote scientific service, i.e. measurement data or data analysis, a short visit (1 week) is required to define the task and the deliverables that must be provided. In case the user prefers to access in person, this can be done in two different ways. The user can prepare his\her own test section at home limiting the period that must be spent in the laboratory. A preliminary visit will be necessary to provide the user with the different interfaces in which he/she must link his experiment. Alternatively, the user will get the complete support in the experiment. In this case the test section can be set up and prepared inside the laboratory. A minimum period of four weeks is required for the final preparation, the set-up and the test execution. A preparation phase is requested and can be done by short visits in the facility and/or by teleconferences. The Research Infrastructure will guarantee full access to the facility, the usage of standard working and measuring devices (pressure probes, hot wires) and the support of the local technical personnel. The Research Infrastructure will provide space for setting up the experiment, data processing without any particular restriction.

Support offered under this proposal:

The Research Infrastructure will be always in charge of the experiment management within the international framework of CICLoPE. This includes planning the measurements with the partners and visiting scientists, ensuring that adequate experimental resources are available in time, setting up the structure allowing to install custom measurement devices and planning the fabrication of custom parts. Scientific support will be offered to all external users by any of the partners involved in CICLoPE. The different partners of CICLoPE have a high level of expertise in high Reynolds number turbulence, experimental techniques and wind tunnel design as well as long track records of successful international collaborations. If asked by the external user, the partners are available to fully interact in both planning, execution of the experiment, and data processing.

A full time technician will be also dedicated to provide technical and logistic support to the users. The laboratory provides full access to the network and the possibility to share offices with the personnel. Open spaces are also offered to store equipment before, during and after the experiments. CICLoPE is located in a beautiful natural environment at a walking distance from the picturesque Predappio Alta where apartments can be easily rented.

Outreach of new users: see networking activities in WP 2a

Review procedure under this proposal: see networking activities in WP 2a

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CICLoPE	1 day	983.79	180	12	360	6

Units of Access: A unit of access is defined as one day. For users that intend to directly use the facility a minimum stay of four weeks will be needed. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. Concerning the time, the first week will be devoted to the instructions to run the experimental facility and the other installation inside the laboratory. The user will either be able to analyse the data for post-processing at the facility or remotely at the home institution. During the stay the institute provides accommodation in the guest houses, office space and access to the full infrastructure resources.

Work package 9: Access to High Rayleigh number Cryogenic Facility (HRCF)

Work package number	9	**Start date or starting event:**			Month 1		
Work package title	Access to High Rayleigh number Cryogenic Facility (HRCF)						
Activity Type	SUPP						
Participant number	6						
Participant short name	ICTP						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *High Rayleigh number Cryogenic Facility (HRCF)*

Location (town, country): *Trieste, Italy*

Web site address: *http://www.ictp.it (Specific facility web site under construction)*

Legal name of organisation operating the infrastructure: *The Abdus Salam International Center for Theoretical Physics*

Location of organisation (town, country): *Trieste, Italy*

Annual operating costs (excl. investment costs) of the infrastructure (€): 191,996

Description of the infrastructure:

***Summary**:*

- *Very High Rayleigh number convection up to 10^{17};*
- *Flexibility in He gas properties providing a range of Ra in single apparatus of up to 12 decades;*
- *Strong Rotation, Taylor numbers up to 10^{15};*
- *Variation of aspect ratio from 0.5 to 4 at high Ra (for aspect ratio 4 Ra up to 10^{13});*
- *Close collaboration with Elettra/ICTP Laser Laboratory at Elettra in further development of optical interrogative techniques such as LIF for cryogenic helium.*

The facility offers the highest Rayleigh numbers achievable anywhere in the world under strictly Boussinesq conditions, with nearly ideal boundary conditions and varying aspect ratios up to 4. State of the art micro-thermometry, in addition to development of cryogenic LIF, and the possibility to apply precision-controlled rotation is important for fundamental studies in convective turbulence, with applications in geophysics. Development of new measurement techniques for liquid heluim, such as particle tracking methods in super fluid flows, will constitute one of the focal points of the research at this facility.

The High Rayleigh Number Cryogenic Facility has as its centrepiece a thermal convection cell with maximum allowable height of 1 meter and 0.5 meter in diameter. The facility can cover a range of 12 decades of Rayleigh numbers, all in the turbulent regime, up to a world-record high of 10^{17} under nominally Boussinesq conditions. It is the largest such facility currently in existence anywhere in the world. The large range of Rayleigh numbers, crucially important for discerning scaling relations, is accomplished by varying the operating point of the cryogenic helium gas used as a working fluid in the facility, which allows the boundary conditions to remain constant. The maximum Rayleigh number puts the experiment at the forefront of experimental convection research, especially in terms of making additional contact with geophysical and astrophysical problems of interest. The cryostat has considerable flexibility with a central shaft which permits access for operating movable temperature probes, adding grids, etc. to the sample space accompanied by an additional top heated plate adapted and available for this purpose. For this reason the range of applications can be extended to isothermal grid flows for instance.

Another attribute of the HRCF is its nearly ideal boundary and operating conditions; namely, 1) a hard, cryo-pumped vacuum that insulates the experiment from parasitic heat inputs due to conduction or convection in the surrounding space;

2) truly negligible heat leakage from radiation;

3) large thermal conductivity of the horizontal heated bounding plates compared to the fluid making nearly negligible any corrections due to the finite plate conduction as the dimensionless heat transfer becomes very large.

For (3) above, there is at least one order of magnitude advantage over similar room temperature experiments using water or air. The Prandtl number is near unity and can be constant over many decades of Ra. Large aspect ratio cells-- important for applications to geophysical problems—can be utilized in this facility without sacrificing high Rayleigh number. Presently, the cryostat sits on a rotating platform, capable of rotations speeds up to 60 rpm, in both directions, and with a maximum acceleration of $2x10^5$ deg s^{-2} and with speed accuracy to within 1%. In non-dimensional terms, this allows access to very large Taylor numbers ($Ta>10^{15}$) characteristic of atmospheric flows. With liquid in the cell, it is straightforward to maintain stably stratified conditions under strong rotation, so that turbulent zonal flows with planetary beta-effect can be studied. This work has already been proposed by Nazarenko (Warwick) and Galperin (USF) for optimization in the ICTP Facility, complementing similar turbulence research being conducted at the large Coriolis facility in Grenoble.

Instrumentation: Germanium resistance thermometers are used for averaged temperature measurements in addition to micronic Neutron-Transmutation-doped (NTD) crystals for measuring fluctuations of temperature in the bulk. Micron-sized thin film devices are also available for such fluctuation measurements. Mean pressure is measured using a series of high-precision Baratron gauges. The Facility and its collaborators have extensive experience in developing Particle Image Velocimetry (PIV) for use in liquid helium both above and below the superfluid transition temperature. In addition, in conjunction with scientists in the Elettra Synchrotron Facility, techniques involving the fluorescence of helium molecules as tracer elements are to be developed in parallel. This technology, relying on the excitation of helium molecules briefly to metastable states, would allow local measurements of velocity with a tracer particle that is more truly non-intrusive. By functioning also in the gaseous phase of helium, the technique would allow the exploitation of the large ranges of Reynolds and Rayleigh numbers available. With its direct partnership with the ICTP/Elettra laser laboratory, the African Laser Atomic Molecular and Optical Sciences Network (LAM), the *Istituto Nazionale di Fisica Nucleare* (INFN), and the Elettra Synchrotron Laboratory, the cryogenic facility affords the possibility to make considerable headway in this area.

Services currently offered by the infrastructure:

The facility welcomes both theorists and experimentalists throughout Europe and the rest of the world who wish to have the unique access available at ICTP to ultra-high Rayleigh number and high Taylor number convection in either small or large aspect ratios. We are receiving notification of intent from scientists around the world to use the ICTP facilities. From 1970 to the present, over 34 thousand European scientists have come to ICTP spending 18,750 person-months at the Center. In addition, ICTP allows connections to be made North-South and East-West between the developed and developing world. By coming to ICTP, the best researchers of the developing world not only benefit from a world class research environment, but by establishing collaborations in research while here and after returning, they themselves help strengthen the state of science in Europe. ICTP's Diploma program also contributes to bringing the best physics and math students in the developing world to universities throughout Europe.

The facility resides at the Elettra Synchrotron Laboratory in the Area Science Park, Trieste. The presence of 23 beam lines and their supporting laboratories, in addition to the neighboring CNR, provides a stimulating research environment and access to many specialized services. By holding or hosting numerous scientific activities, including advanced schools, conferences and workshops continually throughout the year, the ICTP provides to all visitors a stimulating research environment. In addition there are Masters degree programs in conjunction with neighbouring SISSA, and a Ph.D. program in environmental Fluid Mechanics jointly conducted between the ICTP and the University of Trieste that provides for degree training in research directly connected to the proposed activities of the ICTP Cryogenic Facility. A superb scientific library, one of the finest and most extensive in all of Europe, is also available to scientific guests at ICTP.

Description of work

Modality of access under this proposal:

The users will be allowed considerable freedom to perform their experiments, limited only by the capabilities of the laboratory and the rules governing its operation. During the time a user is at the facility he/she will have priority over the equipment which is necessary for the successful operation of the program. Expert assistance will be supplied to visiting scientists for operation of the laboratory and apparatus, so the degree of involvement can be largely supervisory or as much “hands-on” as desired.

Support offered under this proposal:

Users can avail themselves of both the laboratory for and also the many services provided by the host institution, the Abdus Salam ICTP. These include one of the most extensive and up-to-date scientific libraries in all of Europe, with substantial electronic access to scientific literature, as well as high speed computing access and assistance. Situated in the Area Science Park, the experimental facility offers interaction with hundreds of scientists in all areas of research, from bio-physics to material research to chemistry, oceanography, and optical sciences. Associated with these scientific activities are numerous technical persons whose expertise can be easily requested to supplement the assistance of the dedicated laboratory technician. At the Elettra Synchrotron laboratory itself, there are several well-equipped machine shops capable of making modifications with little delay time so that experimental activities need not be put on hold for small repairs or modifications. Personal computer accounts, allowing researchers to access both the electronic and paper library, are available upon arrival. The entire ICTP is set up for free wireless networking as well.

The cost of housing is largely subsidized and available at two ICTP guest houses at much reduced rates compared to commercial hotels. This housing is open to all visitors to ICTP facilities and can accommodate up to 274 persons daily. Longer term stays can be accommodated with area apartment rentals, for which ICTP has multiple agreements with landlords and rental agencies through its own well-staffed Housing Office to provide for intermediate stays of from three weeks to one year.

Outreach of new users: see networking activities in WP 2.

Review procedure under this proposal: see networking activities in WP 2.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
HRCF	1 day	526	200	6	300	3

Unit of Access: The unit of access given here is one day although the expected measurement time would be about 3-6 weeks (with sensor placement and cool-down taken care of by in-house personnel prior to arrival of guest scientists).

Work package 10: Access to CERN Cryogenic Turbulence Facility (GReC)

Work package number	10	**Start date or starting event:**			Month 1	
Work package title	Access to CERN Cryogenic Turbulence Facility (GReC)					
Activity Type	SUPP					
Participant number	7					
Participant short name	CERN					
Person-months per participant:						

Description of the infrastructure

Name of the infrastructure: *GReC @ CERN Facility : GReC jet experiment*

Location (town, country): *Geneva, Switzerland*

Web site address: *http://public.web.cern.ch/public/Welcome.html*

Legal name of organisation operating the infrastructure: *CERN, European Organization for Nuclear Research*

Location of organisation (town, country): *Geneva, Switzerland*

Annual operating costs (excl. investment costs) of the infrastructure (€): 1,147,979 €

Description of the infrastructure:

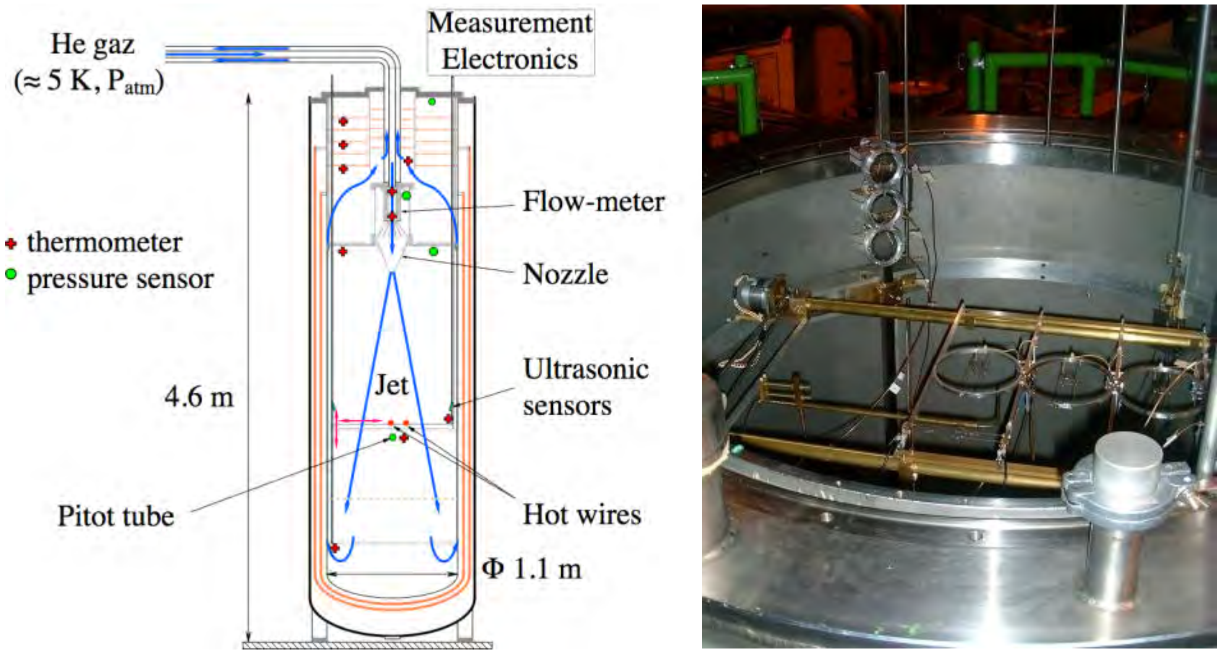
***Summary**:*

- *Very High Reynolds (up to 2x10^7) in axisymetric jet (GReC, R_λ up to 6000);*
- *The whole range of flow scales, down to the Kolmogorov length (few microns) accessible through movable, fast response, hot and cold wire anemometry;*
- *Laboratory size experiments allowing modification and machining on their parts with standard laboratory equipment;*
- *Flow properties well validated by previous experiments with various sensors (acoustic scattering, hot wire,…).*

GReC@CERN takes advantage of the very low kinematic viscosity of gaseous He and a dedicated kilowatt (cooling power at 4 K) cryogenic refrigerator to generate laboratory-size flows reaching very high Reynolds numbers. The flexibility offered by this approach allows exploring systematically the jet flow, which is a paradigm of open turbulent flows.

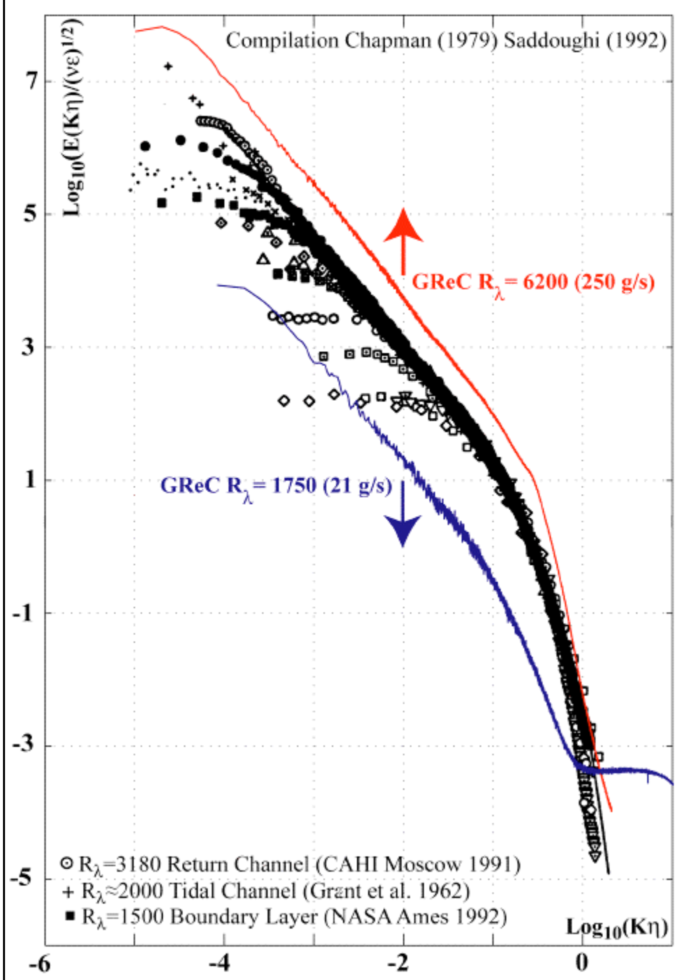
In the context of the EuHIT TNA programme, CERN will offer access to a cryogenic installation unique in Europe in terms of power and performance. Operated in a stand-by duty service, the installation works without interruption throughout the year, except for the two weeks of end-of-year closure of CERN and four weeks of yearly maintenance for each installation. It is hosted in the CERN SM18 cryogenic test facility. Its principal use is for the R&D, test and commissioning work on cryogenic components for High Energy Physics accelerators and experiments (like superconducting magnets or accelerating superconducting cavities operating down to 1.9 K). The installation is part of the unparalleled CERN cryogenics inventory, which includes 8 refrigerators with 18 kW power at 4.5 K, 2 refrigerators with 6 kW at 4.5 K and 14 others with power from 0.1 to 1.5 kW at 4.5 K.

These characteristics make at present of CERN the absolute world-wide reference for large-scale cryogenics infrastructures, in terms of both installations and technical knowledge available on site. Many users from institutes collaborating to the LHC programme or to other HEP activities traditionally access the CERN cryogenic park every year. In the past few years, a group of researchers from different institutes in Grenoble proposed to CERN the use of one 6 kW at 4.5K refrigeration plant for dedicated turbulent experiments: a special removable coaxial transfer line was designed, built and connected to a large cryostat used for the tests of cavities, and the GReC installation (Grands Reynolds Cryogéniques) was born. Although the extremely reduced access time available at that time, GReC successfully met the requirements of producing a controlled free jet with an integral Reynolds number Re_D ranging from $7.7x10^5$ to $1.01x10^7$ (Re_λ from 1750 to 7100) in extremely stable conditions: <±5% in mass flow and ≤±1% in temperature and pressure.



Left : Sketch of the GReC experiment. Right : picture of the inside of the jet chamber, with probes.

The importance of cryogenic He flows for the study of turbulence in high Reynolds regimes, as an invaluable complement to the experimental studies conducted on "conventional" fluids, was strongly reaffirmed – if need there was - during the 3-days EuTuCHe international workshop held at CERN in April 2007 (http://indico.cern.ch/internalPage.py?pageId=3&confId=11920). More than 60 researchers from 10 countries gathered to discuss the achieved and potential results deriving from the use of helium at cryogenic temperatures for turbulence analysis, and their connections and synergies with the studies conducted in room temperature fluids. It was clear that the whole turbulence research community would largely benefit from widened access to state-of-the-art large-scale cryogenics installations.



In red and blue: velocity power spectra measured in the GReC experiment at R_λ = 1750 and 6000

Notwithstanding the workload already charged on CERN cryogenics park, CERN is offering a unique opportunity to direct and indirect access to the GReC installation to a number of European researchers, up to now prevented from benefiting from the advantages of cryogenics flows due to the high costs and complex technologies involved. Fully conscious of the role that it can play in this direction, CERN has accepted to reserve a non negligible fraction of the yearly access to this installation to groups of turbulence researchers in the context of a TNA programme

Beside the direct scientific advances that will be brought by this new programme, it is also expected an important cultural impact on the participants. Not only through the dissemination of technical knowledge relevant to cryogenics and its use for science, but also, in a more general sense, through the direct contact with the scientific environment of HEP at CERN, a real melting pot of scientific, technical and cultural skills. The “hands-on” contact with the world’s largest international research centre, where scientists from different institutes and countries cooperate in a structured and integrated way to reach the required critical mass for fundamental science advances, each one still preserving his own autonomy and visibility, will certainly produce positive effects in terms of culture of structured scientific cooperation.

<u>Services currently offered by the infrastructure:</u>

CERN offers direct access to the GReC jet experiment: the user attends the facility and installs himself his experiment. CERN is providing technical assistance in the following domains:

- preparation of the experiment and advises for adaptation to the user requirements;
- installation of the experiment in the cryostat (handling);
- operation of the refrigerator (exclusively by CERN) and adjustment of the flow conditions according to the user requirements.

Since its foundation in 1954, CERN’s membership has grown from 12 to 20 European states. Today, additional nations from around the globe also contribute to and participate in CERN’s research program. Altogether, Cern’s program involves regular access to its different facilities from 10,000 researchers (laboratory users) from over 500 institutes in 68 countries. Three internal hostels are present on CERN site, providing a global offer of 332 single rooms and 81 double rooms of different levels. This guarantees to researchers accessing CERN facilities from outside a practical and affordable possibility of housing on site during their stay.

Description of work

Modality of access under this proposal:

The access to GReC will be planned after the approval of user's application and safe slots will be reserved accordingly in the CERN test program for the SM18 test facility and the work plan of the technical teams operating the installations. Provision for the specific preparation work for each access (e.g. engineering and construction of special interfaces required or other mechanical works) has been already included in the definition of the user fees. The access time properly defined will start with the conditioning and stabilization to the required operating conditions of the cryogenic line by the CERN operating team. This phase usually takes some days and do not require the direct presence on site of the group(s) accessing the installation. One expert of the group(s) will probably be present one or two days in advance with respect to the start of the measurement phase, in order to verify with the CERN crew the flow conditions and the interfaces (and modifies them, if needed). It is expected that at the end of the first week the requested experimental parameters be achieved and stabilized: this would start the phase of measurement (preparation and execution) and data collecting. In this phase the group(s) accessing the installation will operate the measurements autonomously. At the end of the data-taking phase the data will be provided to the user group(s) and the re-conditioning of the cryogenic line will start. All activities will be carefully recorded and the log of the experimental conditions and of the measurements taken will be readily made available to the whole community. The diffusion of the raw data and the publication of the scientific results will follow the policy for data sharing and Intellectual Property protection of the EuHIT consortium.

Support offered under this proposal:

Following the well-established tradition of service providing at CERN, the researcher accessing CERN cryogenic infrastructures within the Trans-National Activities of the Eu-Hit collaboration will find on site an optimal logistic situation to support their research activities. Rooms in the internal hostels can be reserved and network access will be provided during their stay. A one or two day training course on specific provisions and constraints linked to the work on cryogenic equipment will be offered to external users with no or poor previous experience in cryogenics. The CERN crew dedicated to the operation of the specific installation accessed will provide continuous support during the whole time, including possible engineering needs.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
GReC	2 weeks	49,912.14	1 unit / year	4 / year	70 / year	3

Unit of Access: The whole activity is expected to extend over a two-week period (weekends included), which defines the Unit of Access for the GReC installation: one week with a low-flow of helium allowing preliminary test measurements and another week at maximum flow rate sent to GReC installation for the final measurements.

Work package 11: Access to the Coriolis rotating platform at LEGI (Coriolis)

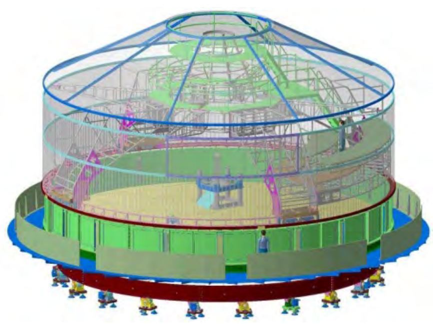
Work package number	11	**Start date or starting event:**				Month 1	
Work package title	Access to the Coriolis rotating platform at LEGI **(Coriolis)**						
Activity Type	SUPP						
Participant number	8b						
Participant short name	CNRS-b						
Person-months per participant:							

Description of the infrastructure
Name of the infrastructure: *Coriolis rotating platform at LEGI*
Location (town, country): *Grenoble, France*
Web site address: http://coriolis.legi.grenoble-inp.fr
Legal name of organisation operating the infrastructure: *Laboratoire des Ecoulements Géophysiques et Industriels (LEGI) of the Centre National de la Recherche Scientifique (CNRS) e*
Location of organisation (town, country): *Grenoble, France*
Annual operating costs (excl. investment costs) of the infrastructure (€): 311,370

Description of the infrastructure:

Summary:

- *Rotating platform with a tank 13 m in diameter and 1.2 m in height;*
- *Unique installation for the study of turbulence influenced by rotation and/or density stratification;*
- *Particle Imaging Velocimetry (PIV) systems for time resolved velocity fields in both horizontal and vertical planes of up to 3 m x 4 m in size.*



The « Coriolis » rotating platform, equipped with a tank 13 m in diameter and 1.2 m in height, is a unique installation for the study of turbulence influenced by rotation and/or density stratification. This is a key feature of turbulence in natural environments, and in some industrial flows. These effects induce strong turbulence anisotropy and wave-turbulence interactions that are of great interest for the fundamental understanding of turbulence.

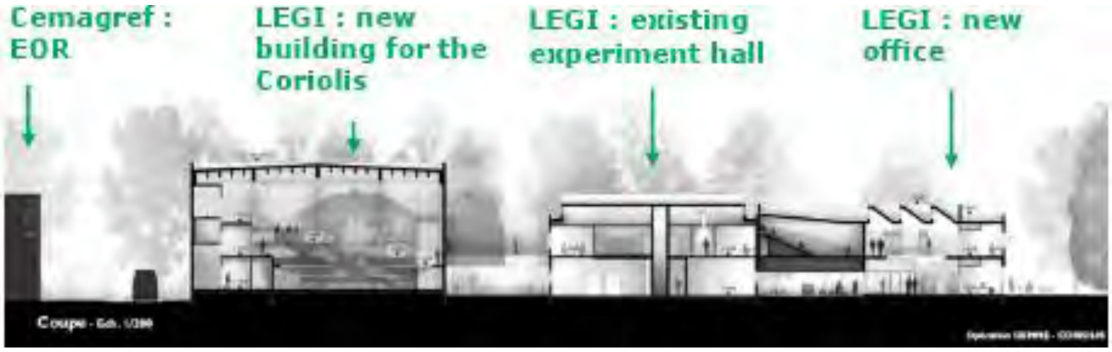
The total weight of the platform is 150 tons and it supports an extra load of 150 tons. Its rotation period can be set with high stability between 10 and 1000 s. The tank can be filled with homogeneous or density stratified water. Stratification is made by filling the tank with a computer controlled mixture from two underground tanks with specified salinity and temperature. All the instruments, including lasers and computers, stay on the platform, where electricity, water and computer network are available, like in an ordinary laboratory. Researchers can stay on the platform during rotation.

Various devices can be used to produce turbulence, such as towed grids, a hydrodynamic loop, topography models to reproduce boundary layers and wakes in the natural environment. Thermal convection can be produced by heating with a 20 kW power generator. Particle Imaging Velocimetry (PIV) systems provide time resolved velocity fields in both horizontal and vertical planes of up to 3 m x 4 m in size, with a relative precision 2%. The laser sheet position can be scanned in a volume, providing three-dimensional three-component velocity fields, a quite unique feature for such large scale systems. Local probes are also available, like ultrasonic velocimeters, salinity and temperature sensors. Mechanical displacements and data acquisition are computer controlled. The installation is also quite appropriate to Lagrangian studies, using various flow tracers or particles, and it will rely on the developments planned in the corresponding JRA.

Services currently offered by the infrastructure:

The Coriolis platform has initiated a successful oceanographic modelling activity in Grenoble, now at the forefront of 'operational oceanography', aimed at forecasting the state of the sea. The installation has been also used to interpret field studies, in particular through European programs MAST and recent NSF grants from USA. It has participated in the EEC access program since 1992, with a total of 40 visiting teams. In total 10 access projects have been completed during the four years of Hydralab III, involving 56 users from 15 different countries, with a majority of first time users. Some further access is scheduled within the current Infrastructure Initiative Hydralab IV, devoted to the water in the environment. This project, ending in 2014, involves a scientific community quite different that in the present proposal.

The Coriolis platform has provided unique information on the influence of rotation on turbulence (Moisy et al. 2011, *J. Fluid Mech.*), and on the combined effects of rotation and density stratification (Praud, Fincham & Sommeria 2005, *J. Fluid Mech.*). This is relevant for the turbulence in the atmosphere and the ocean. The spontaneous generation of a mean flow by random convective eddies, as observed in the zonal flow of the Giant planets, has been demonstrated in one of the access projects (Read et al. 2004, *Geophys. Res. Lett.).* This result has been displayed on the cover page of the journal, and highlighted in the section 'News and Views' of the journal *Nature*. Such laboratory experiments also help to grasp the source of natural fluctuations in complex multiscale systems (Sommeria, 2001, *Nature*). The installation is particularly suited for analyzing boundary effects. Wakes over submarine canyons and sea mounts have been successfully reproduced in recent access projects (Boyer et al. 2005, *J. Phys. Ocean,* Johnson et al. 2006, *Proc. Royal Society*, Wahlin et al. 2008, *Deep Sea Research*).



Cut-through view of the new building under construction for the Coriolis platform

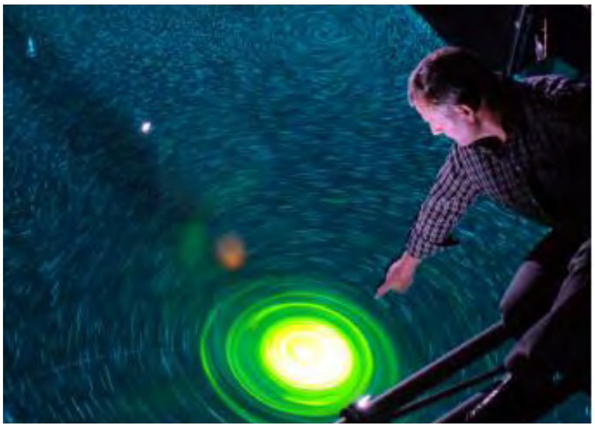
The installation has been dismounted in 2011 and will be fully renovated and re-installed in a new building under construction next to the main experimental laboratory of LEGI (see figure above). The new installation is scheduled to be ready in mid 2013. The new position will favour a closer connection with the turbulence team of LEGI, which coordinates the WP24 of EuHIT 'particles and fields'. A new circular channel configuration will be set-up to study sediment transport and the morpho-dynamics of river beds in the absence of end effects.

Description of work

Modality of access under this proposal:

Once a user group has been selected, the leader is invited to visit the installation to set the details of the experiments. The meeting involves the technical staff of the installation and a local contact scientist, who later serves as a mediator with the technical team. In many projects, scientific collaboration is pursued beyond this minimum help, leading to common publications. A detailed description of the project is written, with sketches and a time table of experimental runs. The appropriate equipment is then designed and the needed supplies are ordered.

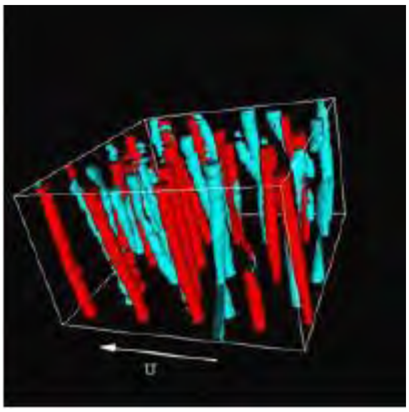
The experiments are scheduled according to the requirements of the visitors and the occupation of the installation. A project typically requires one week for finalizing the set-up, and two to five weeks of experiments (five weeks total in average). At least one group member is asked to stay during the whole period of access for good co-ordination. At least two visitors are requested to be present at any time during the experiments, so that the data can be processed and checked without delay. Additional collaborators often come for shorter periods. Facilities for video conferencing and remote access of collaborators will be developed.



Vortex dynamics visualized by a laser sheet, used for combined Particle Imaging Velocimetry (PIV) and Laser Induced

During the whole duration of access, the visitors have full control of the installation, get prompt help from at least one engineer, as well as from local scientists. After their experiments, user groups have free on-line access to the computer network or they get the data on a mobile disk, and can process their data from their home institution. They have also the possibility to come again for further processing and discussion of their results, within the limits of the available travel budget. User groups are of course encouraged to publish their results in conferences and international journals. Results are advertised on the website of the infrastructure, and will be presented in the Joint EuHIT User Meetings. The raw data are stored and preserved at the infrastructure. They are made publicly accessible in a web server after a two year period of exclusive access by the user group. Further improvement of data documentation and remote access procedures is presently developed within Hydralab IV, and it will be further improved within the JRA and networking activities of EuHIT.

Sand dunes produced in the circular channel configuration



3D vorticity fields showing the emergence of coherent vortices in rotating stratified turbulence (obtained by PIV in a volume, field of view 2.5 x 2.5 x 0.6 m^3))

Support offered under this proposal:

An engineer is in charge of the installation, working full time on its maintenance and instrumentation, with an outstanding experience of its capabilities and related measuring techniques. Additional support is provided by the technical team of LEGI for mechanical mounting, instrumentation, and computer network. The technical team is fully involved in the design of the experiments, and is responsible for their installation. At least one engineer is permanently available to assist the visitors during the regular working time. Since the installation can support only one experiment at a time, much attention can be provided to the user groups.

All techniques are taught to the visitors, including image processing and PIV. Processing programs developed by the local team are available as free-downloadable software (see web page). The contact scientist, but also PhD students and/or postdoctoral researchers working directly on each installation, provides wide scientific expertise.

During their stay, the visitors are provided office space with computer and communication facilities (telephone, fax, mail), same as local scientists. They can use the library of the laboratory and get on-line access to most scientific journals. They are often invited to give a seminar about their own research, and enjoy a very stimulating scientific environment. Visitors get help to find appropriate housing. They have access to the restaurant of the personnel, which favours local exchanges. After their stay, the visitors can get a copy of their data, and remote access to the computer resources of the installation for five years.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan:

Short name of installation	**Unit of access**	**Unit cost**	**Min. quantity of access to be provided**	**Estimated number of users**	**Estimated number of days spent at the infrastructure**	**Estimated number of projects**
Coriolis platform	day	1557	90	15	270	3

Unit of Access: The unit of access being offered is an 8 hour working day in the installation, corresponding to the full use of the installation with support of the technical staff available and costs of consumables. The availability of experienced specialists to support the experiments when needed, makes the efficient use of these costly facilities possible. Support provided for each access project includes:

- Assistance for the detail design of the project, design and fabrication of the specific model set-up;
- Preliminary mounting of the set-up and instrumentation before the first access day;
- Support in finding accommodation during preparatory visit and access;
- Providing office space, communication tools and computer accounts to the visiting group;
- Training for the use of the installation, its instrumentation and data processing tools;
- Dismounting the set-up after the last operating day;
- Unlimited online access to the data and processing programs during two years after the completion of the project.

The travel and subsistence costs (T&S) cover the expected travel from the home institutes of the users to the facility, the lodging of the users during their stay at the facility and daily subsistence allowance, but also T&S-costs of the facility manager to HYDRALAB participant meetings. It will also include the T&S costs related to the Joint User Meeting organized with all participants of EuHIT. Finally a travel budget is also reserved for the participants of JRA to come at the facility for tests of their new prototypes of instrumentation.

Work package 12: Access to LML boundary layer wind tunnel (LML)

Work package number	12	**Start date or starting event:**			Month 1	
Work package title	Access LML boundary layer wind tunnel (LML)					
Activity Type	SUPP					
Participant number	8d					
Participant short name	CNRS-d					
Person-months per participant:						

Description of the infrastructure

Name of the infrastructure: *LML boundary layer wind tunnel*

Location (town, country): *Villeneuve d'Ascq, France*

Web site address: *http://lmlm6-62.univ-lille1.fr/lml/?lang=EN&page=144*

Legal name of organisation operating the infrastructure: *Laboratoire de Mécanique de Lille*

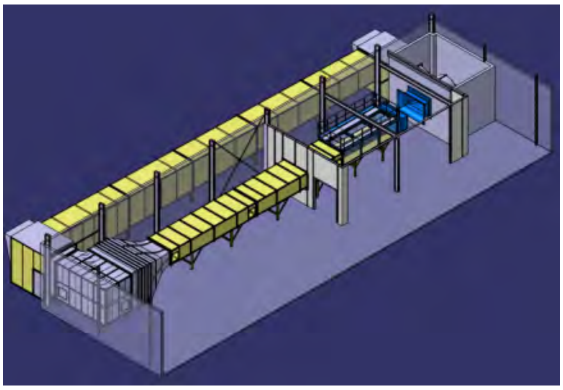
Location of organisation (town, country): *Villeneuve d'Ascq, France*

Annual operating costs (excl. investment costs) of the infrastructure (€): 134,743 €

Description of the infrastructure:

Summary:

- *High Reynolds number turbulent boundary layer at large scale;*
- *Flow resolvable over all scales by current measurement technology;*
- *Advanced Stereo and Tomo PIV expertise of the operating team;*
- *Both flat plate, favorable and adverse pressure gradient boundary layer available;*
- *Study of boundary layer separation possible.*



The facility is unique in Europe in terms of size and Reynolds number and in terms of the optical measurement technology developed around it.

The LML boundary layer wind tunnel was built in 1993. The aim was to build a modern world class facility to enable the study of turbulent boundary layers at high Reynolds number with the most advanced measurement techniques. For that purpose, the wind tunnel had a unique 20 m long test section, to allow thick boundary layers to develop (boundary layer thickness is about 30 cm at the end of the test section, compared to a few mm on an aircraft). This allows of course very detailed near wall measurements. Both velocity (±1%) and temperature (±0.2C) are regulated to allow extensive and precise hot wire measurements. It is also made fully transparent in the last 5 m of the test section, to allow easy setting of any kind of optical measurement.

The present characteristics of the facility are:

- Free stream velocity 3 to 10 m/s

- Maximum boundary layer thickness 30 cm

- Reynolds number range 8 000 to 20 000 based on momentum thickness (fig. 1).

Different models are available to allow studies on boundary layers under pressure gradient (fig. 2). Multiple hot wire anemometry, hot wire rakes, stereo and Tomo PIV, standard and high repetition PIV have been used extensively in this facility thanks to its unique optical accessibility.

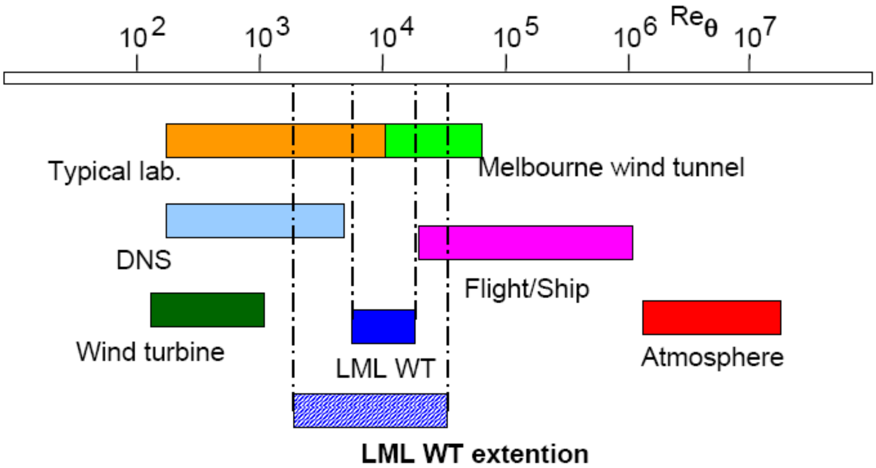


Figure 1. Position of the LML wind tunnel in the Reynolds number range of different facilities and applications.

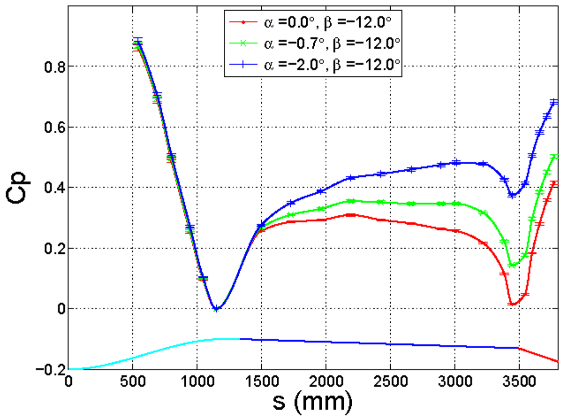


Figure 2. LML-AVERT ramp in the wind tunnel (left) and pressure distribution along the model for different flat plate angles.

The facility provides the following measurement equipment for use with the facility:

- Single and x wire anemometry with traversing system, fully automatized and coupled to the regulation of the velocity and temperature of the wind tunnel to ensure accurate measurement;
- Three high sensitivity microphones from B&K, conditioning electronics and data acquisition system;
- Six unsteady pressure transducers from Endevco, conditioning electronics and data acquisition system;
- Two stereoscopic PIV systems based on 2k x 2K Hamamatsu cameras at 4Hz;
- One tomo PIV system based on 2k x 2K Hamamatsu cameras at 4Hz;
- One high repetition Stereo PIV system based on 2 Phantom V9 cameras allowing 1000x1000 stereo PIV records at 1kHz with a field of view of 10x10 cm^2.

Services currently offered by the infrastructure:

Generally we offer two types of services: i) In situ research with a direct access to the facility. In this case the user in person will be conducting the research at our facility. To these researchers we offer practical guidance as well as technical assistance on the part of our scientific and/or technical staff, which is necessary due to the high complexity of the experimental installations. In preparation of the project the user will work with the facility lead scientist and supervisor, the facility engineer, the manager of the computational support and the facility technician. ii) Commissioned research. In this case, the user can demand for certain measurements to be performed at our facility without being actually present in LML. In this case our personnel will carry out the requested measurements and transmit the results to the user. This type of research is particularly appealing to the users from the computational fluid dynamics community who are interested in validating their numerical data in practical situations.

Description of work

Modality of access under this proposal:

The facility is well suited to perform extensive studies of high Reynolds number boundary layers on flat wall (physics studies), with possible adverse pressure gradient and separation. Flow control experiments can also be performed, either for drag reduction or for preventing separation. It will be open 50 days/year to European partners who want to perform specific experiments for which the facility is well suited. As mentioned above, user access can be given in direct or indirect form. For indirect users ideally a 1-week stay at the facility is required to hand over the data and to familiarize the user with the equipment and the limits and systematic errors of the experiment. For direct users a minimum stay of four weeks will be needed for each individual project. At least three months before the work is to be conducted the user will need to have a preparatory meeting either in person or per teleconference with the facility manager and the facility technician. Requirements and any possible modifications of the experimental system will be defined. In preparation, the institute’s staff will conduct any necessary modifications of the experiment and experimental equipment and measurement systems. During this time, short-term visits of the users are encouraged to ensure proper preparation of the experiments. This can include work by the electronic and mechanical workshops, as well as the scientific and computing staff. When the users arrive, the first week will be devoted to safety training, the instructions to the experimental and computational facilities, and the installation of the experimental system inside the facility. The workload of course, will vary from experiment to experiment. Then the first test runs are conducted. Depending on the requirements the user will then conduct the necessary experiments over the next days and weeks. The user will either be able to analyse the data for post-processing at the facility or remotely at the home institution. It can be expected that post processing, especially of the PIV data will take at least a week.

Support offered under this proposal:

During the stay, office space and full access to the infrastructure of the institute will be given. As described above, the facility scientist, engineer, computer specialist, facility technician and the workshops of the laboratory will support the users. In addition, the users will be working in a very stimulating research environment. The team in charge of the facility is composed of 1 professor, 2 assistant professors, 2 CNRS researchers and 2 CNRS research engineers. Their expertise covers turbulence, optical measurement technology, and CFD. The team has a high level of international visitors and is managing the international master program in turbulence (http://imp-turbulence.ec-lille.fr/).

Lecture rooms and a cafeteria are available in the wind tunnel building and the well-equipped library is within 500m. The scientists of the LML will also be part of the node that develops the DLTD-Service (see WP 17). The local expertise (http://lml.univ-lille1.fr/db/) based on previous EC projects (WALLTURB, AVERT, DESIDER, AEROMEMS, EUROPIV…) will help users in the management of their data and the provision of the analysis tools on the local and EuHIT computing infrastructure.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
LML	1 day	561,43	80	8	160	8

Unit of Access: A unit of access is defined as one day. For users a minimum stay of four weeks will be needed for any one stay. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. When the users arrive, the first week will be devoted to safety training, the instructions to the experimental and computational facilities, and the installation of the experimental system inside the facility. The workload of course, will vary from experiment to experiment. Approximately four days are needed for the SPIV set-up to be made operational. Then the first test runs are conducted. Depending on the requirements the user will then conduct the necessary experiments over the next days and weeks. The user will either be able to analyse the data for post-processing at the facility or remotely at the home institution. It can be expected that post processing, especially of the SPIV data will take at least a week. During the stay the institute provides accommodation in the guest houses, office space at LML, and access to the full infrastructure resources.

Work package 13: Access to Czech Cryogenic Turbulence Facility (CCTF)

Work package number	13	**Start date or starting event:**			Month 1	
Work package title	Access to Czech Cryogenic Turbulence Facility (CCTF)					
Activity Type	SUPP					
Participant number	9					
Participant short name	CUNI					
Person-months per participant:						

Description of the infrastructure

Name of the infrastructure: *Czech Cryogenic Turbulence Facility (CCTF)*

Location (town, country): Prague, Czech Republic. The CCTF comprises three facilities - two are together in Prague at the same location; the third one is operated in collaboration with the Institute of Scientific Instruments ASCR in Brno.

Web site address
http://physics.mff.cuni.cz/kfnt/usindex.html , *http://www.isibrno.cz/cryogenics/conev.html*

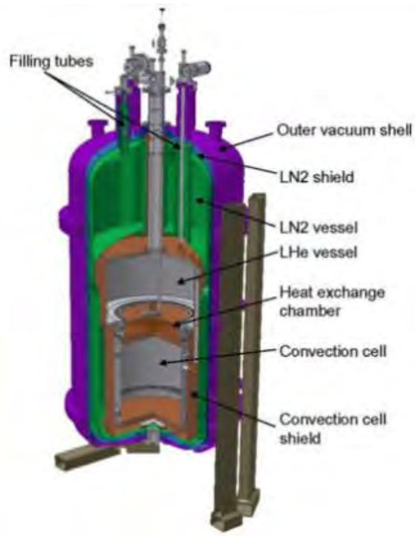
Legal name of organisation operating the infrastructure: *Faculty of Mathematics and Physics, Charles University in Prague*

Location of organisation (town, country): *Prague, Czech Republic*

Annual operating costs (excl. investment costs) of the infrastructure (€): 115,052 €
(CCTF 1: 35,488 €, CCTF 2: 42,952 €, CCTF 3: 36,612 €

Description of the infrastructure:

Summary:



- *First Laboratory in Europe utilizing particle imaging velocimetry and particle tracking visualization of cryogenic helium flow and superflow using micron size flakes of frozen hydrogen and/or hydrogen-deuterium mixture;*
- *Quantum turbulence studied in He II using second sound attenuation and small mechanical oscillators over entire ranges of pressure and temperature of superfluid 4He down to the zero temperature limit, including a new high cooling power commercial dilution refrigerator equipped with superconducting magnet up to 9 T;*
- *Ultra-high Rayleigh number (up to about 10^{15}) turbulent convective flow using cryogenic helium gas as a working fluid.*

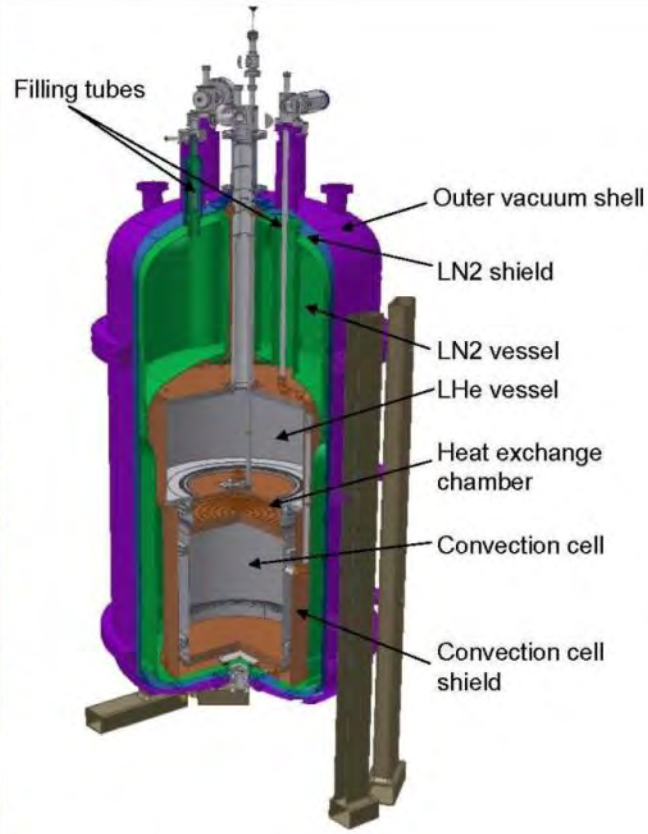
Charles University in Prague, Faculty of Mathematics and Physics, recently invested into the abovementioned equipment for cryogenic fluid dynamics research, based on pre-existing cryogenic infrastructure. Following the devastating floods in Prague in 2002, a new cryohall (investment of 2500 k€) has been designed and built, opened in 2005, with helium liquefier (40 litres/hour, 920 k€) and skilled personnel capable of smooth supply of liquid helium for experiments at low and ultralow temperatures. During 2010 and 2011 the advanced cryogenic apparatuses (see below) extended the experimental horizon of the Department of Low Temperature Physics thus providing new options in cryogenic fluid dynamics research.

Charles University can provide accommodation for visiting researchers in the Pawlovnia hotel across the road from the Laboratory. Optionally, young scientists can also be accommodated in the nearby student dormitories. In Brno, the Institute of Scientific Instruments provides in-house guest rooms for visitors.

Cryoliquids for precooling and operation of experiments are provided by fully established cryogenic infrastructures including running helium liquefiers at both locations.

The CCTF 1 (liquid helium flow visualization) facility in Prague utilizes the well-known visualization methods of particle image velocimetry and particle tracking that have already proved highly useful in studies of conventional room temperature flows. This facility includes a 5W cw laser, fast (6.3 kHz) sensitive Phantom camera, all relevant optics as well as necessary hardware and software supplied by Dantec Dynamics. The helium flow occurs inside the optical tail (5 windows) of a custom-made low-loss open helium bath cryostat; temperatures down to about 1.1 K can be reached using an effective pumping unit based on a roots pump controlled via computer-operated butterfly-type valve. Tracer particles can be produced using a custom-built equipment from a gaseous hydrogen-deuterium-helium mixture; injecting it via a very fast computer-controlled valve into the helium bath. Flows of normal liquid helium as well as of its superfluid phase can be generated and studied.

The CCTF 2 (He II quatum turbulence) facility features a Leiden Cryogenics ^{3}He – ^{4}He dilution refrigerator equipped with a superconducting solenoid producing a vertical magnetic field up to 9 T. It was successfully tested on the supplier premises and is currently being installed in the cryohall in Prague. Two thin thermally anchored capillaries are available for filling and venting the custom-built experimental cells thermally attached to the mixing chamber. Various cells and flow generators, especially oscillating objects such as quartz tuning forks, vibrating wire resonators or grids will be used to address fundamental problems of quantum turbulence in the zero temperature limit in particular. At the appropriate temperature range, the mechanical oscillators may be supplemented by second sound attenuation sensors - a traditional detection technique in the Prague Laboratory – to measure the density of quantized vortex lines. Additionally, for experiments on quantum turbulence above 1.3 K a low-loss open bath cryostat equipped with a computer-controlled bellows flow generator is available.



The CCTF 3 (helium cryostat) for experimental study of Rayleigh-Bénard thermal convection has been designed and constructed in collaboration with the Institute of Scientific Instruments, Academy of Sciences of the Czech Republic and is currently operated jointly on the premises in Brno. It currently contains a cylindrical (30 cm in diameter) aspect ratio one Rayleigh-Bénard cell of arguably one of the best designs so far (smallest parasitic heat leak and sidewall/endplate corrections among existing high Ra cryogenic cells). This apparatus will allow visitors to study buoyancy driven flows up to about Ra ~10^{15} under Boussinesq conditions, utilizing the cryogenic helium gas (up to 3 bars) as working fluid with well-known and *in situ* tuneable physical properties. Miniature temperature sensors to measure temperature fluctuations and mean wind velocity are available. The cell geometry is designed to allow easy modifications including changing the aspect ratio by replacing the middle section of the cylindrical wall.

<u>Services currently offered by the infrastructure</u>:

We offer two types of services: i) *in situ research* with a direct access to the facility, and ii) *commissioned research*, although i) is encouraged. In the first case the user will be conducting the research at our facility in person, with the full support provided by our highly qualified scientist to assist the user with specialised cryogenic techniques. In preparation of the project, the user will also benefit from the help from a supervisor. In commissioned research, the user can demand that certain measurements be performed at our facility without being actually present. In this case our personnel will carry out the requested measurements and transmit the results to the user. This type of research is particularly appealing to users from the computational fluid dynamics community who are interested in validating their numerical data in practical situations.

Description of work

<u>Modality of access under this proposal:</u>

As mentioned above, access for users can be given in direct or indirect form. For indirect users, ideally a 1 week stay at the facility is recommended to hand over the data and to familiarize the user with the experimental methods and equipment. For direct users, a minimum stay of four weeks will be needed for any one project. Before the work is to be conducted, the user will need to have a preparatory meeting either in person or per teleconference. Requirements and any possible modifications of the experimental system, design of experimental cells or inserts will be discussed and defined. The actual development can include work by our electronic and/or mechanical personnel, as well as our scientists. When the users arrive, the first week will be devoted to specific low temperature safety training as well as to introduction to the experimental facilities, and the installation of the newly designed experimental inserts into existing facilities. In most cases, the newly designed cryogenic parts must be tested independently in cryogenic environment; the duration and complexity of tests depending on the specific case at hand. Depending on the requirements, the user will then conduct the necessary experiments over the next days or weeks. During the stay, office space and full access to the infrastructure of the institute will be provided.

Support offered under this proposal:

As described already above, the facility scientist, facility technicians and our workshops will support the users. In addition, the facilities of the Faculty of Mathematics and Physics, Charles University in Prague and/or of the Institute of Scientific Instruments in Brno, such as lecture halls for seminars or libraries will be available to all users.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CCTF 1	1 day	97.00	42	6	84	2
CCTF 2	1 day	118.00	56	8	112	3
CCTF 3	1 day	100.00	35	5	70	2

Units of Access: A unit of access is defined as one day. For visiting users a minimum stay of four weeks will be needed for any one project. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. When the users arrive, the first week will be devoted to safety training, introduction to the experimental facilities, and the design and installation of the new cryogenic experimental system. The workload, of course, will vary from experiment to experiment. Approximately two days are needed for cooling down the experiment by liquid nitrogen and liquid helium to make it operational. About 100 litres of liquid helium is needed to cool down the dilution refrigerator and the conventional cryostat, about half of that amount to cool down the helium visualization cryostat. Then the first test runs are conducted. Depending on the requirements, the user will then conduct the necessary experiments over the next days and weeks. One or two days will be needed to warm up the system and to remove the experimental equipment. The user will either be able to analyse the data for post-processing at the facility or remotely at the home institution. It can be expected that post processing, especially of the particle tracking data will take at least a week. During the stay the institute provides accommodation in the University or Institute dormitories, office space and access to the full infrastructure resources. In the case of the Rayleigh-Bénard convection cryostat situated in Brno, the expenses will be paid to the Faculty of Mathematics and Physics, Charles University in Prague and the relevant part reimbursed to the Institute of Scientific Instruments ASCR in Brno.

Work package 14: Access to Refractive Index Matched Tunnel (RIMT)

Work package number	14	**Start date or starting event:**				Month 1	
Work package title	Access to Refractive Index Matched Tunnel of LSTM-Erlangen						
Activity Type	SUPP						
Participant number	10						
Participant short name	FAU						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *Refractive Index-Matched Tunnel (RIMT)*

Location (town, country): *Erlangen, Germany*

Web site address: http://www.lstm.uni-erlangen.de

Legal name of organization operating the infrastructure: *Lehrstuhl für Strömungsmechanik (LSTM-Erlangen), Friedrich-Alexander-Universität Erlangen-Nürnberg*

Location of organisation (town, country): *Erlangen, Germany*

Annual operating costs (excl. investment costs) of the infrastructure (€): 92,296 €

Description of the infrastructure:

Summary

- *Index matched tunnel operated with cosmetic white oil (with almost the same kinematic viscosity of air at the operating temperature);*
- *Dimensions of test-section: 0.6 m x 0.45 m x 2.5 m (w x h x l), Flow speed: 0 - 4.8 m/s, Turbulence intensity: < 0.1 %;*
- *Measurement systems: 3 component LDA, PIV, Stereo PIV, hot-film sensors;*
- *Test objects made of quartz glass, to resolve internal & near wall;*
- *Broad variety of application areas,* especially flow with complex geometries.

The Institute of Fluid Mechanics at FAU Erlangen-Nuernberg possesses a novel test facility which enables various measurements that were previously impossible. The special feature of the new test facility is the use of cosmetic white oil as the working fluid, which has an optical refractive index identical to that of quartz glass. This prevents refraction at the surface of any quarz object inserted into the flow. As a result, investigations of the flow in the immediate vicinity of the surface of complex objects by optical measurement techniques become feasible.

Major foci of the research conducted in this facility are turbulence and transition. Due to the relatively large dimensions of the tunnel and the achieved high flow rates, the applications range from basic research to practice-relevant model tests.

The first studies conducted in this facility (for AIRBUS) were on the transition between laminar and turbulent flow on a flat plate. The obtained data are used for validating DNS on the same problem.

Furthermore, many other types of boundary layer flows at high Reynolds numbers can be studied. Thereby, the main focus lies on flows through complex structures, like heat exchangers or nuclear fuel rods. Already, the facility has been a part of collaborative activities on the development of surface sensors.

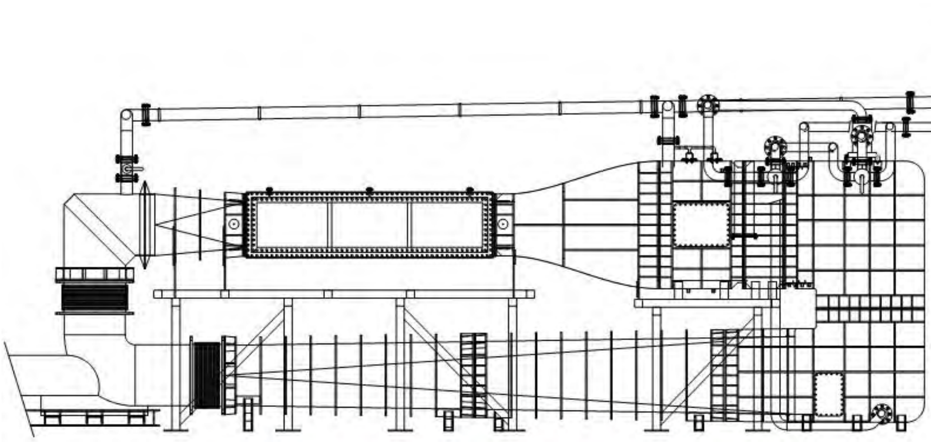


Fig 1. Refractive index matched flow tunnel of LSTM-Erlangen

Services currently offered by the infrastructure:

In situ research with a direct access to the facility: In this case, the user will be conducting the research at our facility. To these researchers we offer practical guidance as well as technical assistance on the part of our scientific and/or technical staff, which is necessary due to the high complexity of the experimental installations. In preparation of the project, the user will work with the facility lead scientist and supervisor and the facility technician. The accommodation facilities, in particular the Welcome Center of the FAU Erlangen-Nürnberg, minimize the organizational effort required for arranging the visits to the RIMC facility of LSTM-Erlangen.

Commissioned research: The user (person or company) can demand for certain measurements to be performed at our facility without being himself present in Erlangen. In this case, our personnel will carry out the requested measurements and transmit the results to the user. This type of research is particularly appealing to the users from the computational fluid dynamics community and companies who are interested in validating their numerical data in practical situations or conduct development work.

Description of work

Modality of access under this proposal:

As mentioned above, access for users can be given in direct or indirect form. For indirect users a 2-days stay at the facility is required to hand over the data and to familiarize the user with the equipment and the limits and systematic errors of the experiment. For direct users a minimum stay of two weeks will be needed for any one project. Before the work is to be conducted, the user will need to have a preparatory meeting either in person or per teleconference with the facility manager and the facility technician. Requirements and any possible modifications of the experimental system will be defined. In preparation, the institute’s staff will conduct any necessary modifications of the experiment, the experimental equipment, and the measurement systems. During this time, short-term visits of the users are encouraged to ensure proper preparation of the experiments. This can include work by the electronic and mechanical workshops, as well as the scientific and computing staff. When the users arrive, the first week will be devoted to safety training, the instructions to the experimental and computational facilities, and the installation of the experimental system inside either of the two facilities. The workload for the last step will vary from experiment to experiment. Approximately two days are needed for the tunnel to be degassed and made operational, after which the first test runs can be performed. Depending on the requirements, the user will then conduct the necessary experiments over the next days and weeks. One day will be needed to discharge the oil from the tunnel and to remove the experimental equipment. The user will either be able to analyze the data at the facility or remotely at the home institution. It can be expected that post processing, especially of the PIV data, will take at least a week. During the stay, office space and full access to the infrastructure of the institute will be given.

Support offered under this proposal:

As described above, the facility scientists, facility technician, and the workshops of the institute will provide support for the users. In addition, the users will be integrated to the daily research life in the institute, especially to that of the Fluid Dynamics and Turbulence Research group at LSTM-Erlangen.

The LSTM-Erlangen has about 60 scientific employees. The institute is a part of the Chemical and Bio-Engineering department, and offers fluid mechanics courses to students in mechanical engineering, computational engineering, energy engineering, and medical engineering. LSTM-Erlangen is also active in the excellence research initiatives, like Erlangen Graduate School of Optical Technologies (SAOT) and Engineering of Advanced Materials (EAM). A lecture hall centre, a cafeteria, and a well-equipped library are within 100m. The guesthouses of the FAU Erlangen-Nürnberg are located within 5 km of the LSTM-Erlangen and can easily be booked for the users.

Outreach of new users: see networking activities in WP 2a

Review procedure under this proposal: see networking activities in WP 2a

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
RIMT	1 day	252.86	292	12	490	6

Units of Access: A unit of access is defined as one day. For direct users a minimum stay of two weeks will be needed for any one project. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. During the stay the institute helps to find accommodation in the guest houses and it provides office space at the RIMT and access to the full infrastructure resources.

Work package 15: Access to Cottbus Turbulence Experiment Facilities (CoGeoF)

Work package number	15	**Start date or starting event:**					Month 1	
Work package title	Access to Cottbus Turbulence Experiment Facilities (CoGeoF)							
Activity Type	SUPP							
Participant number	11							
Participant short name	BTU							
Person-months per participant:								

Description of the infrastructure

Name of the infrastructure: *Cottbus Turbulence Experiment Facilities.*
The CoGeoF comprises five facilities located in the same building in different rooms next to each other.

Location (town, country): *Cottbus, Germany.*

Web site address: *www.tu-cottbus.de/las/ (under construction)*

Legal name of organisation operating the infrastructure: *Brandenburg University of Technology*

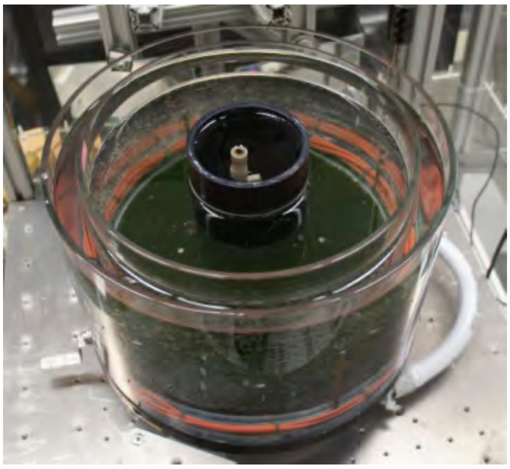
Location of organisation (town, country): *Cottbus, Germany*

Annual operating costs (excl. investment costs) of the infrastructure (€): 83,528 €
(CoGeoF1: 11,436 € , CoGeoF2a: 17,211 € , CoGeoF2b: 16,188 € , CoGeoF3: 10,607 € , CoLaPipeF: 28,086 €)

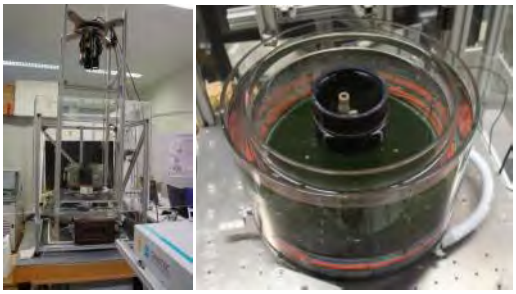
Description of the infrastructure:

Summary:

- *Experiments on rotating platforms suited for applications in the geophysical context;*
- *Measurement systems: stereo PIV (Dantec), Tomo-PIV (Dantec), LIF (Dantec), LDA, infrared thermography (Infratec) simultaneous thermography/PIV, LIF/PIV measurements;*
- *Closed-return air pipe facility with constant temperature conditions and full optical access, 27 m long, high spatial resolution (up to 300mm) at high turbulence levels (Karman number R^+=1.9x10^4);*
- *Measurement techniques: HWA, LDA, PIV, pressure probes, surface microphones.*

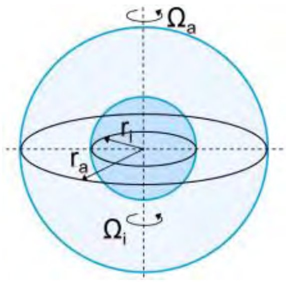


CoGeoF have been established by the BTU Cottbus, Department of Aerodynamics and Fluid Mechanics within the Center of Flow and Transport Modeling and Measurement ($CFTM^2$). CoGeoF is equipped with advanced measurement technologies (Stereo PIV, Tomo PIV, LIF, LDA, infrared thermography). In addition to the listed properties above, CoLaPipeF is equipped with tripping devices for investigation of artificial transition (X-Tripping, inlet fences), besides the possibilities for investigation on natural transition. CoGeoF and CoLaPipeF are part of the Fluid-Center-Building located on the Campus of the Technical University Cottbus. The Fluid-Center is operational since 2004. The $CFTM^2$ was founded 2008 as an initiative to bundle the BTU activities on fluid transport processes and to promote the interdisciplinary exchange within the University and with the industry. CoGeoF consists of five facilities: CoGeoF1 – Baroclinic Wave Tank, CoGeoF2a/b – Two Inertial Wave Tanks (one spherical and one cylindrical), CoGeoF3 – Taylor-Couette-System, and CoLaPipeF – Large Pipe Facility.

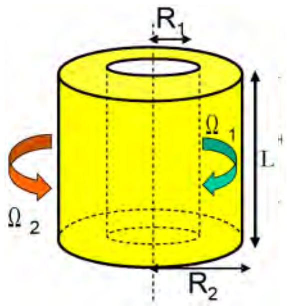


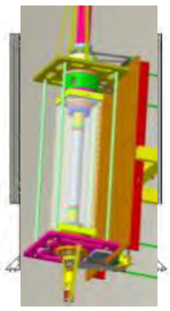
The CoGeoF1 setup consists of a tank with three concentric cylinders mounted on a turntable. While the inner cylinder is made of anodized aluminum and cooled by a thermostat, the middle and outer ones are made of borosilicate glass. The outer side-wall of the experiment gap is heated by a heating coil that is mounted at the bottom of the outer cylinder bath. In our setup, the experiment has a free surface and a flat bottom. De-ionized water is used as working fluid. The thermally driven rotating annulus can be seen as a simple laboratory experiment of atmospheric baroclinic instability. This instability generates a highly complex and nonlinear flow that shows many similarities with irregular atmospheric flows. For large rotation frequencies the flow shows geostrophic turbulence and multiple scale interactions. Presently, the experiment is the reference experiment within the DFG-MetStröm priority program, providing data to numerical modelers. *Specifications*: inner cylinder radius R_{in}=45 or 70mm (in default configuration R_{in}=45mm), outer cylinder radius R_{out}=120mm, maximum liquid level H=150mm. One can arrive in the parameter domain of Rossby and Taylor numbers 0.006<Ro<51 and 10^4<Ta<10^{11}.

Two geometries are available for the CoGeoF2 experiments. In both cases the inner and outer containers have the possibility to rotate independently. The average rotation speeds of the inner and outer containers can be adjusted to the same value and one of the container's rotation can then be modulated in order to excite waves. For example, one can rotate the outer container with constant angular velocity Ω_0, while modulating the angular velocity of the inner one as $\Omega_{in}=\Omega_0(1+\varepsilon \sin \omega t)$, with $0<\omega<2\Omega_0$ and $0<\varepsilon<1$. The experiments allow for studies on wave-mean- and wave-wave-interactions as well as wave turbulence.



Specifications of the spherical tank: Inner sphere radius R_{in}=40 or 60mm (in default configuration R_{in}=40mm), outer sphere radius R_{out}=120mm. Maximum rotation velocity of the inner and outer spheres: $n_{in,max}$=125 rot/min, $n_{out,max}$=40 rot/min.





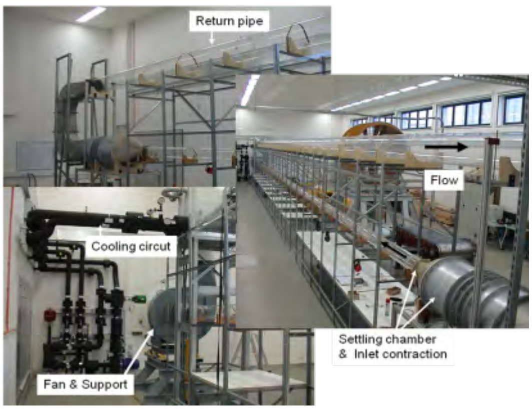
Specifications of the cylindrical tank: The inner cylinder can be replaced and can have different radii or shapes. In the default configuration one uses an cylinder with inclined walls (cone) with $R_{in,down}$=200mm, $R_{in,up}$=150mm. The outer cylinder with radius R_{out}=400mm always has vertical walls. The closed domain filled with water has the height H=480mm.

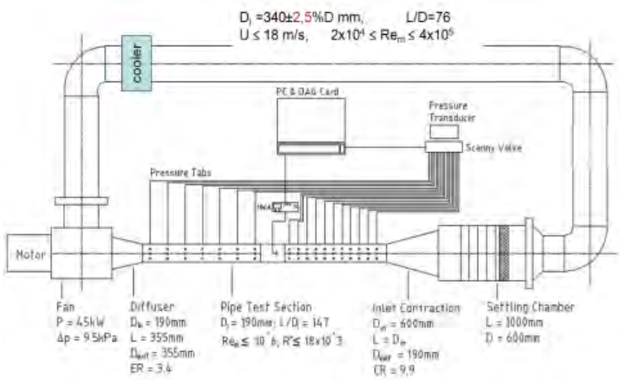
The COGeoF3 system consists of two independently rotating concentric cylinders of radii 35mm and 70mm (radius ratio 0.5). The inner cylinder is able to rotate with a frequency of 80 Hz, the outer one is driven up to 40 Hz. This corresponds to rotation Reynolds numbers up to 106. The length of the measurement volume is 20 times that of the gap width. A unique characteristic of the CoGeoF3 Taylor-Couette-System is that the end plates are able to rotate independently to study the impact of end effects on Taylor vortices and turbulence. The temperature can be controlled very accurately (±0.2K), thus viscosity is constant and not influenced by a variable temperature. Optical access in radial direction allows for non-intrusive optical measurement techniques. The inner cylinder is equipped with a torque measurement system.

The facility provides a thermography system (1.280x980 pixel) in the spectral range 7.5-14µm and temperature range -40-1.200°C, a Dantec Dynamics stereo PIV system and a Dantec Dynamics volumetric velocimetry measurement system with three 2M cameras. Other measurement possibilities: Dantec LIF system, 1D and 2D Dantec LDA systems, two frequency-doubling 15 Hz YAG lasers, five 100mW Linos continous lasers, hotwires, and a calibration tunnel.

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 (up to $Re=10^6$). One major element is the assembly of the radial blower, the three-phase motor and the frequency converter. The radial blower has a nominal power of P = 45 kW and is connected to the pipe on its suction side. The blower itself is connected to a three-phase motor with a nominal rotation speed of 2940 Hz. A frequency converter, within a control range of 1-50 Hz, effects the adjustment control. The assembly provides a flow rate of $0.05m^3/s$ to $2.5m^3/s$ and produces a maximum velocity of 80 m/s at the contraction exit with low turbulence intensity level, i.e less than 0.4%. The maximum velocity that can be achieved with the experimental setup corresponds to 0.22 Mach number, avoiding any compressibility effects. Aiming at a stable test facility, the centrifugal blower is installed at the end of the pipe test section and it delivers its output directly to a 340 mm-diameter return line through a heat exchanger. The pipe test section contributes mostly to the total pressure loss of the facility. A cooling system is installed in order to keep the temperature constant inside the pipe test section.

The pipe diameter of the suction side of the facility is made of a high-precision smooth Acrylic-glass tube, having an internal diameter D_i of 189.7±0.23 mm (i.e. a relative error of 0.12%) and total length of 27 m, providing a test section $L/D_i \leq 140$.





Specifications: Fluid mechanical parameters: Mean velocity: U ≤ 80 m/s, mean based Reynolds number: $Re_m \leq 10^6$, wall friction velocity: $u_\tau \leq 3$ m/s, Kármán number: $R^+ = 1.9 \cdot 10^4$, Working fluid: Air; geometrical parameters: L/D = 142, surface roughness: ε = 5 μm; Pipe material: Acrylic glass

Measurement systems: Hot-wire anemometers, pressure probes, DPT 6000 Barometer, Prandtl tubes, stereo and volumetric PIV systems, LIF system, 1-d and 2-d LDA systems, hotwire and calibration tunnel.

<u>Services currently offered by the infrastructure</u>:

Generally we offer two types of services: i) in situ research with a direct access to the facility, and ii) commissioned research. In the first case the user in person will be conducting the research at our facility. To these researchers we offer practical guidance as well as technical assistance on the part of our scientific and/or technical staff, which is necessary due to the high complexity of the experimental installations. In preparation of the project, the user will work with the facility lead scientist and the facility technician. The guesthouse of the BTU will minimize the organizational effort required for arranging the visits to the CoGeoF facility. In the second case, the commissioned research, the user can demand for certain measurements to be performed at our facility without being actually present in Cottbus. In this case our personnel will carry out the requested measurements and transmit the results to the user. This type of research is particularly appealing to users from the computational fluid dynamics community who are interested in validating their numerical data in practical situations.

Description of work

Modality of access under this proposal:

In the case of commissioned research, our personnel will perform the measurements. In the case of in situ research, the users will perform the measurements under the supervision of our scientific and computing staff. In the former case, a minimum of a three-days stay is required in order to control the experimental details, to be familiar with the limits and with the systematic errors which can occur, and to be able to save and handle the data obtained from the experiment. For direct users a minimum stay of 2 weeks is obligatory. At least one month before the work is to be conducted the user will need to have a preparatory meeting either in person or by teleconference with the facility manager and the facility technician. Requirements and any possible modification of the experimental system will be defined. Short term visit of the users are encouraged in order to ensure a good preparation of the experiment. The working period of the external users will be chosen after discussion with the CoGeoF staff. During the stay, office space and access to the infrastructure of the university will be given.

Support offered under this proposal:

The facility scientists, technicians, and computer specialists will support the user. About 30 scientists and technicians work in the Fluid-Center on rotating flows, convection, and turbulence. Two associated assistant professorships support the Fluid-Center in numerical modeling and on acoustics. Lecture rooms and a lecture hall, the cafeteria, and a well-equipped library are within 200m on the University Campus. The guesthouse is within walking distance from the experimental facility.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
GeoF1:	1 day	55 €	150	10	314	5
GeoF2a:	1 day	82 €	150	10	314	5
GeoF2b:	1 day	71 €	150	10	314	5
GeoF3:	1 day	51 €	150	10	314	5
CoLaPipeF	1 day	134 €	150	15	314	5

Units of Access: A unit of access is defined as one day. For users, a minimum stay of two weeks will be needed for any one stay. In addition, a preparatory short-term visit is encouraged to ensure proper preparation of the experiments. When the users arrive, the first three days will be devoted to a laser safety training, the instructions to the experimental and computational facilities, and the installation of the experimental system inside the facilities. The user will either be able to analyze the data for post-processing at the facility or remotely at the home institution. It can be expected that post processing will take at least a week. During the stay the institute provides accommodation in the guest houses, office space at the CoGeoF, and access to the full infrastructure resources.

Work package 16: Access to Turin Rotating Platform Facility (TurLab)

Work package number	16	**Start date or starting event:**				Month 1	
Work package title	Access to Turin Rotating Platform Facility (TurLab)						
Activity Type	SUPP						
Participant number	12						
Participant short name	Unito						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *Turin Rotating Platform Facility (TurLab)*

Location (town, country): *Torino, Italy*

Web site address: *http://www.turlab.ph.unito.it/turlab.php*

Legal name of organisation operating the infrastructure: *Dipartimento di Fisica, Universita' di Torino*

Location of organisation (town, country): *Torino, Italy*

Annual operating costs (excl. investment costs) of the infrastructure (€): 195,889 €

Description of the infrastructure:

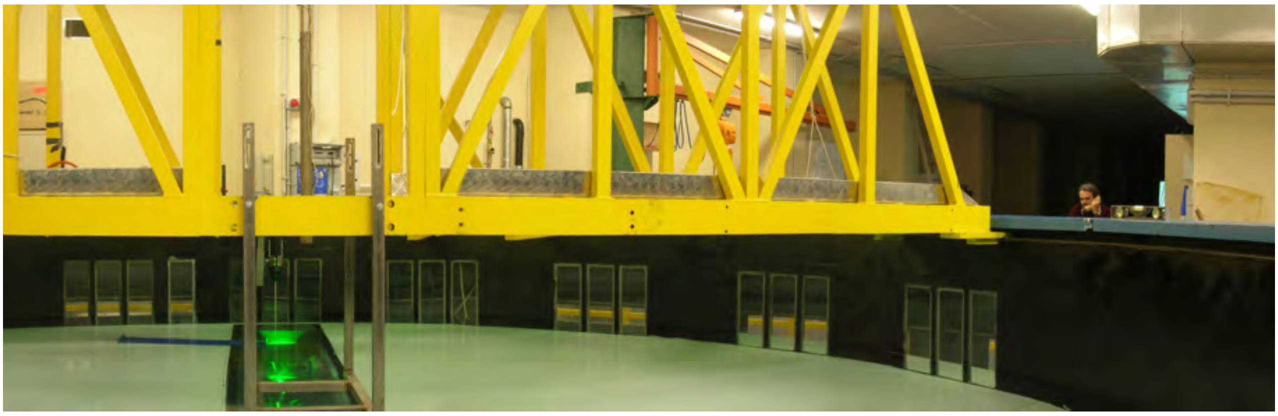
Summary:

- *Rotating platform equipped with a tank of 5 m diameter and 1 m depth for the study of turbulence in presence of rotation and stratification;*
- *Smooth platform movement over oil film, digitally controlled speed with a period between 3 s and 360 s;*
- *Optical access from the top and from the lateral wall by several windows, three glass channels on the floor for accessing with lasers and/or with cameras;*
- *Turbulence generators including grids, rotating disks of different diameters, and complex obstacles on the bottom;*

- *15 W continuous laser and cameras up to 500 Hz at resolution 1280x1024 for both 2D and 3D PIV and PTV.*

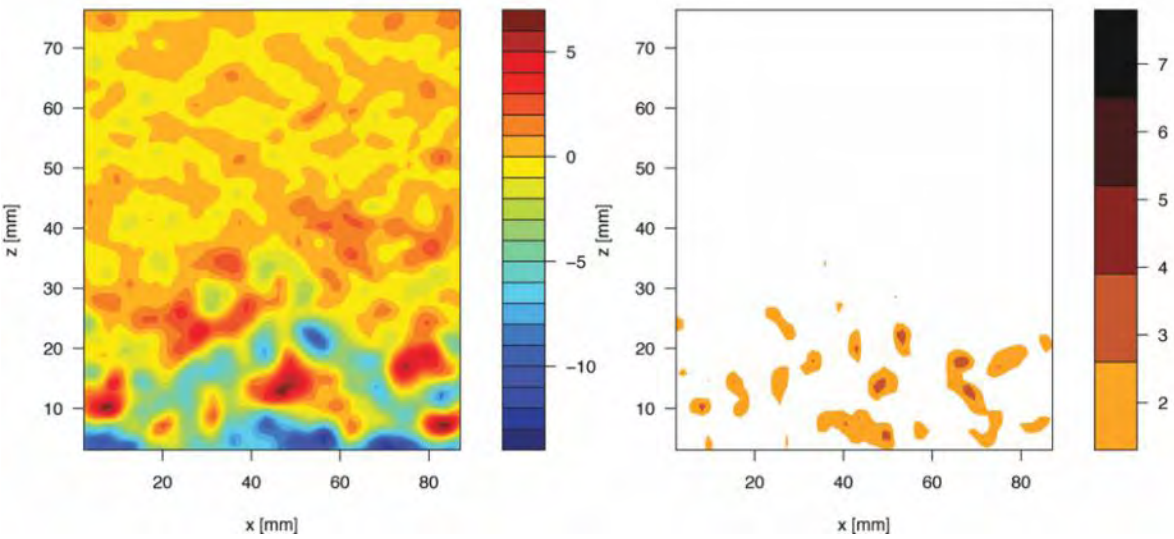
The Turlab facility in Torino is one of the largest rotating platforms available for scientific investigations of turbulence in presence of rotation and/or stratification.

It was built by the University of Torino between 2004 and 2005 with an investment of 800 k€ for the experimental facility and 400 k€ for measurement equipment for a total of 1.2 M€. It is located about 10 m underground in the basement of the Physics Department. In addition to the tank room, the laboratory has several other rooms for supporting the experimental work, including a machine shop, a computer room and offices for guests. The Turlab laboratory is managed by a steering committee of 6 scientists belonging to two Universities and to the National Council of Research. Technical support is provided by two full time technicians and one part time computer engineer. The tank on the platform, with an inner radius of 2.5 m, is provided with several windows on the lateral side and three glass channels on the bottom for optical access. A removable bridge co-rotating with the tank provides easy access to the top layer. It can be filled with homogeneous water or density stratified water up to a height of 80 cm.



The platform is moved by a three-phase electric engine and the tank floats over a thin layer of oil which ensures the virtual absence of any vibration. Platform speed is digitally controlled, together with acceleration and deceleration, the rotation period is between 3 s and 360 s. Different devices can be used to induce turbulence in the tank, including towed grids, rotating disks and water pumps. The tank is also used for studying the boundary layer over complex boundaries by introducing obstacles on the bottom. Illumination of the flow is provided by a solid state diode continuous laser (green) with maximal power 15 W. Laser sheet can be placed in any direction and almost any position in the tank thanks to the glass windows on the side and bottom. Measurement fields are up to 50x50 cm in vertical cross section and up to 140x140 in horizontal cross section.

The Turlab facility is equipped with several cameras. Dalsa cameras with resolutions up to 2352x1728 at 60 Hz and Mikrotron cameras with frequency up to 500 Hz at resolution 1280x1024. Both 2D and 3D PIV systems are available with Matlab graphical interface for calibration, velocimetry and analysis. The facility is also appropriate for Lagrangian measurements with different kinds of tracers. Storage hardware is composed of a cluster of HP servers (28 cores) with a 6 TB raid disk space for data analysis and storage. The laboratory has also two different acoustic probes for measuring 3D velocity components in a small sample volume with rates up to 200 Hz.



Vorticity cross-sectionfrom velocity field inTurlab measurements. From: *Ferrero et al. Bound. Layer Met. 130 (2009).*

Description of work

Modality of access under this proposal:

Once a proposal for an experiment has been selected, the proposer group is invited to visit the facility and set the details of the proposal. In this phase, all the specific requirements for the experiment will be discussed together with a local researcher and the technicians. On the basis of the particular requests for the experiments and of the schedule of the facility, a timetable for the set of experiments will be fixed. After this preliminary phase, the local staff will perform all the necessary modification to the facility and the acquisition system. During this time, short-term visits of the guest group are encouraged.

Support offered under this proposal:

The duration of the visit for performing the experiment is variable with a typical stay of four weeks. One full day is necessary to fill the tank and to reach solid body rotation after which the first test runs are performed. After the analysis of the preliminary runs, the main experimental runs are performed. During this phase, the guest group has full control of the experimental facility with the support of local technicians and researchers. The host institution will also provide office space, computers, and high-speed internet connection for all users, as well as access to other services of the Physics department, such as the local library. Preliminary analysis can be performed on site, using the laboratory cluster on which the guest users have an account. After the experiment, the group has free access to their data by internet connection, both for analysis on the local cluster or for transferring them to their home institution.

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: see networking activities in WP 2a.

Implementation plan

Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
TurLab	1 day	536.68	120	20	240	5

Unit of Access: The unit of access is one day. The typical measurement time would be around 4 weeks with additional two days for preliminary visit.

Work package 17: Digital Library of Turbulence Data (DLTD) - Service

Work package number	17	**Start date or starting event:**			Month 1		
Work package title	Digital Library of Turbulence Data (DLTD) - Service						
Activity Type	SUPP						
Participant number	13						
Participant short name	CINECA						
Person-months per participant:							

Description of the infrastructure

Name of the infrastructure: *CINECA, Consorzio Interuniversitario*

Location (town, country): *Casalecchio diReno, Bologna, ITALY*

Web site address*:* *http://www.cineca.it*

Legal name of organisation operating the infrastructure: *CINECA, Consorzio Interuniversitario*

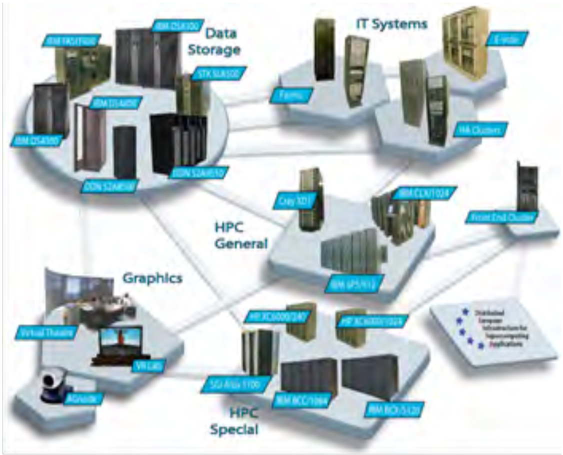
Location of organisation (town, country): *Casalecchio di Reno, Bologna, ITALY*

Annual operating costs (excl. investment costs) of the infrastructure: 4,927,870 €

Description of the infrastructure:

Summary*:*

- *Europe's largest digital library service for data coming from numerical simulations and experiments in the field of fluid dynamics (400 TB accessible online);*
- *Most efficient and effective transnational access to outstanding experimental and numerical data;*
- *Broadest variety of advanced tools for exploring and analyzing data on our high performance computing facilities (26.6 TFlops);*
- *High quality technical and scientific user support.*



CINECA will represent one of the world's largest data bases at the disposal of the European turbulence community, easily accessible through communication networks. Its data storage and computational resources will be further enhanced due to the participation in several EU-funded activities like DEISA, PRACE and HPC Europa.

CINECA is the largest supercomputing center in Italy for public and private research activities and one of the largest in the world (ranking 48th in the latest Top500 List - http://www.top500.org). Its statutory aims comprise the promotion of the use of the most advanced computer based information processing systems to support public and private scientific and technological research. The present CINECA main HPC platforms are represented by a 5000 processors AMD Opteron based Linux cluster (peak performance 26.6 TFlops) and a 512 processors IBM Power5 processors based architecture (peak performance 3.9 TFlops). A number of data storage facilities are available. Temporary data can be stored on a high performance GPFS 20 TB area during runs. Final data can be stored and managed on a permanent disk area of about 400 TB (progressively increasing in size, presently SFS technology based) and, finally, on a tertiary cartridge based storage (StorageTek technology) (to update). All data is constantly on-line and accessible. Complementary computing systems support data analysis exploration and advanced visualization, thanks also to several VR facilities. CINECA offers skills and advanced expertise in various fields of science and technology, from code development, parallelization, optimization, to visualization and data management, to web applications and services, and finally, to experimentation and exploitation of innovative high-end technologies. CINECA has a long tradition in the support of HPC scientific applications, providing researchers with computing resources, technical support and expertise, scientific collaboration. This happens at national level, as CINECA acts as the National Supercomputing Center in Italy via the ISCRA grant programe (http://iscra.cineca.it), and at European level with PRACE Tier 0, PRACE Tier 1, the evolution of DEISA, and the HPC-Europa projects. The HPC-Europa (http://www.hpc-europa.org) project leads to a continuous flow of European scientists at CINECA.

Services currently offered by the infrastructure

Apart from the institutional support to the University, specific agreements with the major national research institution (National Research Council, SISSA-ISAS, INAF, INSTM etc.- see, as an example, http:/inaf.cineca.it) are ongoing, as well as programs on the European level (see above). Researchers are given access to the available HPC computing systems and supported by dedicated staff with different levels of skills and competencies: technical staff, for everyday helpdesk support and to solve quickly and effectively incidents or specific system problems, and scientific staff, for research collaborations, code development, consultancy, and training. Scientific publications in dedicated journals (e.g. “Electronic structure of single DNA molecules resolved by transverse scanning tunnelling spectroscopy”, Nature Materials, 25 Nov 2007) and public scientific software development (see, for instance, http://visivo.cineca.it), represent the major outcome of such collaborations. During the year, CINECA organizes a number of schools and courses to introduce researchers and students (master degree, Ph.D.) to the topics related to HPC, like scientific visualization, data management, or programming languages. The total number of users who exploit CINECA resources during a year can be quantified as about a thousand Italian users and a hundred international users. In the last years, an increasing number of these users (and, more generally, the scientific community as a whole) have started focusing on issues related to data and its storage, management, description, and access. In fact, the dramatic growth of the amount of data produced by numerical simulations and experiments/observations poses serious problems on its organization and exploitation. Here, innovative and effective solutions are required. CINECA has started investigating and experimenting with solutions that encompass all the stages of data management, from their storage (high performance file systems, efficient long term storage, distributed file systems) to their description (data models, standards, file formats) to their organization and access (DBMS and ODBMS, storage resource brokers), participating in various international projects and communities (like, for example, the Virtual Observatory Alliance – http://www.ivoa.net – or the FP6 LHDL project http://www.livinghuman.org). One of the first achievements of this effort has been the realization of a public digital repository of fluid dynamics simulated data, http://cfd.cineca.it, which already stores and publishes more than 1 TB of data coming from turbulence applications.

Description of work

This work package aims at the creation and management of Europe’s largest digital library service for data coming from numerical simulations and experiments in the field of fluid dynamics (in the order of 200 TB accessible online). This service will collect outstanding experimental and numerical data from the other access facilities of the consortium and provide the most effective access to them. CINECA will provide high quality technical support for the development of TurBase, a virtual turbulent research platform developed in WP3. CINECA will represent one of the world's largest data repositories and libraries at the disposal of the European turbulence community, easily accessible through a solid communication networks. CINECA's data storage and computational resources will be further enhanced and consolidated due to the participation in several EU-funded activities; in facts CINECA is hosting member in PRACE (www.prace-project.eu), member of EUDAT, the European data Infrastructure (www.eudat.eu), and coordinates HPC-Europa, the Transnational HPC Access program (www.hpc-europa.eu). CINECA actually operates as a Tier 1 system in PRACE and will install a Tier 0 system in 2012.

Objectives: The main objective is to provide the technical and hardware infrastructure to TurBase, a data repository/library to support researchers with fundamental data management functions for the efficient deposit, access, sharing, and preservation of scientific data sets. These data sets are the result of distributed experiments and numerical simulations in the field of turbulent flows and fluid dynamics. Easily accessible tools and services will permit project's researchers to access and manipulate data to advance the science frontier of their experiments. The underlying infrastructure will be designed to be robust, open, and extensible, and to support the development of advanced services fostering data mining, integration, analysis, and visualization functionalities. The latter services are to be engineered by the work of scientists in WP3. Further goals include improving technical aspects concerning the access to scientific data and information, in order to promote models for sustainable access and enhancing coordination among different scientists. The implementation of the repository will guarantee high scalability along dimensions of capacity and technology. Beckups of the provided data will also reduce the impact of unexpected loss of digital information.

Success factors for an efficient data hosting service will require to provide:

- Easy deposit, similar to commercial hosting services (e.g. DropBox, Amazone S3, etc.); Deposit web service technologies for easy up/download of data and easy access control to share and to collaborate;
- Easy access through meta-data based searches;
- Integration and connectivity with other scientific European e-infrastructures (e.g. EUDAT, PRACE) and national infrastructures;
- High level of quality, including reliability and scalability;
- Authentication, authorization, and accounting of users;
- Long term preservation of scientific data.

The result of this task must also ensure an easy implementation and operation of the data repository.

Means: Elements of interest for the achievement of the above goals are: Evaluation of the availability of technologies and tools which to build the repository upon; Support of the community in accessing the repository; Collaboration with other working projects (WP3, WP2a) for the definition of common data access models and meta-data schema; Fostering of the collaboration with other projects (i.e. EUDAT, PRACE).

Services: This activity will provide an equally robust and diverse system for digital data management and access. A set of appropriate data services will be implemented to accommodate community preferences, to furnish functions for data management, and to guarantee long-term preservation of archived data. The repository is envisioned to promote interoperability between diverse repositories supported and managed by different organizations, to deliver computational performance, and to ensure data reliability and integrity. The success factors for the service will be quantified on the quality and quantity of centralized data access. The EuHIT data archive will provide data hosting services in which users can easily deposit, manage and share data to collaborate with colleague researchers across Europe. We will provide the following services to the European turbulent community: (i) Easy deposit similar to the commercial hosting services (see above); (ii) Integration and connectivity with other scientific European e-infrastructures (e.g. EUDAT, PRACE) and national infrastructures; (iii) High level of quality, including reliability and scalability; (iv) Authentication, authorization, and accounting (AAA); (v) Long term preservation of scientific data.

Furthermore, this work package will provide the following technical services for the implementation of the Application Programming Interface developed in WP3: (i) Implementation of data standardization; (ii) Data exploration and sharing (adoption of a common meta-data schema); (iii) Evaluation of advanced data management systems for the deposit of scientific data (i.e. SciData) (iv) Data mining (e.g. evaluation of the Map Reduce algorithm).

Outreach of new users: see networking activities in WP 2a.

Review procedure under this proposal: An advisory board of three leading scientists in the community, namely Prof. C. Meneveau (JHU Baltimore, USA), Prof. S. Chen (Beijing University, China), and Prof. J. Schumacher (Illmenau University, Germany), will be asked to assess the quality and quantity of services provided under this working package every year. Furthermore, see networking activities in WP 2a.

Implementation plan

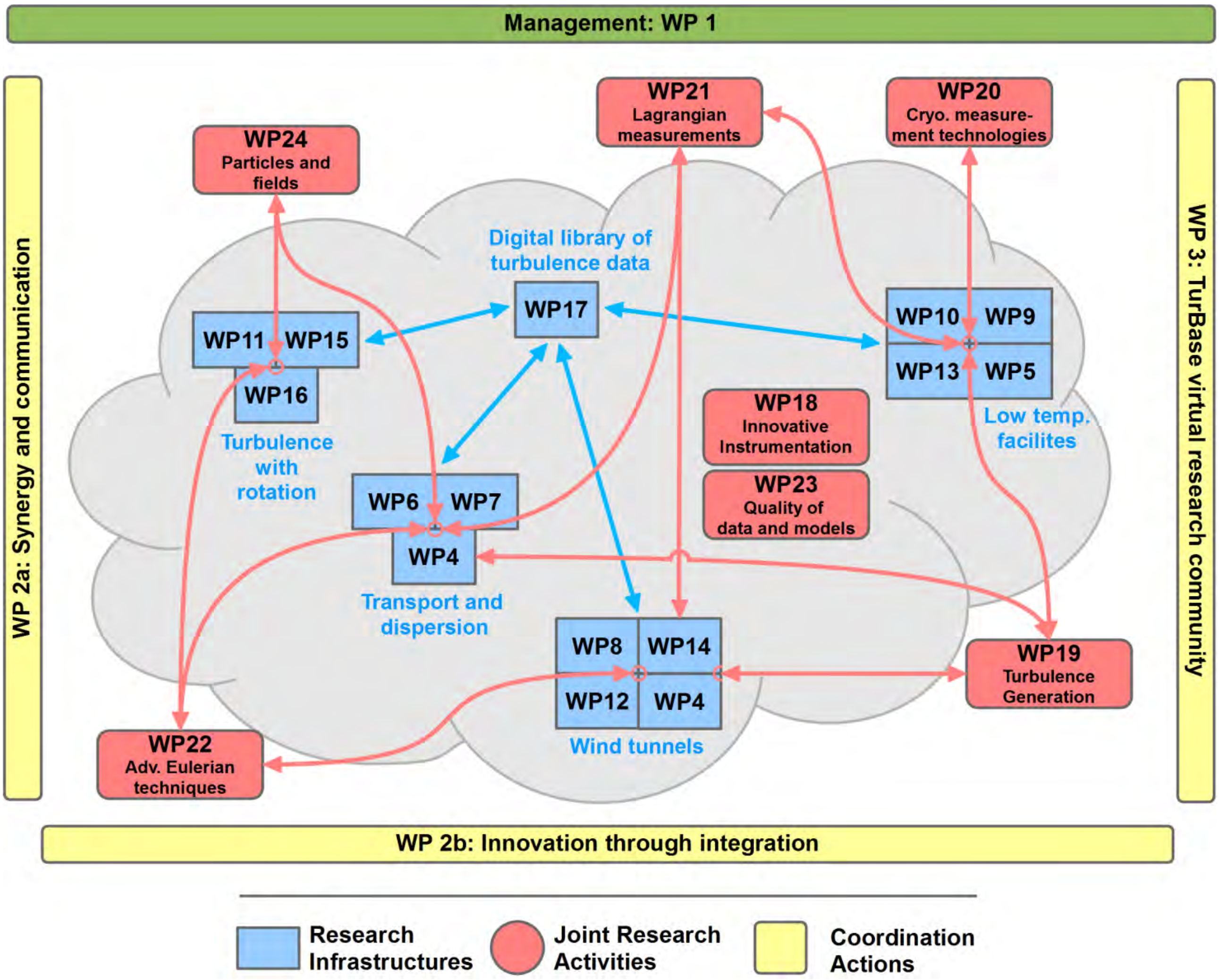
Short name of installation	Unit of access	Unit cost	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CINECA				0	0	100

Costs

The cost of the service is estimated as the 2.1% of the total cost of running the entire HPC infrastructure. The 2.1% fraction is the estimated fraction of the infrastructure which will be dedicated to the project in terms of:

- Storage space
- Direct costs for running the infrastructure
- Computing time for accessing data
- Data repository set up, maintenance and take up
- Core and advanced services set up, maintenance, and improvement
- Helpdesk support
- Specialized support

Graphical presentation of the components showing their interdependencies (PERT diagram)



1.3.2 Complementarity of participants

The evaluation process led to a consortium of **22 partners** coming from **10 countries** and involves **27 laboratories** (shown right). Furthermore, two international organizations (CERN & ICTP) became members of the consortium. Looking into the detailed description of the partner institutions demonstrates that a well-balanced group of academic institutions, national and international research centres and industrial SMEs has been constituted. This ensures a maximum of exploitation of the results towards science and research as well as industry. Star performers of worldwide leading enterprises like NORDEX Group and Dantec Dynamics A/S will be involved in the advisory board of the consortium. The group is capable of providing the facilities with necessary service and technology, which is available from the associated labs. All participants act in leading positions in their respective fields. The group incorporates as well editors of renowned scientific journals (e.g. New J. Phys., J. Fluid Mech., Phys. Rev. E) as editor-in-chief or members of their editorial boards. It is worth mentioning here, that most of the partners are experienced in managing large projects and naturally each of them has its own, strongly developed national and international collaboration.

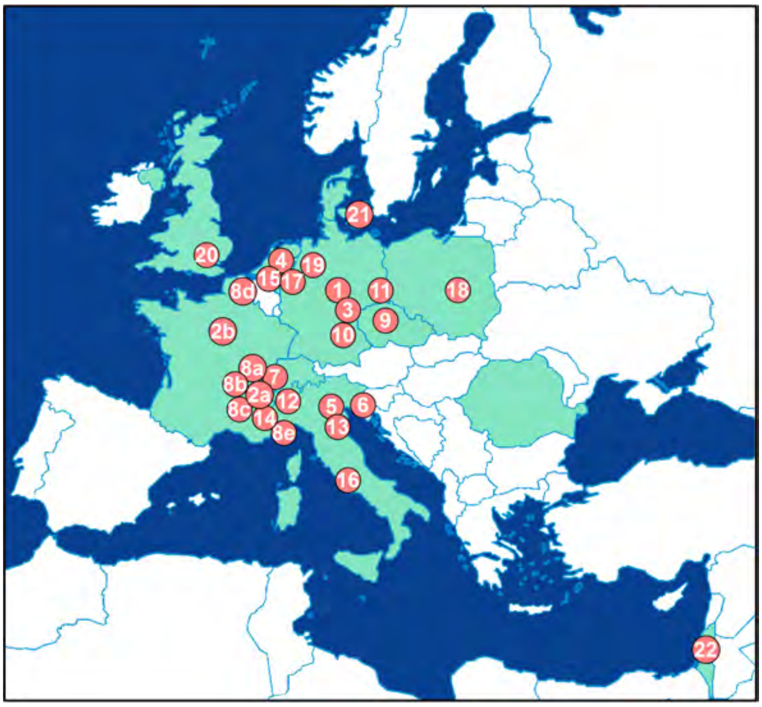


Figure 5: Location of the EuHIT partners

1.3.3 Complementarities of Trans National Access Activities

The group comprises 13 research infrastructures with 23 installations and one data service facility. They were evaluated as the best combination to provide not only access to world leading infrastructures, but also to the best possible instrumentation available in the research community. The majority of the research infrastructures result from national efforts of the order of several million Euros investments over the past ten years. They are designed to explore turbulence in various fields like aerospace (WPs 4, 8, 12, 14, 15), engineering (WPs 4, 5, 10, 14), meteorology and atmospheric sciences (WPs 4, 6, 9, 13), oceanography (Wps 11, 16) or geophysics (WPs 7, 11, 15, 16). The research groups working at the infrastructures tackle problems, which have been motivated and approved by national science agencies. The infrastructures providing trans-national access are:

- WP 4: Goettingen High Turbulence Facility (GTF1, GTF2, GTF3),
- WP 5: Grenoble Helium Infrastructures (SHREK, HeJet),
- WP 6: Barrel of Ilmenau,
- WP 7: Twente Turbulence Facilities (TWT, T3C),
- WP 8: CICloPE,
- WP 9: High Rayleigh number Cryogenic Facility,
- WP 10: CERN Cryogenic Turbulence Facility (GReC),
- WP 11: Coriolis rotating platform,
- WP 12: LML boundary layer wind tunnel,
- WP 13: Czech Cryogenic Turbulence Facility (CCTF1, CCTF2, CCTF3),
- WP 14: Refractive Index Matched Tunnel,

- WP 15: Cottbus Turbulence Experiments Facilities (CoGeoF1, CoGeoF2, CoGeoF3, CoLaPipeF),
- WP 16: Turin Rotating Platform Facility
- WP 17: Digital Library for Turbulence Data (DLTD).

Each individual facility is characterized by at least one feature of worldwide uniqueness. For example the low temperature helium experiments in WPs 5, 9, 10, and 13 permit the study of the global properties of a broad variety of model flows covering an unsurpassed level and range of turbulence. In contrast to these rather small-scale experiments the large-scale facilities in WPs 4, 6, 8, 11, 12, and 16 work with ordinary fluids like air, water or compressed SF_6. They permit measurement access to the very important fine structure of turbulence by providing worldwide unique spatial and temporal resolution. At the experiments in WP 7 the behaviour of particles in two-phase highly turbulent flows, e. g., of water and gas bubbles can be studied, using state-of-the-art flow measurement techniques. More detailed information can be found in the summaries of the associated work packages WP4 – WP16. In order to collect and to publish this huge amount of experimental data CINECA, Italy's largest supercomputing centre and Europe's leading digital library for data from numerical simulations and experiments in the field of fluid dynamics (400 TB accessible online) supports this structure (WP 17). This research infrastructure handles the gigantic amount of data and provides a variety of advanced tools for exploring and analysing data on its high performance computing facilities (26.6 TFlops).

In conclusion, EuHIT facilities are the best European infrastructures with a complimentary range of flows. They are built to address scientific questions of isothermal, free and wall bounded flows, as well as convective flows. They are suited to study global and local properties of turbulence in the worldwide singular range of Reynolds and Rayleigh numbers. Taking into account the personal expertise of the scientists working at or closely associated with the facilities and their collaborators, the group incorporates the best potential to resolve some of the many open questions regarding omnipresent natural and industrial turbulent flows - open questions that have direct impact on grand societal challenges, for example, energy supply, transport, and climate change facing the European community today.Complementarities of JRA's and their service towards the TNA's

1.3.4 Complementarities of Joint Research Activities and their service towards the infrastrcutures

In order to bring first-class support to the RIs and to optimize their scientific potential the JRA's play a key role in the entire structure of the EuHIT initiative. They explore new fundamental technologies or techniques underpinning the efficient and joint use of the participating research infrastructures. As described above in the selection procedure, the proposals were primarily ranked by the criteria 'How useful are the deliverables for the RIs?

This process results in three JRA's dedicated to:

- Next generation and innovative instrumentation (WP 18)
- Turbulence generation (WP 19)
- Cryogenic measurement technologies (WP 20)
- Lagrangian measurement of turbulence with strong mean flows (WP 21)
- Advanced Eulerian measurement techniques (WP 22)
- Quality assessment of data and models (WP 23)
- Particles and fields (WP 24)

The tasks within these activities incorporate the development of a broad variety of innovative sensors for temperature, velocity, acceleration and pressure suited for room temperature applications (WP 18, 22) as well as low temperature helium experiments (WP 20). They will provide the next generation imaging measurement methods for flow analysis like Particle Image and Particle Tracking Velocimetry (WP 21, 22, 24) and apply them to the special conditions of low temperature up to -272°C, high pressure up to 15 bar, large mean flows or very small fluctuating velocities (<1 cm/s). Industrial enterprises like SmartInst or Vision Research are actively involved in these activities and benefit from the complementarities of the work packages. WP 19 addresses the technologically very important question of how to generate and control turbulence in the research facilities with the aim to replicate the conditions found in nature and in industrial settings. These developments will not only produce higher Reynolds numbers in the laboratory, but will enable the systematic investigation of large-scale intermittency, tailored mean flow profiles, and objects present in the flow. Quality assessment of data and models (WP 23) will systematically compare experimental data obtained from the facilities with numerical and modelling results. This will provide the much-needed quality control of the numerical, experimental, as well as modelling data, and will identify the limits of our current understanding. Virtually all deliverables from these work packages can be applied to more than one installation

1.3.5 Networking as the integrative part

The EuHIT networking activities will foster a culture of co-operation between research infrastructures and scientific and industrial communities and help developing a more efficient and attractive European research area. At the core of the EuHIT initiative, the networking actions are the main bonding agents within the Integrating Infrastructure as well as towards the outer research community. The activities aim to stimulate the evolution of a virtual community at the field of turbulence research and a broad dissemination of the knowledge to various fields like aerospace, chemical, biological, and environmental research, mechanical and electrical engineering, meteorology, atmospheric sciences, oceanography as well as astro-, geo-, plasma-, and condensed-matter physics. The networking actions are also the natural hinge points between the scientific aspects of turbulence research and the technological developments sought by the EuHIT project. Networking actions are divided into three work packages:

- WP 2a: Synergy and communication,
- WP 2b: Innovation through Integration,
- WP 3: TurBase: Establishing a virtual turbulence research community.

Particularly, they are conceived to:

- provide the management of access provision and pooling of distributed resources (WP 1),
- allow for the most efficient running of the Consortium (WP 1),
- ensure dissemination and /or exploitation of project results and knowledge, outreach toward industry, contribution to socio-economic impacts, promotion of innovation (WP 2a),
- establish a virtual research community (WP 2b),
- define common standards, protocols and interoperability, benchmarking (WP 3),
- develop and maintain common databases for the purpose of networking and management of the users and infrastructures (WP 3),
- foster a culture of good practices, consultancy and training courses to new users (WP 2b),
- establish and intensify the collaboration with national or international related initiatives (e.g. COST MP0806, ICTR) and support to the deployment of global and sustainable approaches in the field (WP 2a),
- provide adequate opportunities for an effective implementation of scientific and/or technical advances coming from or beneficial to the EUHIT programme (WP2b, 3).

Networking Activities will ensure that options and ideas are discussed, that information circulates and that the entire community of turbulence researchers benefits from the effort of integration of the RIs.

In particular, WP 2a "Synergy and communication" is the structuring work package, with the goal of setting up a truly integrated network and to provide it with standardized and up-to-date tools via the EuHIT Web portal. The Web portal will include the knowledge base TurBase that combines high quality data with the knowledge from ScholarTurb. The entire work package WP 2a is also adapted to manage the optimized trans-national access to the EuHIT RI and to favour the stabilization of a culture of synergic cooperation well beyond the lifetime of the EuHIT project. It will structure and support the communications between different activities and between the potential users from academia and industry, and the funders. In the same work package, tasks of rapid and efficient dissemination of the on-going activities and the result of the JRA's and the RI's internally to the EuHIT community are foreseen. These actions will be used both, to foster the contacts between different activities, and to trigger timely actions of the governing bodies of EuHIT and specific actions of scientific and external dissemination assigned to WP 2b and WP 3.

Work package WP 2b “Innovation through integration” covers activities to reinforce the partnership with industry, e.g. transfer of knowledge and other dissemination activities, activities to foster the use of research infrastructures by industrial researchers, involvement of industrial associations in consortia or in advisory bodies. It shares the fundamental tasks of scientific dissemination of the outcomes of the project with a more pronounced action toward the community directly involved in the specific study of the physics of turbulence. It will integrate all stakeholders (from industry, academia, and government) in the optimal use of the Europe-wide turbulence facilities. Through setting up a user friendly high-level webpedia on turbulence (ScholarTurb) that is within the web-portal it will disseminate online, up to date and reliable EuHIT results and achievements in turbulence theory, modelling and experiment to the widest possible scientific and public audience.

Work package WP3 “TurBase: Establishing a virtual turbulence research community” will contribute to the development of the turbulence research community through the creation of TurBase, a freely accessible living knowledge-base for high-quality turbulence data. In tight collaboration with the CINECA data service structure TurBase shall provide easy access to experimental and numerical data, as well as data derived from theoretical models. It shall foster the use and deployment of standards and efficiently curate, preserve and provide access to the data and metadata collected or produced by EuHIT in particular and the turbulence community in general. The activities in this work package will contribute 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 practises and deployment of standardized data will promote clustering of new research initiatives helping the growth of a wider community in the European area.

(i) Subcontracting

Fabrication of electronic circuits for the smart particles; 10.000 €; Partner 12-a

External Conceptual Design Report for the cryogenic He RIs; 50.000 €, Partner 8

Cost of Audit Certificates; 48.000 € in total; for partners where EC contribution is > 375.000 €

2 Impact

3.1 Expected impacts listed in the work programme

The integrated research infrastructure EuHIT constitutes an essential cornerstone in a new approach towards the integration of turbulence research across Europe. The creation of EuHIT goes hand in hand with the realization that progress and innovation in topics of immediate importance to Europe requires a much-improved understanding of turbulence. Below we address how EuHIT contributes towards the expected impacts listed in the work program. We first present how EuHIT optimizes the impact on the communities actions. Then we show that, due the uniqueness of infrastructures, EuHIT can only be realized in Europe. We continue with the unique structuring impact of EuHIT on the way turbulence facilities operate, evolve and interact with each other and with users from academia and industry. We close with a discussion of how EuHIT promises to optimize the research facilities for the future and how it will have major impacts on innovation in European R&D.

How does EuHIT optimize innovation across Europe?

To a large extent further advances in key economical and societal issues facing Europe are hindered by a lack of detailed knowledge of turbulence. This is best captured by the impact of turbulence research on specific topics of European importance. EuHIT provides essential and much needed infrastructure access for the following communities:

(A) Environment:

- Atmospheric and oceanic flows on Earth have huge turbulence levels with Reynolds numbers up to 10^{10}. Turbulence is key to the spread of pollutants, aerosols and bio-agents in the biosphere. Our current understanding of such processes is limited. For example, right now we cannot predict in a quantitative manner, how a cloud of pollutants will disperse as a function of the Reynolds number and of the size of the initial cloud. Unclear is also, how turbulence influences particle dynamics as function of particle density, size, and concentration, and how particles at higher concentration affect the dynamics of the flow. This has direct consequences for example for the albedo of marine stratus clouds, which plays a crucial role in both the prediction of the future climate and the short-term meteorological forecast. Management of issues related to climate and geological hazards and any innovation requires improved knowledge of turbulence. These issues can be best addressed at **GTF**, **BOI**, **TTF**, **CORIOLIS**, **CoGeoF**, and **TurLab**.
- Rotation plays the leading role for all geophysical and astrophysical flows. It can lead to baroclinic and inertial waves and alters the flow structure and turbulent transport fundamentally. In addition, stratification impacts most environmental flows. EuHIT unites world-leading infrastructures that best address these issues: **HRCF**, **CORIOLIS**, **CoGeo**F, and **TurLab**.
- The lack of understanding of the coupled turbulence/aerosol dynamics and of convective currents underlies a persistent uncertainty in the prediction of the earth's future climate. A better understanding of turbulence is needed to evaluate pressures on environment and climate from anthropogenic and natural emissions and to render more precise the predictions on the energy balance due to phase changes that are highly coupled to the dynamics of drop formation in turbulent clouds and the concomitant effect on radiation balance. Different fundamental and complimentary aspects are best addressed at **GTF**, **TTF**, **BOI**, **CORIOLIS**, **CoGeo**F, and **TurLab**
- Turbulence at the air/sea interface determines the uptake of CO_2 into the oceans. An improved knowledge is needed to improve our understanding of the consequences for the oceanic CO_2 capture. In EuHIT fundamental issues relating to two-phase-flows can be studied at **TTF** and to turbulent boundary layers at **CICLoPE, LML,** and also at **BOI**.

(B) Energy:

- Any process of energy efficient combustion and burning requires turbulent mixing of the combustibles. This can be either gaseous/liquid combustibles, as for example in a combustion engine, turbine, or a burner, or gaseous/solid as in the combustion of coal for energy purposes. Better fundamental stochastic models for turbulent mixing are needed to allow for the development of more efficient and cleaner technologies. Fundamental issues can be studied with Lagrangian Particle Tracking at highest Reynolds numbers at **GTF**, **TTF** and **BOI**.

- The transfer of energy in heat exchangers is determined by the properties of turbulent flows. The design of more efficient ways of heat transfer is limited by a lack in understanding of high Rayleigh-number turbulent convection and of the behaviour of turbulent boundary layers. Various complementary fundamental aspects are best addressed with **GTF**, **BOI, TTF, CICLoPE, HRCF, and CCTF.**
- Wind energy relies on recovering energy from wind with giant propellers. Energy gain is maximal for the highest wind speeds*, i.e.,* strongest turbulence, since the lift of the propeller blade determines the energy transfer from wind to propeller. Current technology does not incorporate well the effect of turbulent velocity fluctuations on the design of wind turbines. A better knowledge of turbulent flows and its interaction with wind-farms at the large scale and the propeller turbulence boundary layer interaction at the small scale will help advance the technology. EuHIT's exceptional facilities **CICLoPE** , **LML**, **RIMT**, and **GTF** provide the ideal environment for fundamental research.
- Future fusion reactors will need complex turbulent forced flows of cryogenic fluids to cool the superconducting magnets. So far, expensive experiments are needed to validate the cooling of the magnets. Progress in the understanding of cryogenic turbulent, achieved with the **GHI, HRCF, GReC, CCTF** and **RIMT** facilities, can help to improve the situation. Moreover, the development of flow sensors made in this project, will allow improved tools for investigating cryogenic forced flows.
- Natural gas is transported in large gas pipelines, at high Reynolds numbers, which can be achieved in **GHI**, **CICLoPE, LML** and **CoGeoF**, with very well controlled and characterized conditions. In addition, **RIMT** provides a test-bed for the study of flows through valves and conduits. It is hoped that, in the future, due to a better understanding of turbulence, such gas pipelines can be optimized from the point of view of energy transport losses.
- In nuclear fission reactors, diphasic turbulent flow modelling rests on simplified physical models, which require adding a margin to keep the nuclear power plants always operating in safe modes. **TTF** is ideally suited to address fundamental issues on multiphase flows.

(C) Transport:

- The development of more efficient and environmentally friendly air, ground, and water transportation relies to a large part on the development of quieter, cleaner and more efficient propulsion systems. Progress requires a better knowledge of turbulent fluid flows in turbines and engines. This includes the effect of turbulence on sound emission, mixing, the effect of turbulence at the boundary layers and the associated heat transfer, and the statistics of turbulent fluctuations and the corresponding mechanical load at the turbine blades. The best facility for the study these effects is **RIMT**, **LML** and **CICLoPE**. Highest Reynolds number for load and mixing measurements are available at **GTF**.
- Often transportation takes place under conditions where the large-scale fluid is highly turbulent. This is due to the turbulence of the atmospheric boundary layer or to the self-generated turbulence from vehicular traffic. Currently all transportation vehicles are designed in environments where the external flow conditions are laminar, thus not representing the everyday environment. The unique EuHIT facilities **RIMT**, **GTF**, **CICLopE, GReC,** and **LML** provide complimentary facilities for measurements under well-controlled conditions at parameters corresponding to the natural environments.

(D) Food, Agriculture and Marine-Management and Biotechnologies:

- Flows in oceans and rivers are turbulent. Through the air/water interface turbulence drives an enhanced transport of air into the upper ocean levels. This is a problem of current research with impact on sustainable development and production of biological resources and marine managment. The best facility for the study of two-phase flow is **TTF** and the **GTF** for Lagrangian particle tracking.
- Turbulence determines the environment of plankton, which is the main food source for most higher developed ocean life. Currently, our understanding of the effects of turbulence on the biology of plankton is rudimentary. A better comprehension of these effects can be achieved

using particle-tracking methods at the **GTF.**

- Transport of aerosols and sand plays an important part in erosion and desertification of land and forest environments. An increased understanding of the impact of turbulence in boundary layers and aerosol transport is needed for better management and risk assessment of biological resources. This can be ideally addressed at **CICLoPE, LML, CoGoeF** and **GTF.**
- Turbulent mixing is essential for any large-scale bioreactors. These flows are often multiphase and highly turbulent. The turbulent mixing of multi-phase flows can be investigated at **TTF**, whereas **GTF** provides the most advanced particle tracking technology for EuHIT users.

(E) Security:

- As discussed already above under the topic “Environment” turbulence is key in the spread of pollutants. To increase the security of citizens in case of incidents involving an emission of dangerous or even toxic substances it is imperative to understand how compounds disperse when released in the turbulent atmospheric boundary layer. One item of particular concern is that turbulence can lead to rare but at the same time very large fluctuations of concentration. Turbulent dispersion at highest Reynolds number can be addressed at **GTF, TTF, CICLoPE** and **BOI**

(F) Nano Science, nanotechnologies, materials & production technologies:

- Turbulence is important for the mixing of nano-particles in fluids and gases. This is related to the discussion above under the topic “Energy”. Understanding how turbulence disperses and coagulates nano-particles is essential to assess the risk associated with the release of nano-particles in the air during a production process. This can be investigated through the Lagrangian particle tracking available at **GTF** and the numerical databases at **DLTD.**

Why does this require a European initiative and approach?

The best European infrastructures have joined forces to establish the integrating activity EuHIT in order to allow a wider and more efficient access to and the use of the cutting-edge facilities that have emerged on the national scale over the past 5 to 10 years. These facilities are unsurpassed in flow properties, but also and most importantly include the worldwide best measurement technology. Currently they are not open for trans-national access; in fact, most of them are only accessible within university programs or national research institutions. The European initiative EuHIT changes this situation completely and establishes the first ever cutting edge facility-network in turbulence research providing access to a broad trans-national user base. Concomitantly, within joint research activities of EuHIT the instrumentation of the facilities will be pushed towards the next level of innovations, which will multiply the scientific yield for the community. EuHIT explicitly establishes a strong link to industry and innovation portential by including industrial partners and advisory board members from indusrty.

How does EuHIT achieve integration within other international or national research activities?

The members of EuHIT represent more than 11 countries are involved in one way or another in all major national and international research initiatives on turbulence. It is through these initiatives and the networking work-packages that the international integration will be achieved. In addition, two international laboratories participate in the program, CERN and the UNESCO’s International Center for Theoretical Physics (ICTP) in Trieste, thereby further insuring international integration.

How does EuHIT achieve impact in innovation?

EuHIT incorporated industry participation in all government functions and R&D. Radu Colan from Vision Research Europe and the founder of SmartInst, Jean-Francois Pinton are members of the EuHIT Steering Committee. In the advisory board Uwe Ritschel from NORDEX Group, one of the leading wind turbine manufacturers, and Palle Gjelstrup, from Dantec Dynamics A/S, Europe’s leading company in fluid dynamics measurement technologies, shall advise EuHIT in all innovation and scientific questions. Work package 2b is specifically designed to innovate through integration of industrial researchers. Work package18 has SmartInst and VRI-Europe as partners in the development of the next generation technologies.

How is EuHIT structuring the way turbulence facilities operate, evolve and interact with each other and with users in Europe?

With its thirteen trans-national access and one service activity EuHIT offers not only the best complimentary set of world leading infrastructures, but also the best possible research tools to the community of European turbulence researchers. Twenty-two institutions participate in EuHIT's joint research activities structured in a way to optimally advance the development of the tools for the infrastructures. A European networking and educational program has been devised with the aim to foster a culture of cooperation among each other and all users in Europe. EuHIT enables the optimal use of resources by creating a community of researchers, providing common data bases and standards, defining good practices, ensuring dissemination of knowledge, and training researchers from industry and academia in the most modern equipment and data analysis techniques. The joint research activities will act as a breeding ground for technological breakthroughs. Pooling intellectual resources and focusing the effort of each group on specific tasks minimizes duplication and maximizes exploration and innovation of the best fluid dynamics technology. Simultaneously, young researchers are trained in the cutting-edge technologies. The structuring impact of EuHIT, with its tight integration within the three international activities, will extend well beyond the 48 months period of the grant.

What is the structuring impact of EuHIT on the turbulence research in Europe?

As discussed above, the integrated research infrastructure EuHIT constitutes an important cornerstone in a novel approach towards the integration of turbulence research across Europe. To date, research facilities on turbulence are not open trans-nationally. To overcome this, researchers from Europe create a trans-national infrastructure that builds upon successful examples in high-energy physics accelerators, synchrotron and free electron laser X-ray sources, and radio astronomy. The structuring impact of EuHIT is the integration of turbulence research across national and international boundaries. EuHIT enables a wider and more efficient access to and the use of the cutting edge facilities that have emerged on the national scale over the past 5 to 10 years. Thus, EuHIT will help to ensure the competitive advantage of European turbulence research.

How will EuHIT optimize the turbulence research infrastructures for the challenges expected in the future?

The immediate challenges facing all the infrastructures are in the simultaneously resolving of the large range of spatial and temporal scales of the turbulence. This challenge is fully addressed by the joint research activities described earlier. They are designed to advance the measurement technologies and to make them available to the research and industry. For the coming ten years the flow properties of the research infrastructures can be expected to remain world leading.

How will EuHIT impact the future of R&D in Europe?

Within EuHIT the work packages of the Joint Research Activities are developing the most advanced fluid dynamics measurement technology. Such technological advances are essential to provide the best future infrastructure and services at EuHIT's turbulence facilities. Furthermore, almost all of the technologies will also be ideally suited for general fluid dynamics measurements. These cutting-edge technologies will have a huge impact on R&D in Europe, especially in transport, aerospace, and energy industries. In addition, EuHIT will train a large number of graduate students both though the training component in the networking activity and in the joint research activities. In addition, EuHIT will provide R&D in Europe with junior scientists and engineers that are well versed in cutting-edge measurement technologies.