Summary of Workshop Discussion
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New in this workshop, compared to the previous one, was the employment of a manufactured solution for code verification. All participants agreed that this has been useful and informative. However, there was a general impression that the present manufactured solution is too easy, i.e. it does not contain all the difficulties of a complex turbulent flow. Additional manufactured solutions, e.g. for time-dependent problems, were welcomed.

Were the results of this second workshop for the backward-facing step more consistent than those of the first, thanks to the code verification with the MS? This question could not be answered positively yet, partly because not all participants had completed the case. Besides, there is a clear indication that attaining the asymptotic range in the calculation of the backward-facing step may require a number of cells significantly larger than used in the workshop. It was further suggested that part of the problem may be related to a too low level of the specified turbulence quantities at the inlet of the computational domain.

Prof. Celik raised the question of uncertainty estimation on coarse grids. He pointed out that in many practical situations grids used are unlikely to be in the asymptotic range, while most of the available error estimators have that requirement. As a result the uncertainty estimation may be unreliable. What is to be done? Can averaging help? Should one then work with an RMS of the estimated error or do local error estimation and average the result? The problem was acknowledged and it was considered unrealistic to rely on an automatic statistical procedure; an informed approach, looking carefully at relevant matters, was favoured. Nevertheless this does not solve Prof. Celik's problem.

Participants agreed that error estimation becomes more difficult when turbulence models are involved. The nature of the transport equations involved and the use of various limiters complicate matters significantly. This is clearly indicated by the results obtained in the manufactured solution proposed for the workshop.

If a third workshop is to be held in Lisbon, what should be the focus?
It was argued that it is unrealistic to expect consistency in the calculations performed by different codes. The diversity of solution algorithms, implementation of boundary conditions and turbulence model implementations makes this goal impossible to achieve. Even for the proposed manufactured solution, only a small number of groups computed the flow without any modification of the proposed solution. Therefore, it was accepted that it is better to go for self-consistency, which would allow each group to choose the most appropriate boundary conditions for their code.

In order to assess the quality of the error estimators with data outside the asymptotic range, a reference solution decisively in the asymptotic range is required. Therefore, it was suggested to keep the backward-facing step as the test case for the next workshop, but to demand from the participants a clear demonstration that the best results obtained

are in the asymptotic range. This will allow the evaluation of the error estimators on coarse grids.

A manufactured solution should be kept as the first test case. This serves as a code verification exercise and also as a confirmation of the performance of the error estimators with data in the asymptotic range. Although the present manufactured solutions can be used, alternative solutions, preferably more demanding than the one of this workshop, are welcomed. However, the manufactured solution must include all the equations required for a turbulent flow calculation, i.e. the turbulence model equations have to be included.