



**Technical Report**  
RAL-TR-95-038

# **A Progress Report of the EPSRC Computational Fluid Dynamics Community Club**

## **April 1992 - March 1995**

C Greenough and D Thomas

August 1995

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Computational Fluid Dynamics  
Community Club**

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## Summary

The EPSRC Community Club in Computational Fluid Dynamics was founded in March 1990 as one of four clubs set up under the EASE Programme and has now completed its fifth year of operation. This report covers the period April 1992 to March 1995 over which the membership of CFDCC has remained steady at around 700 members. The membership reflects a wide range of interests including the computation of flows around aircraft and in combustion engines, the mixing of chemicals in the process industry, the slow motion of viscous materials in the production of glass and the flow of rivers and tides.

The main achievements of the Club this period include:

- **Technical Meetings:** There have been fifteen CFDCC meetings over the period. Although the attendance at the technical meetings and workshop varied depending on the subject, the average attendance has been around 60 of whom about 15% were from industry. As in past years the contributions at the meetings have been of a high standard and the discussion well informed. Where possible these meetings have been organised jointly with other bodies interested in CFD such as CCP12, ERCOFTAC, ICFD, IMechE, the Royal Aeronautical Society and MODAGFCM.
- **EPSRC/IMechE Expert Meeting:** A notable success has been the EPSRC/IMechE Expert meeting on 'Uncertainty in CFD' which was held in Bournemouth in November 1994.
- **Quality Assurance in Fortran:** CFDCC has started a series of two-day hands-on workshops on QA in Fortran 77. These have been well attended.
- **Common Academic Software Library:** The provision of public domain and other software has continued. Four collections of programs are now available including the TEAM suite.
- **Commercial Software:** The Club continued the support of CFDS-FLOW3D, FLUENT, PHOENICS, STAR-CD and FEAT on the super-computer at DRAL for use by the academic community. All these were transfer to the Cray-YMP when it came into service.
- **Problem and Data Set Catalogue:** The catalogue has grown slowly during this period. The gathering of data and results has proven quite difficult. However references to more than 50 sources of flow data and test problems have been collected for use by the community. The CFD community continues to make considerable use of the data provided. There have been over 3000 accesses to the Catalogue and the data files.
- **Summer School:** The CFDCC Introductory School has been held three times in this period. Each school has been well attended and provided a highly interactive introduction to CFD for the attendees. A measure of the success of the schools is that the school of 1994 was over subscribed.

The Club co-operates with complementary CFD organisations in the UK in all its work in order to benefit the CFD community. This is reflected through the large number of joint meetings and representation on the Steering Group which oversees the operation of the Club.

The direction of CFDCC has continued in providing opportunities for the CFD community to meet and discuss topics of interest in modelling, test problem and data, and the rapid developments in computing and information technology now available to them.





## **1 Introduction**

This is the third report of the Computational Fluid Dynamics Community Club (CFDCC) set up by the Computing Facilities Committee of the SERC Engineering Board. It covers the period April 1992 to March 1995 in the CFD Community Club's activities.

CFDCC is one of four such Clubs set up under the Engineering Applications Support Environment (EASE). The Club has continued to grow and has now over 700 registered members. During the past three years thirteen specialist meetings have been held; some of these being jointly organised with the DRA Areospace, RMCS and ERCOFTAC UK. The CFD Community Club continues to provide a very effective mechanism for research workers in the area of CFD to collaborate and disseminate the results of their research.

## **2 A Historical Background**

The CFD Community Club was founded in late 1989 in response to the recommendations made to the subject committees of the SERC by the Advisory Group in Computational Fluid Dynamics, chaired by Professor Hutchinson (Cranfield). The CFD Community Club was one of four such Clubs set up under the SERC Engineering Boards EASE programme. The Club had its Inaugural Meeting in March 1990 at which the scope and objectives of the Club were set down and discussed. Since that meeting the programme of the Club has developed and it is recognised within the community as a focus of CFD activity.

Since this first meeting the Club organised over fifteen major technical meetings on subjects ranging from numerical accuracy in CFD computations to the visualisation of CFD results. Many of these meetings have been in co-operation with other bodies such as ERCOFTAC, IMechE and DRA. Coupled with these meetings a core technical programme has been developed including the establishing of access to commercial CFD packages, a common software library and a catalogue of experimental data and test problems.

The Club is continuing to develop its programme and to broaden the scope of its support to the CFD community. EPSRC provides funding for a small amount of core effort established at the Rutherford Appleton Laboratory to support the programme and funds to take out licenses on software requested by the community.

## **3 Community Club Objectives**

At its Inaugural Meeting the Club developed its initial set of objectives. These have been revised as necessary to reflect the changing needs of the community. A summary of the current objectives of the Club are:

- to organise specialist technical meetings on subjects of interest to researchers in CFD which can provide a forum in which to present and discuss research interests of the CFD community,
- to increase the awareness of advanced computing and software engineering techniques in the community by an exchange of views and information,
- to propose new activities to SERC committees for funding which aid the effective use of advanced computing techniques in CFD research, and

- to promote the exchange of CFD software and data throughout the community.

Through its programme of meetings and technical developments the Club has successfully promoted these objectives and has gained a large following in the community.

## **4 A Review of Activities during 1992/1995**

Club's program has continued developing the range of events organised and scope technical work performed. Although the basic structure of the CFD programme has remained the same, recommendations and comments from the community have been used to direct the work plan where ever possible. Discussion sessions at Club meetings have also ensured that the Steering Group has been able to plan a programme that addresses the needs of the community. The main elements of the CFD programme have been: the technical meetings and workshops, the common software library, software assessment and development, data sets and test problems.

### **4.1 Club Meetings**

Over this period CFDCC has held fifteen technical meetings including two QA Workshops and four CDFD Schools. These have built on the meetings programme of previous years. The other meetings have been made up of one-day seminars on a set of wide ranging subjects. Titles have included:

- Future Trends and Requirements in CFD Research
- Upwind Methods in CFD
- Workshop on the Visualisation of Numerically Generated Data
- Boundary Conditions for CFD
- Modelling Fluid Flows Using Vortex Methods
- CFD in Clean Technology
- Engineering Applications of CFD
- CFD Methods in Civil, Coastal and Marine Technology Applications
- New Opportunities and Directions in Aeronautical CFD
- CFD in Ship and Yacht Design

The attendance at these meetings has ranged from around 30 to over 90 depending on the subject. This is what might expect. The meeting on vortex methods only attracted around 30, whereas the meeting on upwind methods was attended by over 80. In general the audience at the meetings has reflect the size of the community working in these areas.

At all meetings there have been general discussion periods. These have in general been very lively and have developed some interesting debates. These open discussion periods and the feedback questionnaire, given out at all meeting, have given rise to suggestions for future meeting subjects.

## 4.2 Common Software Library

As part of the Club activities a library of common CFD software has been set up. The software has been contributed by members of the CFD community and is intended to encourage the exchange of software between research groups. Four pieces of software are already available.

The first is the TEAM (Turbulent Elliptic Algorithm Manchester) suite which consists of four two-dimensional programs originally developed at UMIST. This includes:

**TEAMKE:** finite difference/finite volume  $k - \epsilon$ ;

**TEAMASM:** algebraic Reynolds-stress turbulence model

**GEORG:** generates orthogonal grids by solving the inverse form of two Laplace equations

**TEAMCOG:** general purpose program to simulate steady, incompressible flows using ADI

Secondly, there is the FLUX program which solves the one-dimensional linear advection equation with unit speed or the inviscid Burgers' equation. It is primarily intended for teaching purposes and allows the user to test various algorithms and discretisation schemes.

Thirdly, there is a program which solves the two-dimensional Navier-Stokes equations in their primitive variable formulation, using the NAG/SERC Finite Element Library. This implementation is not efficient, but it is intended as a starting point for developing other finite element based approximations to the Navier-Stokes equations. An example of the results from this program are shown in Figure 1 and Figure 2.

Finally there is a vortex code which solves for the two-dimensional impulsively started, viscous, incompressible laminar flow around a circular cylinder.

Each program has been made conformant to standards, tested and documented to ensure its usability. It is planned to add more software to the library in the future. However the growth of this type of library is dependent on the willingness of the community to contribute. With the growing need to exploit the results of academic research there is an increasing tendency for groups not to be willing to allow free access to their research programs.

As part of the work CFDCC will develop a catalogue of both commercial and public domain CFD software, with contact details, and make it available through HENSA.

## 4.3 Data Sets and Test Problems

A catalogue of data sets and test problems has been compiled. It consists of a list of published reports and papers containing well-characterised and carefully carried out experiments or computations. In addition a collection of results from turbulent flow experiments which were collected by flow experts for the Stanford conferences on Complex Turbulent Flows held in 1980 and 1981 have also been included in the data catalogue. This data will be updated as new information is gathered.

## 4.4 Availability of Software and Data

Both the common software library and the catalogue of data sets and test problems are available on the Higher Education National Software Archive (HENSA). HENSA can be accessed over the network using the address `unix.hensa.ac.uk` and login name `archive`. Access can be made either through `telnet` or anonymous `ftp`. You will be asked for your e-mail address. The HENSA file

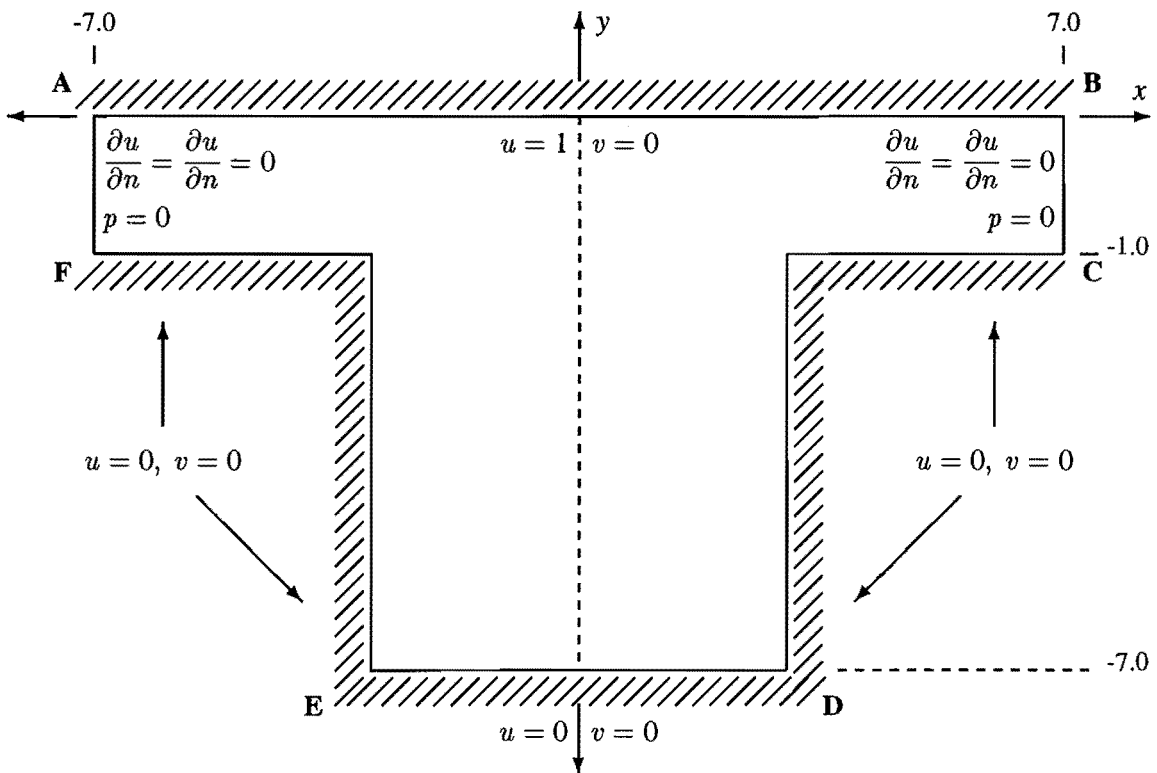


Figure 1: Problem Definition

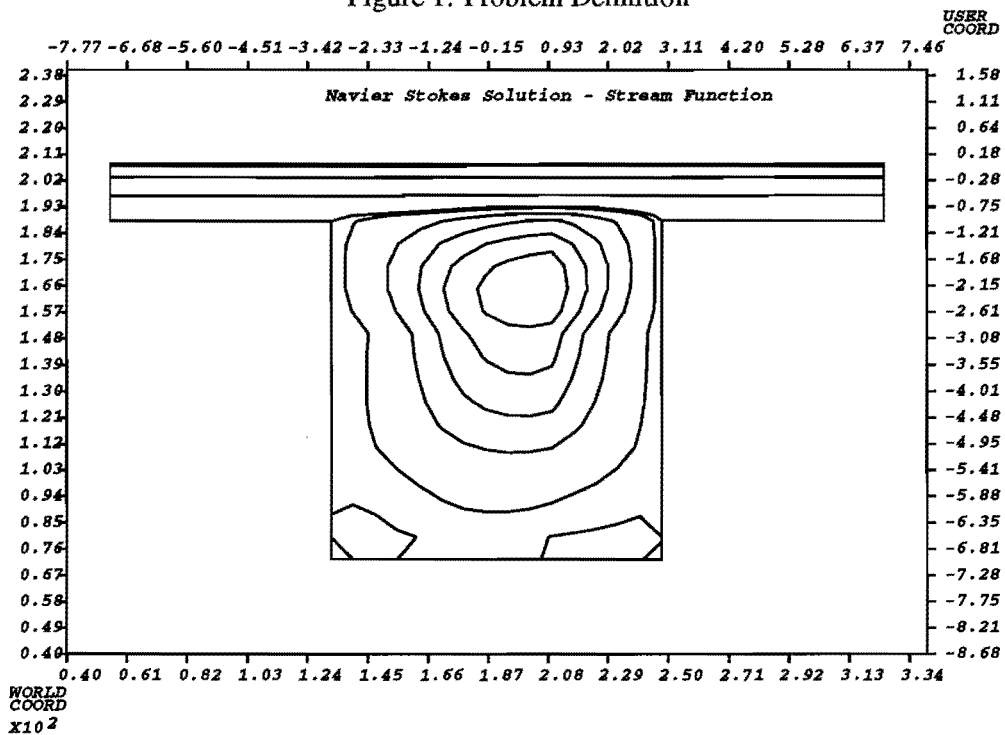


Figure 2: Contours of Stream Function

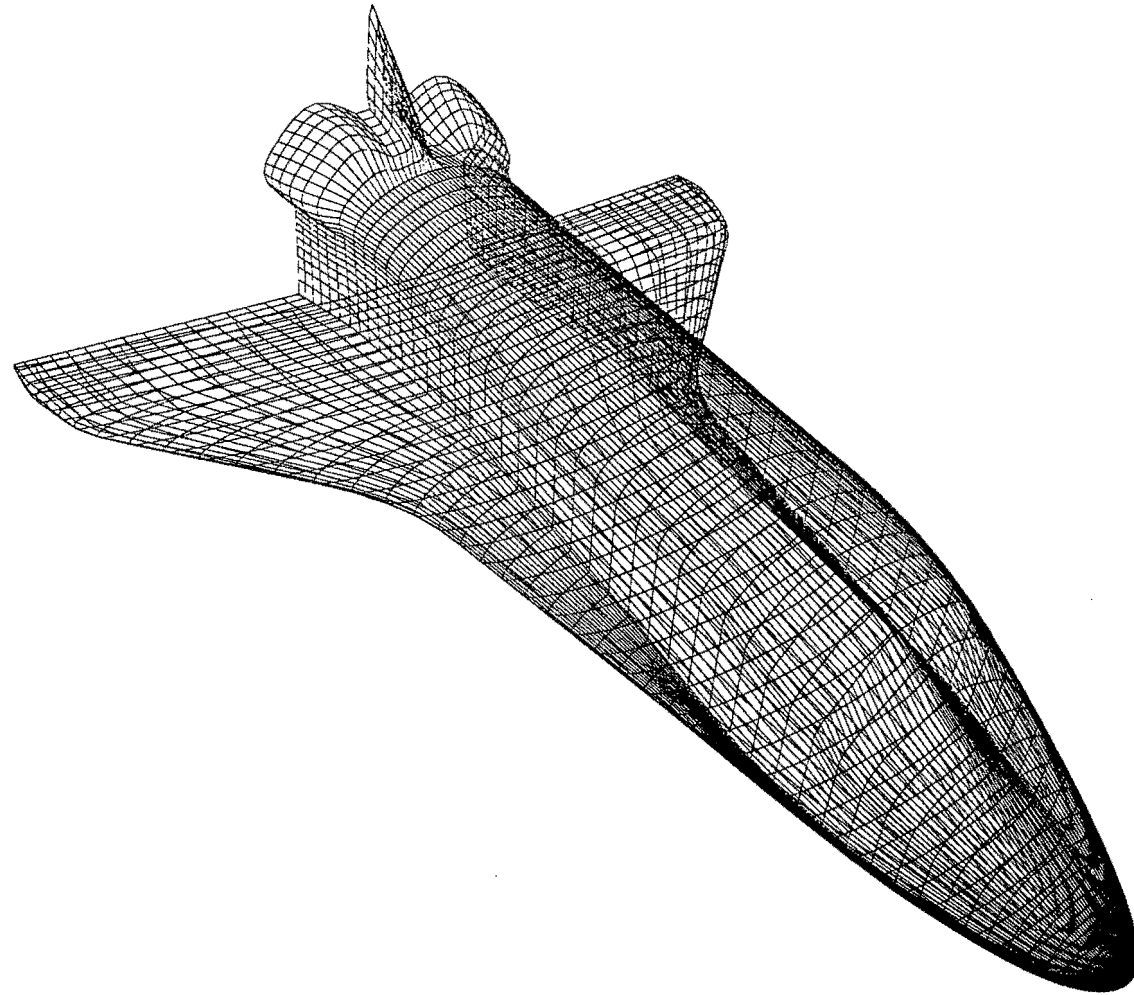


Figure 3: Mesh Geometry of the US Space Shuttle (Test case for ERCOFTAC/CFDCC Workshop on Grid Generation)

store is navigated using standard Unix commands such as `cd` and `ls`. The chapter provided by CFDCC is in the archive under a directory `/pub/misc/cfd` which contains two sub-directories `data` and `software`.

The HENSA archive can also be accessed through the World Wide Web (www) using the address <http://www.hensa.ac.uk>.

#### **4.5 Access to Commercial Software**

Requests have been received from research council grant-holders for access to some of the commercial CFD packages such as PHOENICS and FLOW3D on the Cray at RALAtlas Centre. CFDSG have negotiated special licenses with the software vendors so that the academic community can use the software on the Cray for academic research purposes, without obtaining a separate Cray license. Currently five packages have been made available on the Cray YMP at the DRAL Atlas Centre:

- CFDS-FLOW3D (CFD Services, Harwell)
- FEAT (Nuclear Electric)
- FLUENT (FLUENT UK)
- PHOENICS (CHAM Limited)
- STAR-CD (Computational Dynamics)

Three of the packages (FLUENT, FEAT and STAR-CD) require the users to hold a current workstation licence. Further information on how to access given access to these programs can be obtained from Dr RG Evans at the Atlas Centre (contact details are given in Appendix I).

### **5 Introductory School on CFD**

The running of the CFDCC Introductory School on CFD has continued. The fourth such school was held from 9th to 13th January 1995. Each year attendance at the school has been very good. All of the 24 available places being taken.

The school seeks to provide a straight-forward introduction to the basic background to computational fluid dynamics. The goal of the school has been to provide new research students with a starting point in CFD modelling techniques including: the nature of fluid flow and the Navier-Stokes equations, discretisation schemes and solution strategies, and the modelling of turbulence.

The school was intended to be highly interactive and this has been achieved by a combination of formal lectures and practical sessions. During and after each lecture the participants are encouraged to ask questions and discuss any difficulties they have encountered. The practical sessions illustrate the contents of each lecture by running and modifying specially constructed test cases.

The main lecturing staff at the school have been:

- Professor Derek Causon (Manchester Metropolitan University)
- Mr Steve Fiddes (University of Bristol)
- Professor Jim McGuirk (University of Loughborough)
- Dr Bassam Younis (City University)

In addition staff of DRAL have acted as tutors during the practical sessions.

In 1993, the school was run jointly with RMCS when Dr RD Rhodes and Dr D Bray joined the lecturing team and provided lectures on the nature of turbulence and experimental techniques.

In 1995 Professor Bill Jones of Imperial College joined the school at very short notice to lecture on Combustion and Pressure Correction Methods.

The contents of the school have been developed after each school using the comments of the participants and the observations of the lecturing staff. This has led to the introduction of new topics into the lecturing schedule and the removal or reduction of others. In this way the lecturing team hopes that the school will meet the needs of its target audience.

Over the last two schools it has been evident that those attending the school are not the developers of new CFD algorithms and software, but more the users of CFD in particular applications. A strong interest has been shown in commercial software and its capabilities. As a result the school content has been changing. The trend is away from the development of new techniques toward acquiring an understanding of CFD in order to make intelligent use of CFD programs and realistic interpretation of the results of an analysis.

In conclusion, the CFDCC School in CFD has proven very successful in providing new research staff with a good grounding in the problems and techniques of CFD.

## **6 Workshop on Quality Assurance for Fortran 77 Programs**

It has long been recognised by the CFDCC Steering Group that the promotion of good software development standards were essential in modern scientific and engineering research. The design, development and modification of large software systems was an important skill required by most research staff. This was thought particularly true of CFD.

The CFD community is not alone in this understanding of the importance of good software development practice. Whenever software is developed as part of a research project there can be both short term and long term benefits to the project if good practice is followed. Be it simply in making the software reusable by future research students or allowing current students to share software, or even to improve the prospects for the exploitation of the research in a commercial product.

Although the academic community is typically not required to develop software to standards such as ISO 9000 & BS 5750, it is generally accepted that making a better job of software development will improve the efficiency and cost-effectiveness of the research process.

As a result of this conviction, CFDCC developed a pragmatic guide to reasonable software development in the research community and sought to promote this through a number of workshops on software development. The primary goal of these was:

*To improve the quality of the software written during research activities thereby improving the quality of the research and obtaining better value for money*

The Steering Group believed that by attaining this goal there would be significant benefits to the CFD community. Among these would be:

- The software developed on research grants will be easier to maintain and reuse.
- Software exchange within the research community will become easier and hence more likely.



Figure 4: Participants in the Forth CFD School held at The Cosener's House, Abingdon in January 1995. *Back row, left to right:* A Hatem, Chris McNab, Simon Jackson, Steve Fiddes, Marcus McCallum, Radenko Drakulic, John Ashby, Michael Slack, Mohammad Al-hajeri, Bassam Younis, F Sarvar. *Fourth row:* Bill Jones, David Mortimer, Derek Causon, Simon Lucas, Paul Campbell, Shaun Smith, Jonathan Hartland *Third row:* Sanjit Maanan, Tony Chesneau, Nigel Henderson *Second row:* Chris Greenough, David Stribling, Michael Nkansah, Debbie Thomas, Dirk Hermans *Front row:* Cecil Scott, Paula Agutter, Avril Moore, Ennio Pasqualotto



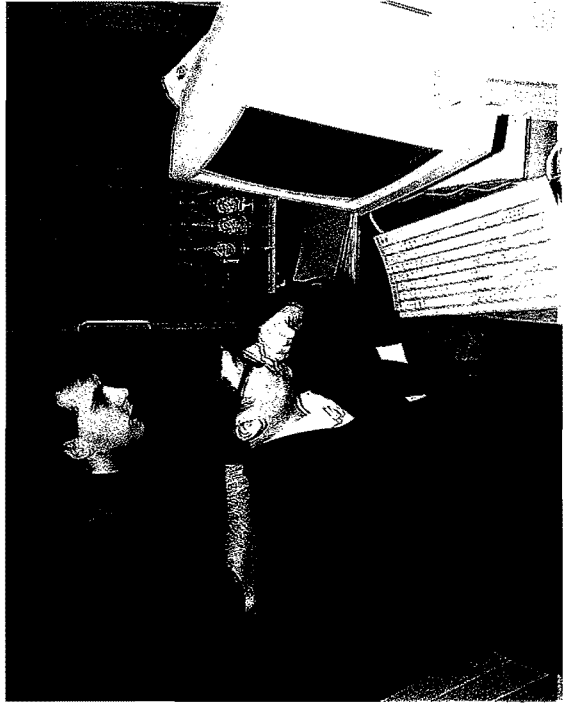
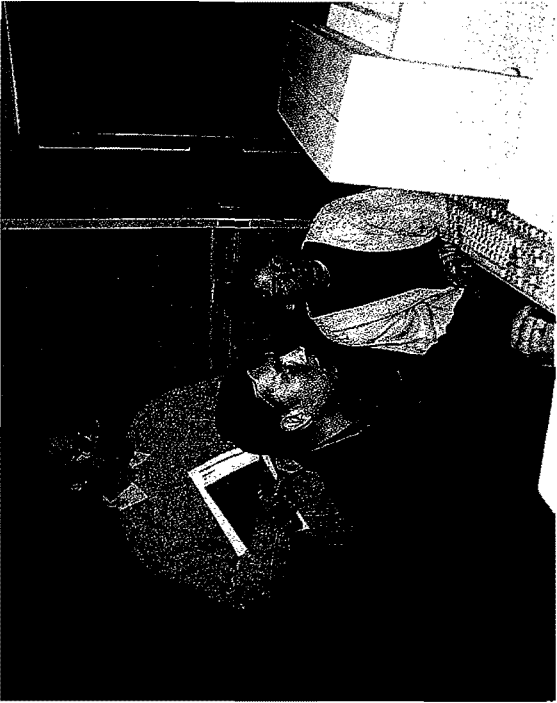
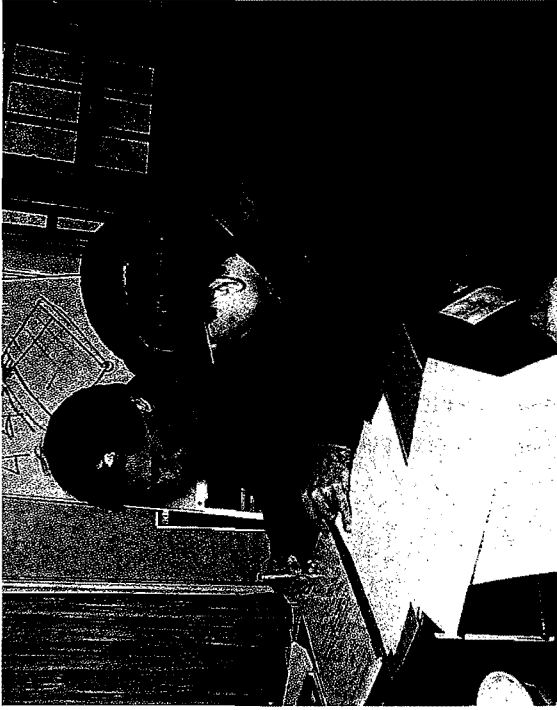


Figure 5: Scenes from the Third CFD Community Club School.

- There should be a large reduction in software duplication within research projects with new projects building on the successful results of previous work.
- As the quality and documentation of software developed in the future improves there is the possibility of setting up a national archive for research software open to the whole community.
- Research students will be better trained in good software development practices.

CFDCC has now run two such workshops and a third is planned. The current format of the two-day workshop includes on the first day both introductions to the concepts of software quality but also an introduction to some practical methods of software design and testing. Subjects such as Fortran 77 portability and coding styles are also covered. Because of the introduction of the Fortran 90 standard a lecture on the Fortran 90 language has been included.

The emphasis of the workshops has been on practical solutions and throughout the two days the participants have the opportunity to use both commercial and public domain QA tools. The second day of the workshop is given over to using these tools on the software developed by the participants.

To date these workshops have been well attended and the participants have indicated that the time was well spent.

## 7 EPSRC/IMechE Expert Meeting

In November 1994 the EPSRC and IMechE held their annual expert meeting at the Swallow Highcliff Hotel, Bournemouth. It was the fifth in a series of meetings intended to study specific engineering topics and to consider the actions necessary to promote future development. In this year the subject to be addressed was *Uncertainty in Computational Fluid Dynamics*. This subject was selected by the joint EPSRC/IMechE panel from a long list of topics after a submission was made by CFDCC. Previous topics had included: mechatronics, composite structures, IT and product design and joint prostheses.

The organising panel included members from EPSRC, IMechE and CFDCC. They were:

- Dr E Fisher (Chairman, IMechE)
- Dr C Greenough (CFDCC)
- Professor AD Gosman (CFDCC)
- Professor M Leschziner (CFDCC)
- Dr RB Dean (CFDCC)
- Mr R Liwicki (EPSRC)
- Mr F Mak (IMechE)
- Miss S Cook (IMechE)

The panel objective was to draw together the right academics and industrialists to address this subject and to identify the underlying sources of uncertainty to fluid dynamic computations.

The meeting brought together some 44 experts, including academics, researchers, consultants, engineering designers and representatives of regulatory bodies. The delegates took part in a series

of expert presentations followed by discussion sessions. Each of these periods sought to identify the sources of uncertainty in CFD and to provide insight into their elimination or control. The ranges addressed ranged from geometric modelling, through turbulence representation to software quality. Each area was believed to contribute to uncertainty in CFD computations.

The meeting brought these discussions to a focus by drawing up some conclusions and recommendations which will be published by the EPSRC and IMechE.

## **8 The CFD Community Club Membership and Steering Group**

The registered membership of the Community Club has been steady and stands at some 700 academics and industrialists, representing more than 65 higher educational institutes (HEIs) and 60 companies. Approximately 70% of the membership is from the academic community. The membership reflects the wide range of applications found for CFD techniques, from the computation of air flow around complete aircraft to the slow motion of viscous materials in the production of glass.

The membership of the Steering Group tries to reflect the interdisciplinary nature of CFD. There have been a number of changes in the composition of the Steering Group since the last report.

The most significant is retirement of Prof GP Hammond as Chairman. The CFD community owe a considerable debt of thanks to Prof Hammond for his chairmanship of the CFDCC Steering Group. It has been through his careful leadership that the Club has successfully grown to its present membership and developed its current range of activities. The chair has now been taken by Mr GP Thompson of Binnie & Partners. Mr Thompson has a strong background in the application of CFD to environmental flows and has been a member of the Steering Group since 1992.

Other changes that have happened since 1992 are: Prof JCR Hunt (Cambridge) and Dr NP Weatherill (Swansea) have left the group and GP Thompson (Binnie & Partners), Prof DM Causon (Manchester Metropolitan), Dr EH Fisher (IMechE), DJ Nicholas (ERCOFTAC) and Prof MA Leschziner (UMIST) have joined the group.

The current Steering Group members are:

- GP Thompson – Binnie & Partners (Chairman)
- Prof DM Causon – Manchester Metropolitan
- Dr RB Dean – WS Atkins (Industry)
- Dr EH Fisher – Newcastle (IMechE)
- Prof AD Gosman – Imperial
- Prof P Hutchinson – Cranfield
- Prof MA Leschziner – UMIST
- DJ Nicholas – RAL (ERCOFTAC)
- Prof BR Williams – DRA, Aerospace (MOD AGCFM)

The SERC staff that support the activities of the Community Club and attend Steering Group Meetings are:

- Dr D Emerson – Daresbury Laboratory (Secretary of CCP12).

- Ms RM Eden – Swindon Office.
- Dr C Greenough (Project Co-ordinator) – Rutherford Appleton Laboratory.
- Mrs D Thomas (Secretary) – Rutherford Appleton Laboratory.

The Steering Group continues to meet on a regular basis to discuss and plan the activities of the Club. The Steering Group has agreed to strengthen its industrial representation and is currently considering possible new members.

Besides advising on the operation of the Club, the Steering Group also monitors developments in computing hardware and research issues through the members' own research programmes. In addition to this the Steering Group has a representative of the Collaborative Computational Project in Parallel CFD (CCP 12) to keep it informed of developments coming from this programme.

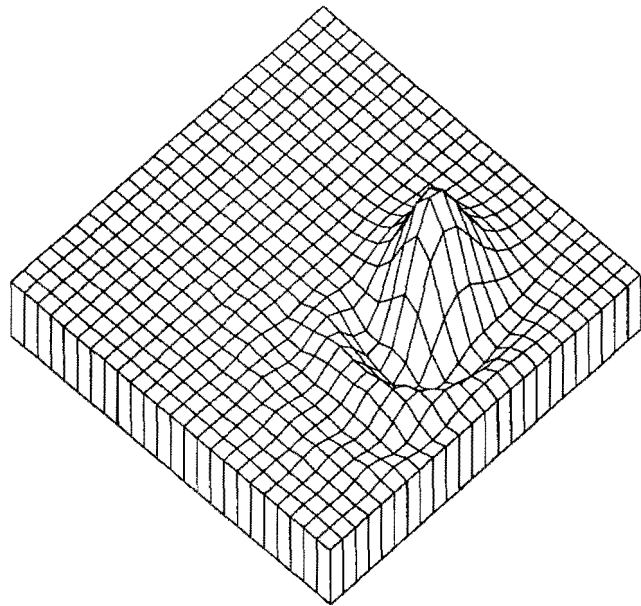
## 9 Relationship with other Complementary Organisations

There are many organisations within the United Kingdom and Europe that provide activities for research workers in CFD. Among these are the European Research Community on Flow, Turbulence and Combustion (ERCOFTAC), the Institute for Computational Fluid Dynamics (ICFD) which is a collaboration between Oxford and Reading Universities, the DTI Advisory Group on Computation Fluid Mechanics (AGCFM), IMechE and the EPSRC Engineering Board Collaborative Computational Project 12 (CCP12). The Community Club has made it a matter of policy to involve such organisations in its programme by holding joint meetings and by having suitable representation on the Steering Group. In this way the Club can ensure that its activities are complementary to the others being organised, and that within the UK CFD activities are co-ordinated.

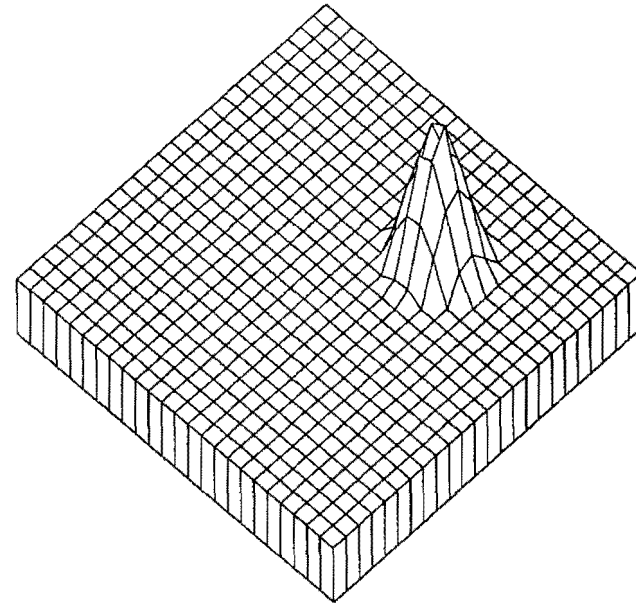
## 10 The Future Programme

The Club's programme will continue to develop under the guidance of the Steering Group and in response to requests from the community. The Club's emphasis will continue to be on technical meetings and workshops. As the material develops the software and data set libraries will be updated. The main elements of the programme will be:

- **Technical Meetings** This programme will continue and include meetings on topics suggested by the CFD community and the CFD Steering Group. In particular the workshop on quality assurance will be run again in July. This year the workshop will look more closely at the benefits that can be gained by using Fortran 90.
- **Introductory School** The Introductory School will continue to be held in January each year. The objective of the school is to provide a foundation in the physical understanding of fluid flow and the consequences for the numerical solution of fluid flow problems for those just starting postgraduate research.
- **Test Problem and Data Sets Catalogue** The Data Catalogue will be developed during the year as new material is identified.
- **Common Academic Software Library** This library will be augmented during the year and made available to the community through HENSA. In addition a catalogue of available commercial and public domain CFD programs.



Numerical Solution



Analytic Solution

Figure 6: Output from the two-dimensional numerical scheme testbench CONE

- **Commercial Software** The range of commercial CFD software available to the community will continue to be supported on the Cray-YMP at DRAL. Provision of this support will be reviewed in the Autumn.
- **Software Development Guide** The guide for the development of engineering applications software in Fortran 77 will be revised and some elements of Fortran 90 will be include. The QA Workshop will be run again and Fortran 90 and Fortran 90 tools considered.

## 11 Further Information

Further information on the activities and reports of the CFD Community Club can be obtained from the authors of this report. E-mail requests for further information and inclusion on the Club's mailing list can be made to *cfdcc@inf.rl.ac.uk*. CFDCC has a World Wide Web page at <http://www.cis.rl.ac.uk/clubs/CFD/index.html>. The authors can be contacted on Abingdon (01235) 445307 or 446712.

## Appendix I – CFDCC Contacts

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## Appendix II – CFDCC Workshops and Seminars

### 1. Future Trends and Requirements in CFD Research

**Venue:** Rutherford Appleton Laboratory

**Date:** Monday, 6 April 1992

**Chairman:** Prof GP Hammond (Bath)

**Speakers:** Prof GP Hammond (Bath), Dr BA Younis (City), Prof K Morgan (Swansea), Prof MA Leschziner (UMIST), P de Lusignan (EC, Brussels), Prof M Meneguzzi (CER-FACS), Prof D Bradley (Leeds)

**Attendance:** 57 (36 Academic, 21 Industrial)

### 2. Upwind Methods in CFD

**Venue:** Rutherford Appleton Laboratory

**Date:** Tuesday, 26 May 1992

**Chairmen:** Prof PL Roe and Dr PK Sweby

**Speakers:** Dr PK Sweby (Reading), Dr R Hillier (Imperial), Dr EF Toro (Cranfield), Prof PL Roe (Michigan), Prof DM Causon (Manchester), Prof K Morgan (Swansea)

**Attendance:** 64 (54 Academic, 10 Industrial)

### 3. Workshop on the Visualisation of Numerically Generated Data (Joint meeting with ERCOFTAC UK South Pilot Centre)

**Venue:** The Cosener's House, Abingdon

**Date:** 15 to 19 June 1992

**Speakers:** Prof JCR Hunt (Met Office), Prof DB Spalding (CHAM), Dr IP Jones (CFDS), Dr J Ludwig (CHAM), Prof E Onate (Barcelona), Prof C Hirsch (Brussels), Dr ThH van der Meer (Delft), Dr AG Hutton (Nuclear Electric), Dr HCT Pagendam (DLR), Dr M Gobel (FhG, Darmstadt), Prof AD Gosman (Imperial)

**Attendance:** 51 (28 Academic, 23 Industrial)

### 4. Boundary Conditions for CFD (Joint meeting with Defence Research Agency AGCFM)

**Venue:** University of Surrey

**Date:** 21 to 22 September 1992

**Chairman:** Dr. B.R. Williams (DRA)

**Speakers:** Dr CM Albone (DRA), Dr N May (ARA), Mr D Ng (BAe), Prof KW Morton (Oxford), Prof JJ McGuirk (Loughborough), Prof GP Hammond (Bath) Dr WP Jones (IC)

**Attendance:** 86 (40 Academic, 46 Industrial)

### 5. Introductory School in Computational Fluid Dynamics (Joint meeting with RMCS)

**Venue:** The Cosener's House, Abingdon



**Date:** 4 to 8 January 1993

**Speakers:** SP Fiddes (Bristol), Dr BA Younis (City), Dr DG Rhodes (RMCS), Prof DM Causon (Manchester), Prof JJ McGuirk (Loughborough), Dr D Bray (RMCS)

**Attendance:** 17 ( 13 Academic, 4 Industrial)

6. Modelling Fluid Flows Using Vortex Methods

**Venue:** University of Manchester

**Date:** Wednesday, 17 March 1993

**Chairman:** Prof PK Stansby (Manchester)

**Speakers:** Prof PK Stansby (Manchester), Dr PG Bellany-Knight (Manchester), Prof JMR Graham (ICST), Prof RI Lewcastle, Dr M Downie (Newcastle), Dr DM Summers (Napier)

**Attendance:** 35 (34 Academic, 1 Industrial)

7. CFD in Clean Technology

**Venue:** Rutherford Appleton Laboratory

**Date:** Thursday, 22 April 1993

**Chairman:** Prof GP Hammond (Bath)

**Speakers:** Prof GP Hammond (Bath), Dr AGL Borthwick (Oxford), Prof BD Crittenden (Bath), Dr B Rogg (Cambridge), IJS Winiarski (CTU, SERC), Prof N Syred (Cardiff), Prof JCR Hunt (Met Office)

**Attendance:** 37 (36 Academic, 1 Industrial)

8. Improving the Quality of Fortran Programs

**Venue:** Rutherford Appleton Laboratory

**Date:** 27 – 28 July 1993

**Chairman:** Dr SK Robinson

**Speakers:** Dr SK Robinson (RAL), Mrs C Sinclair, J Collins (Sim & Comp Consultants), Dr J Appleyard (Polyhedron), I Hounam (NAG Ltd), E Samuels (Programming Research Ltd), J Kelly (Program Analyser), Dr C Greenough (RAL)

**Attendance:** 29 (26 Academic, 3 Industrial)

9. Engineering Applications of CFD (Joint conference with IMechE)

**Venue:** IMechE Headquarters, London

**Date:** 7 – 8 September 1993

**Attendance:** 74 (31 Academic, 43 Industrial)

10. CFD Methods in Civil, Coastal and Marine Technology Applications

**Venue:** University College, London

**Date:** Wednesday, 17 November 1993

**Chairman:** Mr G Thompson (Binnie & Partners)

**Speakers:** Prof J Chaplin (City), Prof R Eatock Taylor (Oxford), Prof H Peregrine (Bristol), Prof P Bettess (Newcastle), Prof R Falconer (Bradford), Prof R Burcher (University College, London)

**Attendance:** 52 (50 Academic, 2 Industrial)

**11. Third CFDCC Introductory School in Computational Fluid Dynamics**

**Venue:** The Cosener's House, Abingdon

**Date:** 10 – 14 January 1993

**Speakers:** SP Fiddes (Bristol), Prof DM Causon (Manchester Metropolitan), Prof JJ McGuirk (Loughborough), Dr BA Younis (City)

**Attendance:** 23 (22 Academic, 1 Industrial)

**12. New Opportunities and Directions in Aeronautical CFD**

**Venue:** Rutherford Appleton Laboratory

**Date:** Wednesday, 20 April 1994

**Chairman:** SP Fiddes (Bristol)

**Speakers:** Prof G Hammond (Bath),

**Attendance:** 69 (60 Academic, 9 Industrial)

**13. Improving the Quality of Fortran Programs**

**Venue:** Rutherford Appleton Laboratory

**Date:** 6 – 7 July 1994

**Speakers:** Dr SK Robinson (DRAL), Dr C Greenough (DRAL), RE Thomas (DRAL), Dr J Reid (DRAL), Mrs D Thomas (DRAL). Additional vendors presentations during demonstration sessions.

**Attendance:** 16 (9 Academic, 7 Industrial)

**14. CFD in Ship and Yacht Design**

**Venue:** University of Newcastle

**Date:** Wednesday, 16 November 1994

**Chairman:** Prof P Bettess (Newcastle)

**Speakers:** Dr P Gallagher (WS Atkins), Dr S Turnock (Southampton), SP Fiddes (Bristol), S Watson (DRA Haslar), Prof JMR Graham (Imperial), Dr EJ Glover (Consultant), Prof G Hearn (Newcastle)

**Attendance:** 32 (30 Academic, 2 Industrial)

**15. Fourth CFDCC Introductory School in Computational Fluid Dynamics**

**Venue:** The Cosener's House, Abingdon

**Date:** 9 – 13 January 1995

**Speakers:** SP Fiddes (Bristol), Prof DM Causon (Manchester Metropolitan), Prof JJ McGuirk (Loughborough), Dr BA Younis (City), Prof WR Jones (Imperial College)

**Attendance:** 23 (22 Academic, 1 Industrial)

## **Appendix III – Proceedings of Workshops and Seminars**

For each of the workshops and seminars listed the collected papers and view graphs have been collected under a single cover. These are available to all members of the academic and industrial community.

1. Future Trends and Requirements in CFD Research, CFDCC Proceedings 8, April 1992
2. Upwind Methods in CFD, CFDCC Proceedings 9, May 1992
3. An Introduction to Computational Fluid Dynamics, CFDCC Proceedings 10, January 1993
4. Modelling Fluid Flow Using Vortex Methods, CFDCC Proceedings 11, March 1993
5. Improving the Quality of Fortran Programs, CFDCC Proceedings 13, July 1993
6. CFD Methods in Civil, Coastal & Marine Technology Applications, CFDCC Proceedings 14, November 1993
7. An Introduction to Computational Fluid Dynamics, CFDCC Proceedings 15, January 1993
8. New Opportunities and Directions in Aeronautical CFD, CFDCC Proceedings 16, April 1994
9. Improving the Quality of Fortran Programs, CFDCC Proceedings 17, July 1994
10. CFD in Ship and Yacht Design, CFDCC Proceedings 18, November 1994

## Appendix IV – CFDCC Reports and Articles

During the year the activities of the Community Club have led to a number of reports and articles describing the membership and activities of the Club. Copies of these are available to all members of the academic and industrial community.

1. Workshop on Turbulence Modelling, *Dr CJ Fitzsimons*, ECN No. 37 (March 1992)
2. Visualisation in CFD, *Dr CJ Fitzsimons*, ECN No. 39 (July 1992)
3. Future Trends and Directions in CFD, *Dr C Greenough & Dr CJ Fitzsimons*, ECN No. 39 (July 1992)
4. Upwinding in CFD, *Ms MK Bopari*, ECN No. 39 (July 1992)
5. Workshop on Boundary Conditions in CFD, *Dr CJ Fitzsimons*, ECN No. 39 (July 1992)
6. Introductory School in CFD, *Dr CJ Fitzsimons*, ECN No. 40 (September 1992)
7. Workshop on the Visualisation of Numerically Generated Data, *Ms MK Bopari*, ECN No. 40 (September 1992)
8. A Catalogue of Experimental Data for CFD, *Dr JV Ashby*, ECN No. 41 (December 1992)
9. An Introduction to CFD, *Mrs D Thomas*, ECN No. 41 (December 1992)
10. CFD Common Software Library, *Ms MK Bopari*, ECN No. 42 (January 1993)
11. European Co-operation in the Field of Scientific and Technical Research, *Dr C Greenough*, ECN No. 42 (January 1993)
12. Annual Report of CFD Community Club, *Mrs D Thomas & Dr C Greenough*, ECN No. 42 (January 1993)
13. Report of Introductory School in CFD, *Mrs D Thomas & Ms MK Bopari*, ECN No. 43 (March 1993)
14. The Introductory School – A Student's View, *Prof HV Rao*, ECN No. 43 (March 1993)
15. Modelling Fluid Flow using Vortex Methods, *Mrs D Thomas & Ms MK Bopari*, ECN No. 44 (May 1993)
16. Improving the Quality of Fortran Programs, *Mrs D Thomas*, ECN No. 44 (May 1993)
17. CFD Software on the Atlas Cray YMP, *Dr J Gordan*, ECN No. 45 (July 1993)
18. Improving the Quality of Fortran Programs – Review, *Mrs D Thomas, C Lowe, C White*, ECN No. 46 (September 1993)
19. New CFD Software for the HENSA Library, *Ms MK Bopari*, ECN No. 47 (November 1993)
20. Introductory School in CFD, *Mrs D Thomas*, ECN No. 47 (November 1993)

21. More CFD Software on the Atlas Cray, *Dr J Gordan*, ECN No. 48 (January 1994)
22. Vortex Code Available on HENSA, *Ms MK Bopari*, ECN No. 48 (January 1994)
23. CFD Methods in Civil, Coastal and Marine Technology Applications, *Mrs D Thomas*, ECN No. 48 (January 1994)
24. CFDCC Winter School, *Dr T Matthews (Reading)*, ECN No. 49 (March 1994)
25. New Opportunities and Direction in Aeronautical CFD, *Mrs D Thomas*, ECN No. 51 (July 1994)
26. Improving the Quality of Fortran Programs, *Dr Phil Mawby (Swansea)*, ECN No. 52 (September 1994)
27. Osbourne Reynolds Centenary Symposium, *Prof BE Launder (UMIST)*, ECN No. 53 (November 1994)
28. CFD in Ship and Yacht Design, *Dr JV Ashby (DRAL)*, ECN No. 54 (January 1995)

## **Appendix V – Terms of Reference of the CFD Steering Group**

The Terms of Reference of the SERC Computational Fluid Dynamics Community Club are:

1. To advise the Rutherford Appleton Laboratory on running a Community Club in CFD under the EASE Programme,
2. To make recommendations on a programme of activities to benefit the CFD research community,
3. To maintain a knowledge of computing requirements for CFD research.
4. To monitor the provision and use of existing computing facilities for CFD research,
5. To make recommendations on the provision of new computing facilities for CFD research,
6. To liaise with other CFD initiatives in the UK and elsewhere,
7. To establish close links with industry to ensure that end-users requirements are taken into account by the CFD research community and that industry is aware of CFD research activities and needs,
8. To encourage, as appropriate, international collaboration in CFD research,
9. To report to the Community Club in CFD at least annually, and
10. To report through relevant Subject Committees to the Engineering Research Commission on the activities of the Community Club and on the provision and use of existing computing facilities for CFD research at least annually.