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The Annual Report of the EASE Visualisation Community Club

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**The Annual Report of the EASE
Visualisation Community Club**

July 1991 - December 1992

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December 1992**

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Foreword

Visual thinking has always been important in engineering and science. Leonardo da Vinci and James Clerk Maxwell, for example, were noted 'visualizers': Clerk Maxwell built clay models to represent functions of two variables - the forerunner of the 'carpet plots' commonly used today.

Early computational science and engineering also saw visualization as important: von Neumann saw the potential for numerical experiments to simulate nature, having the same 'look and feel' as physical experiments. So the notion of visualization is certainly not new, and indeed one can point to pioneering work in the UK during the 1960s at UKAEA Culham Laboratory, Aldermaston Laboratory and the SERC Rutherford Laboratory, where movies were made to present results from numerical calculation.

But the subject has risen to major prominence in the last decade - for two main reasons. Firstly, the need is now overwhelming: recent advances in computational power for numerical simulation, and in the technology for image capture, have both resulted in the generation of vast quantities of data which can only be assimilated with visual aids. Secondly, computing technology now offers us colour graphics as a standard option on a workstation - so that graphics is no longer a special effect but is available to all.

There also now exist a number of very powerful visualization software systems: AVS, IRIS Explorer, IBM Data Explorer and Khoros. These enable an engineer to import a set of data, perhaps as output from a CFD code or other numerical software, and quickly generate a view of the data. The systems are interactive, so the engineer can easily explore different views of the data. Application modules can be inserted into these systems, and so a user can incorporate their own numerical code directly.

The SERC Visualization Community Club was set up in 1991 to provide a forum for engineers to share their own experiences on visualization. As is clear from this report, the Club has had a very active first year, with a range of seminars, meetings and workshops. Although the development of the large visualization software systems has tended to be focused in the US, it has been evident that there is much innovation within the UK, both in the use of these systems and in the search for new and more effective display techniques.

The Club also provides an important outlet for the work of the visualization group at RAL. They have participated in major product evaluations, and provided training and support for AVS - now available to the Higher Education community via a CHEST deal. Their work is disseminated through Club mailshots.

An interesting development has been the videoing of Club meetings. It seemed unsatisfactory to distribute copies of speakers' OHP slides, when very often the most interesting visual material was on video or 35mm slide. Thus we have experimented with the idea of recording sessions on video, and preparing an edited version for distribution. We hope this will prove a success.

The Club is 'directed' by a Steering Group which meets regularly to plan events, and to advise the visualization group at RAL on their work programme. I should like to take this opportunity to thank my fellow members of the Steering Group, and of course the RAL staff who work hard for the Club - Mr. J R Gallop and Mrs. R Popovic, who is the Secretary of the Club and its Steering Group.

We look forward to another stimulating year in 1993.

KWB

Summary

This is the first annual report of the SERC Visualisation Community Club set up under the Engineering Applications IT Support programme (EASE) with funding from the Engineering Research Commission (ERC). It covers the period July 1991 to December 1992.

Achievements in this period include:

- Establishment of the Community Club which now has around 200 members.
- Close links established with Engineering Committees through cross membership with the Steering Group.
- An Inaugural Meeting in 1991 and four technical events on the topics of:
 - “Use of Colour and Hardcopy and Video in Visualisation”
 - “Visualisation in Engineering”
 - “Data in Visualisation”
 - “Visualisation Software”.
- An evaluation of visualisation software was completed and a 139-page report issued including several case studies used in the evaluation. The Application Visualisation System (AVS) was selected as the most appropriate for a CHEST deal. This has now taken place and the software is available on favourable terms to all HEIs.
- Technical support for visualisation has been provided to engineering researchers by addressing user requirements in the areas of data import and export, new visualisation techniques, colour and presentation and by producing visualisation case studies.
- The Community Club has started a video library consisting of video records of meetings to complement the paper documentation by including speaker's 35mm slides and animations in colour. It also contains collections of visualisation examples contributed by the community which will assist new users.
- A hands-on course on “Graphics and Visualisation: Methods and Tools” for postgraduates nationally was developed and given in January 1993 in cooperation with the UK Advisory Group on Computer Graphics (AGOCCG).
- A course on the integration of user interface software, based on OSF/Motif, with graphics was given for the first time in December 1992.
- The EASE programme at RAL has also supported the technical activities of AGOCCG whose objectives are to raise the general level of computer graphics use in the UK Higher Education Community and has helped to set up the UK AVS User Group.

The programme of activities will continue in 1993, but with diminished resources, and will include:

- Further extension of the Club membership to include researchers from a wider range of engineering disciplines.
- Extension of the Steering Group to include a representative from each of the ERC Committees.
- A carefully-targeted poll intended to extend our knowledge of the visualisation requirements of the engineering research community.
- Four Community Club technical events.
- Widespread dissemination of well-presented case studies in applying visualisation to problems met in the engineering community as examples for others to follow.
- An awareness course on visualisation for engineers will be run in conjunction with AGOCCG and repeated as necessary.
- Ongoing evaluation of commercial visualisation software.
- Technical improvements to tackle hard visualisation problems which involve time varying, multivariate and/or multidimensional data.
- In a still immature and fast moving field, information updates and advice will continue to be provided.
- Further presentations of existing courses and the development of new courses to meet user requirements.
- Continuing technical support for the AGOCCG programme.

1. Introduction

This is the first annual report of the SERC Visualisation Community Club set up under the auspices of the Engineering Research Commission (ERC) and covers the period from July 1991 to December 1992. The Club is one of three such Clubs run within EASE. The Club has now around 200 registered members and held five events during this period. It is also involved in directing visualisation technical activities carried out at RAL. The Visualisation Community Club provides a very effective mechanism for engineering researchers using visualisation techniques to collaborate and disseminate knowledge and results of their work and also to promote the wider use of these techniques within engineering research.

2. Historical Background

In March 1991 Computing Facilities Committee (CFC) met to consider the future of the EASE programme. After considering all the activities currently supported it decided that it should focus future support on only two of these, an Education and Awareness programme, and the provision of visualisation facilities for engineers including the necessary graphics and user interface support. This constituted the EASE core programme for 1991/1992 and beyond. During the summer of 1991, this proposed core programme was considered by all the Engineering Board subject committees and eventually by the new Engineering Research Commission. The conclusion of this review was support for the core programme as proposed during 1992/93 with the addition of a small number of other activities. These recommendations were endorsed by the Engineering Board.

Since 1989, SERC has been a partner, along with other Research Councils and the Computer Board (subsequently the University Funding Council), in establishing and running the UK Advisory Group On Computer Graphics (AGOCCG). Part of the graphics effort within the EASE programme has been directed towards joint activities and objectives with AGOCCG. A workshop on visualisation was held in February 1991, jointly supported by AGOCCG and EASE. The recommendations of this workshop were influential in shaping the proposed visualisation programme for EASE.

Community Clubs are an effective and successful mechanism within EASE for bringing together researchers with a common interest, frequently from different subject disciplines within the engineering community. These clubs are not exclusively limited to either engineers or academics which gives the members access to a broad range of experience. It was therefore a natural step to establish an EASE Community Club in Visualisation. This happened during the summer of 1991. The Inaugural Meeting of the Visualisation Community Club was held on 11 October 1991 and from that date activities of the Club have grown.

3. Organisation of the Visualisation Community Club

3.1 The Role of the Visualisation Community Club

The role of the Visualisation Community Club is to help researchers, developers and users interested in visualisation by:

- providing a forum in which to present and discuss their requirements;
- guiding activities within EASE to meet these requirements;
- increasing awareness through exchange of views and information;
- assisting the emergence and use of relevant standards;
- promoting exchange of visualisation software and data;
- providing a mechanism for disseminating information to the visualisation community through seminars, meetings, workshops and courses.

3.2 Membership

The registered membership of the Visualisation Community Club has grown steadily from around 90 at the time of the Club's Inaugural Meeting, to around 200 as it stands now. Approximately 75% of the membership is from the academic community and the remainder is from industry and other government bodies, individuals and foreign country representatives. The membership reflects the wide range of subject areas using visualisation: electromechanical, process and civil engineering, CFD, medical imaging, geography, maths, remote sensing, image processing, biology and more.

3.3 The Steering Group

At the formation of the Club it was agreed that a Steering Group should be formed. The Group forms a regular point of contact between the community and EASE technical staff at RAL. Its role can best be described through the Terms of Reference of the Steering Group which are given in Appendix I.

The Steering Group has the important functions of focusing the needs of the committees of the ERC in order to direct the work of RAL staff and of feeding back the results of the Community Club's activities to these committees.

The current Steering Group members are drawn from the academic world. The membership of the Steering Group represents three Engineering Research Commission committees and some members also sit on the AGOCC. Below is the list of the current members:

- Dr. R. W. Ainsworth University of Oxford
Electromechanical Engineering Committee
- Prof. N. T. Bowman De Montfort University (at Leicester)
Construction Committee
- Dr. K. W. Brodrie (Chairman) University of Leeds
AGOCC representative
- Mr. J. R. Gallop Rutherford Appleton Laboratory
- Mr. W. T. Hewitt University of Manchester
- Mr. S. Larkin University of Manchester
AGOCC Visualisation Support Officer
- Mrs. R. Popovic (Secretary) Rutherford Appleton Laboratory
- Dr. N. Pratt SERC Central Office
- Prof. J Swithenbank University of Sheffield,
Process Engineering Committee

The Steering Group has agreed to expand its membership by inviting representatives from other Engineering Research Commission committees that are not currently represented. In addition to this, the Steering Group has decided to invite up to three engineering researchers (one of whom will be from industry) in order to deepen membership.

The Steering Group meets approximately quarterly to discuss and plan activities of the Club.

3.4 RAL Support Staff

In summer 1991 ERC approved funding for 6 technical staff at RAL in 1992/93 to provide visualisation facilities for engineers including the necessary graphics and user interface support. This effort is located in the Visualisation Group of Computational Modelling Division in Informatics Department.

The leader of the group is Mr. J. R. Gallop and its members are Miss J. Haswell, Mr. R. J. May (from March 1992), Dr. R. Maybury, Mr. P. L. Popovic (to May 1992), Mrs. R. Popovic and Dr. L. Sastry.

4. Relationship with Other Complementary Groups

4.1 AGOCCG

AGOCCG - the Advisory Group On Computer Graphics - coordinates computer graphics activities for the benefit of users in UK universities and other HEI's. It is supported by the University Funding Council (UFC) and by the Research Councils. In particular UFC supports a full time coordinator for AGOCCG - Dr. A. M. Mumford of Loughborough University.

AGOCCG is responsible for ensuring that appropriate graphics products are available as widely as possible in the UK academic community. These products include implementations of graphics standards, including GKS, PHIGS and CGM and other products that are of general use - including UNIRAS, PostScript previewing and Cricketgraph. Products can be identified by evaluation of commercial packages or developed in the community. Where possible, software distribution is by network, from the HENSA Unix archive at University of Kent. AGOCCG ensures that information is disseminated by a bimonthly newsletter and technical reports. It also develops training materials which can be used at any site by, for example, someone in the local computing service.

Since 1991, AGOCCG has developed a programme on visualisation in cooperation with technical staff at RAL. During 1992 AGOCCG has supported the appointment of Mr. S. Larkin based at University of Manchester as the AGOCCG Visualisation Support Officer. His activities are helping to increase awareness of visualisation products and methods in the community. Mr. Larkin is a member of the Visualisation Community Club Steering Group.

RAL provides the chair of AGOCCG, until the end of 1992 this was Prof. F. R. A. Hopgood and the post is now held by Dr. D. R. S. Boyd, and the secretary of AGOCCG (Dr. Sastry).

More information about AGOCCG's work can be found in the bi-monthly Graphics Newsletter, shortly to be renamed Graphics and Visualization (contact is Rachel Miles at RAL, e-mail: rym@uk.ac.rl.inf).

By coordinating the work of AGOCCG and the EASE programme at RAL, the quality of the underlying provision of computer graphics in the UK is increased and benefits accrue to the engineering research community. As this general provision improves, the EASE effort at RAL can then focus more on developing advanced support for engineering researchers.

4.2 UK AVS User Group

An inaugural meeting of the UK User Group for the Application Visualisation System (AVS), licensed under a CHEST deal, was organised at RAL in September 1992. An interim planning group has been formed and this group will be responsible for properly constituting the User Group in 1993. Mr. J. R. Gallop (RAL) is chair of the interim planning group and Mr. W. T. Hewitt (University of Manchester) is secretary (both are on the Steering Group of the Community Club).

4.3 Visualisation in Europe

Eurographics is the Association for Computer Graphics in Europe. There are several working groups which hold regular (usually yearly) workshops. One of these is on Visualisation in Scientific Computing. Mr. J. R. Gallop (RAL) is local organiser of the 1993 workshop which will be held in April at the Cosener's House in Abingdon.

5. Activities during 1991/92

5.1 Community Club Events

During this period five major events have been organised by the Club. Details of these are given in Appendix II. Only a short account of the events is included here, however full reports and proceedings have been prepared and are listed in Appendix III. There are also video records of the "Visualisation in Engineering" and the "Visualisation Software" meetings (see Appendix IV). Attendance for academics is normally free, but industry delegates pay a meeting fee. Any costs not covered by meeting fees are borne by the EASE programme.

5.1.1 Inaugural Meeting

The first Visualisation Community Club meeting was held at RAL on 11 October 1991 and chaired by Dr. D. R. S. Boyd (RAL). Around 50 people, or approximately half the total membership at that time, attended. The objectives of the meeting were to formally set up the Club, to present examples of visualisation use in some areas represented by the Club members and to discuss the proposed role of the Club and its future programme.

The meeting started with Dr. Boyd giving the Club's background and explaining its role and organisation within the context of other community clubs. He also listed sources of funding, as well as EASE activities and projects in visualisation.

Mrs. R Popovic (RAL) continued with the Club's members survey statistics. The survey of the October 1991 membership showed that approximately a third of membership were involved in Computational Fluid Dynamics (CFD), a third used in-house software and a half were using SUNs as visualisation hardware. Stardent's Application Visualisation System (AVS), UNIRAS and apE were the most frequently mentioned software, while VAX, Silicon Graphics', Stardent and various PC systems were the most frequently mentioned hardware in the survey.

The speakers of the day concentrated mainly on ways to apply various visualisation methods and techniques in their research areas. Dr. K Refson (Oxford University) discussed advantages of using visualisation in molecular dynamics. Dr. P H Milne (University of Strathclyde) talked about applying visualisation in flood risk assessment, flood warning and evaluation of proposed flood control scheme. Mr. Graves (Guy's Hospital) presented the state of the art of visualisation of blood flow, using MRI, while Prof. I M Smith (University of Manchester) gave a talk on animation in solid mechanics.

Approaching visualisation as a server-provider, Mr. N Wiseman (NERC Computer Services) discussed the gap between the promises of visualisation and the tools currently at hand.

In the concluding part of the meeting, Mr. J R Gallop (RAL) outlined the visualisation activities of AGOCCG and Dr. K W Brodlie, Chairman of the Club's Steering Group, highlighted the role of the Club, listing some existing and possible activities. This lead into an open discussion, where many useful comments and suggestions were put forward for consideration by the Steering Group at their November 1991 meeting, which defined the Club's programme for the 1992.

5.1.2 Effective Use of Colour and Hardcopy and Video Facilities in Visualisation

The seminar was held at RAL on 17 March 1992 and chaired by Mr. J R Gallop (RAL). Around 60 people attended. The purpose of the seminar was to help researchers in effective use of colour and to help solve their problems with output of visualisation results using hardcopy and video facilities.

Various aspects of understanding and proper use of colour were discussed. Prof. J Lansdown (Middlesex Polytechnic) and Mr. L W McDonald (Crossfield) concentrated on the perception of colour and guidelines for organising and manipulating colour when communicating information. A range of speakers then discussed problems of using colour in print and video. Mr. R L Middleton (Edinburgh University) gave a thorough description of all known techniques for producing a colour printout. Mr. C D Osland (RAL) discussed the pitfalls of producing colour video, while Mrs. M M Hindmarsh (Newcastle University) and Dr. D Clarke (I-MEDIA) talked about their experiences in recording research results or teaching material on video.

Finally, Mr. M Lamming (Xerox EuroPARC) approached the familiar problem - why a print image is disappointing compared with the corresponding display image - and provided a practical solution.

As the emphasis of this event was on understanding the problems associated with the use of colour and giving ideas how to solve them, the particular success of the meeting was in the focus it provided for the colour matching work of RAL's visualisation group.

5.1.3 Visualisation in Engineering

The meeting was held at Sheffield University on 28 May 1992 and chaired by Prof. J Swithenbank (Sheffield University). Over 40 people attended. The entire event was recorded on video and a reduced video record is available (see Appendix IV). The purpose of the meeting was to stimulate new uses of visualisation in engineering by presenting results achieved in a wide range of engineering applications.

The speakers of the day (listed in Appendix II) painted a rich picture of the use of visualisation in modern engineering. From field analysis through to semiconductor device simulation and virtual reality systems, visualisation has found its place in engineering not just as a presentational tool, but also as an aid for mathematical model validation and a prime force in improving engineers' understandings of physics of a process. Not least important was the fact that in commercial organisations, visualisation was reported to have improved communication between engineers and increased awareness at senior levels of decision making. This was perhaps one more proof, if such were needed, of new visualisation frontiers.

5.1.4 Workshop on Data in Visualisation

The Community Club organised a workshop on "Data in Visualisation" which was held at the University of Manchester on the 15-16 October 1992. The two days consisted of a number of talks from invited speakers with discussion periods being allocated throughout the day. The guest speaker was Prof. R B Haber from the Department of Theoretical & Applied Mechanics, University of Illinois.

The workshop aimed to look at the following three areas:

- problems importing engineering source data into visualisation systems,
- a reference model for scientific visualisation, and
- formats for the transfer of graphical/image data.

Each attendee was asked to submit a short position paper detailing their application areas and any data problems they were experiencing.

The workshop was chaired by W T Hewitt, Director of the Computer Graphics Unit and S Larkin, AGOCG Visualisation Support Officer.

Throughout the two days the following presentations were given:

Introduction and Aims of the Workshop	W T Hewitt	University of Manchester
A Model for Scientific Visualisation	Prof. R B Haber	University of Illinois at Urbana-Champaign
A Notation to describe visualisation	K W Brodlie	University of Leeds
Data Types in Visualisation Systems	S Larkin	University of Manchester
CAD/CAM Data Types	J Owen	University of Leeds
A STEP towards CFD	A Steer	Nuclear Electric Plc
Express	M Mead	RAL
Graphical Data Interchange	A M Mumford	Loughbrough University of Technology

The principal conclusions were:

- All the existing data models presented at the workshop provided some new insight into the problem of describing engineering source data but there is a need to rationalise them.
- It would be useful to apply these data models to some more real examples as this gave an additional aid to understanding the application problem.
- There was a clear difference in level of abstraction between data models, structure and format and there is a danger of concentrating only on data formats.
- It is necessary to make visualisation users aware of existing solutions and provide information on their use, possibly via case studies, and advise people on some of their problems.
- A study day involving Express experts and visualisation experts should be run to consider Express as a possible mechanism for data used in visualisation.
- Problem is not only getting the data in, but the incorrect assumptions about the data made by most visualisation systems.
- Translator software is likely to dominate in the short term, until standards are developed.

5.1.5 Visualisation Software

The meeting was held at RAL on 11 November 1992 and chaired by Dr. Brodlie. Over 50 people attended. The entire event was recorded on video and a reduced record is being made available (see Appendix IV). The purpose of this meeting was to present existing visualisation software and to discuss its current deficiencies and future trends.

The speakers presented talks on the following subjects:

- massively parallel systems in graphics - Dr. R J Hubbard (University of Manchester);
- historical development of fluid flow visualisation methods and techniques - Dr. T David (University of Leeds);
- IBM Explorer visualisation system - Dr. D Watson (IBM UK Scientific Centre);
- multimedia in visualisation - Dr. D Morris (University of Leeds and Silicon Graphics);
- case studies using AVS - Mr. S Larkin (University of Manchester);
- GRASPARC, the DTI/SERC funded project - Mr. G Banecki (NAG Ltd.).

The meeting closed with a panel session on “Current Deficiencies and Future Remedies”. The panellists, Mr. J R Gallop (RAL), Dr. I Curington (AVS Inc.), Dr. D Watson and Dr. D Morris, responded to a range of questions from the audience on:

- provision of data export/import from/to current visualisation systems as well as handling data within the system;
- provision of visualisation techniques that are currently missing and, in general, how to expand flexibility and internal configurability of the tool;
- systems performance (how to parallelise them) and user interface
- handling errors either introduced by visualisation or already existing in data;
- cross-coupling different pieces of software and of diverse applications;
- provision of advanced flow patterns, feedback loops and reverse flows
- provision of sensible colour maps and in general systems that are better suited to human perception.

5.2 Evaluation of Visualisation Software Products

A large number of visualisation products have become available. Most visualisation users do not have time to spend on a detailed study of the market, especially as it requires some effort to penetrate behind what in some cases are superficial attractions. Therefore an evaluation of visualisation systems on behalf of the user community was carried out in 1991/92 with support from AGOCC and EASE.

Most products are special either to a particular machine or to a particular class of problems. The evaluation was restricted to dataflow (also called application builder) visualisation systems, because this group of products held out the promise of an interactive visualisation system that was flexible enough to accommodate a wide variety of visualisation problems and would run on a variety of hardware platforms.

The evaluation was carried out by RAL and the Universities of Leeds, Leicester and Manchester.

To provide practical experience of each system, which was necessary to test the claims of the products, the evaluation included several case studies. These case studies are described in detail in the evaluation report and represent a good collection of practical applications of visualisation.

The evaluation highlighted a number of points, including: the need for user awareness, support and interoperability, interfaces to traditional library software, and the need for a deeper usability study. There was an additional recommendation to offer support in scientific visualisation through widespread availability of AVS, but also to track other systems, in particular the Silicon Graphics Iris Explorer, and review the situation in 6 months.

As a result of the evaluation, AVS has become available to UK universities and other HEI's through CHEST. The CHEST deal allows a university to obtain AVS by a reasonably priced site-wide deal.

Future evaluations will cover means to produce 35mm slides and tools for animation within visualisation products.

5.3 Software Support

Although present day dataflow visualisation systems such as AVS provide a useful general framework, for many problems it is necessary to implement further modules. A large and increasing body of AVS modules is being built up at the International AVS Center in North Carolina and is shadowed at the University of Manchester. In addition, a number of modules of general use to the EASE community have been implemented by RAL during the year.

These can be characterised as:

Data In And Data Out (Data Import/Export)

The problems of getting data into a visualisation system and then getting the data out were identified by the Steering Group as one obstacle to effective use of visualisation software.

- The CFD Community Club is building up a catalogue of data sets. Since this catalogue is being made widely available through HENSA at the University of Kent, facilities for reading these data sets into AVS are being implemented.
- Pictures from AVS can be archived or sent to a printer or plotter. A standard method of archiving and transmitting pictures is the Computer Graphics Metafile (CGM) and software has been written to create CGMs from AVS which was not previously possible.

What Happens To The Data When Read In (Filters And Mappers)

A number of modules to support particular visualisation techniques are being produced. Problems being addressed include:

- unstructured data where symmetry exists;
- scattered data in 3D;
- simple data manipulation.

Use Of Colour

Good use of colour is a vital part of many uses of visualisation. At the conclusion of a work session, a user may commit the picture on a colour display to a colour printer. Even if the colours on the printer are strong, the result is usually a disappointing discrepancy from the screen display. Greys are not grey and colours that should be distinguishable from each other are not. Using an ad hoc method to correct a picture can eventually work but still involves much experimentation for each set of colours used. Therefore following the talk of Mike Lamming at the March 1992 Community Club meeting, some software tools have been produced which allow a user to produce a good match between screen and print. Once set up, subsequent good prints can be produced for the same screen/printer combination. The result restores greys and produces distinguishable shades of colour. The method and the software are applicable whichever visualisation software has been used. This software is being prepared for general distribution and use within the academic community. This will also be distributed via the HENSA Software Archive.

5.4 Application Case Studies

The evaluation of visualisation software in 1991/92 used a number of case studies to test the systems and to illustrate how they could be used.

The responses received from individuals suggest that the case studies represented one of the most useful aspects of the evaluation report. Therefore it is planned that new case studies will be undertaken and disseminated.

The applications are diverse and in this initial phase of the work, data has been drawn from a variety of sources, but in all cases the techniques used are relevant to engineering researchers:

- ***electromagnetic field data*** - the requirement is to understand electromagnetic field data in 3D. The data is provided as a set of complex vectors on a 3D unstructured grid. 3D vector data is difficult for the human to visualise. Others have commented on the visual complexity produced by using simple arrows. Figure 1 shows an improved method, developed at RAL, which combines streamlines and transparency to attempt to convey both the direction and the strength of the field;
- ***space science data*** - for a number of reasons, the experimental data does not lie on a regular grid. This applies to many subject areas. Here astrophysics data is used as an example of irregularly sampled sets of scattered data in 3D;
- ***medical and quantum mechanical data*** - the data is provided as a regularly disposed set of scalar values in 3D. The medical data - being immediately recognisable when an appropriate visualisation method is chosen - is useful for teaching the use of volume visualisation methods;
- ***remote sensing data*** - the problem here is to improve our knowledge of the motion of sea currents identified by their sea surface temperatures so that the mechanisms of global warming may be better understood. However the data is obscured by cloud and methods of algorithmically removing the cloud are being developed. Techniques for visualisation of multiband 2D images are being developed in this study.

5.5 Awareness, Training and Dissemination

The Community Club has initiated or participated in many activities during the year aimed at increasing awareness, training and exploitation of visualisation.

- Dr. K. W. Brodlie (Chairman of the Community Club Steering Group) of the University of Leeds organised and prepared a week-long AGOCC Postgraduate course on "Graphics and Visualization: Techniques and Tools" at Leeds in January 1993. The course resulted from the efforts of a large number of people from Universities of Leeds, Bath and Manchester, RAL and the AFRC Computing Centre.
- Two books were published in 1992, resulting from the workshop jointly organised by AGOCC and EASE at RAL in 1991. They are "Scientific Visualization: Techniques and Applications" by K W Brodlie et al. and "An Introductory Guide to Scientific Visualization" by R A Earnshaw and N Wiseman, both published by Springer-Verlag, 1992.
- A video collection has been initiated (see below section 5.6).
- Collection of a 35mm slide set showing many examples of visualisation is underway. A pilot study to investigate their distribution on CD-ROM is being supported at Leeds University.
- A programme of visits to visualisation users sites by RAL staff was begun.

- Although useful publications on visualisation are now available, the Steering Group identified a gap, namely a simple, rapidly updatable guide which provides information on how to get started to the UK academic community. For this purpose “Getting Started in Visualisation” has been produced by RAL.
- Two mailshots have been produced during the year. These are detailed in Appendix V. The AGOCCG Technical Report on Evaluation of Visualisation Software was a part of one of these.
- Several articles on the activities of the Club have appeared in the Engineering Computing Newsletter (see Appendix V).
- It is also possible to direct queries on visualisation or send information about visualisation by electronic mail to *chest-visual@uk.ac.mailbase*

5.6 Video Records and Video Collection

Video is an increasingly important medium in scientific and engineering visualisation, for both exploration and presentation of data. It is also natural to use video as a medium for disseminating information about visualisation. The Steering Group decided to form a library of video records at RAL and to produce:

- a 30min edited video record of each of the Club’s seminars and meetings, which will supplement written records by capturing speakers’ colour slides and video animations;
- a Video Collection of science and engineering visualisation examples contributed by the community with supporting written material.

RAL will maintain the video library, advertise it, and distribute copies of tapes to the community as required.

The list of currently available tapes is listed in Appendix IV.

5.7 Graphics and User Interfaces

RAL staff cooperated with AGOCCG on the provision of a range of basic graphics software including:

- release of RAL-GKS to the HENSA Software Archive;
- release of RALpage (PostScript previewer) to HENSA;
- further development of RAL-CGM available through HENSA;
- funding a contract at the University of Manchester to produce and make available for distribution a PHIGS Toolkit;
- evaluating PHIGS implementations, leading to a CHEST deal for FIGARO.

In addition RAL provides support for software designed to help engineers produce good user interfaces. Work has focused on:

- evaluating easy to use User Interface Builders based on Motif (for publications see Appendix V);
- integrating graphics such as PHIGS into this framework.

A practical course on the integration of Motif based user interface software and graphics has been developed and run in December 1992 and will be repeated in 1993.

6. The Future Programme

The Forward Look for the EASE programme contains a reduction in the technical staff funded at RAL for visualisation, computer graphics and user interfaces to 4 people in 1993/94 and to 3 people in 1994/95. While this will inevitably reduce the scope of the work, the Steering Group will attempt to produce a balanced programme within the available resource.

6.1 Programme of Events

Below is the table of events planned for 1993:

Event	Type	Date	Venue	Chairman
3D Visualisation in Engineering	seminar	24 March	RAL	J R Gallop and W T Hewitt
Visualisation in Engineering Teaching	seminar	26 May	University of Sheffield	J Swithenbank and R Smith
Visualisation in Electromechanical Engineering	seminar	29 September	University of Oxford	R W Ainsworth
Parallelism and Visualisation	seminar	mid November		R J Hubbard

6.2 Technical Support

The technical support work until now has paid particular attention to general purpose solutions, as has been detailed earlier. We believe that visualisation is still an evolving subject and is being applied mainly by those with the enthusiasm to tailor systems to their own requirements. We see the technical support work moving to a phase where the general purpose work will still be important, but that work on specific engineering problems will increase.

The strands of the work will be as follows:

- Case studies: develop these through close contact with specific engineering research projects funded by the SERC - depending on the need, this could simply be initial advice to the researcher on how to get started with their specific problem, or further work could be done helping the researcher adapt or develop techniques that are not already available. Following on the experience of the case studies used in the 1991/92 evaluation of visualisation software, the Steering Group has placed great importance on building up and disseminating a set of case studies which would be of direct benefit to others. Initially the case studies would be available on paper. As printing costs can be expected to stay high and as networking improves, it will be important to be able to provide a case study document on-line and ways of achieving this will be investigated. In addition the video collection will be extended.
- Continue to provide awareness and support. This will be through keeping introductory material up to date; running courses targeted at engineering researchers; complementing the general basic courses run by the AGOCG Visualisation Support Officer; and providing advice on request.
- Evaluations: since visualisation software is a rapidly moving market, a further assessment will be conducted to provide information to the community and recommendations on future

purchases. Animation is becoming important and an evaluation of AVS Animator will be made.

- Continue developments to improve the quality of visualisation software available to the community. The visualisation events have identified a number of areas where problems exist. These include multidimensional and multivariate problems, time-varying problems, flow problems, interchange of software and data. Within the level of resource available, work on this will be extremely limited.
- Graphics and user interface support: in funding the work on visualisation, CFC and subsequently ERC requested that some support should be devoted to graphics and user interface work that was not solely in support of visualisation. This work will continue. It includes support for user interface tools based on X toolkits; investigating user interface builders; support for graphics; support for integration of graphics and Motif-based user interface software and presenting courses in this area.

7. Conclusion

The Visualisation Community Club began in October 1991, and now runs an ongoing series of technical events which provide a forum for the exchange of information and ideas about visualisation in engineering research.

The activities of RAL staff supporting the Community Club are coordinated by a Steering Group containing cross-members with the main committees of the ERC.

Several items of software for visualisation and graphics have been developed and released and training courses have been held.

By establishing links with other bodies, the Community Club has increased the effectiveness of its work. A key connection here is with AGOCC. However, by comparison with initiatives in the USA and continental Europe, effort devoted to support of visualisation in the UK is still low.

Appendix I - Terms of Reference of the Visualisation Community Club Steering Group

- To advise the Rutherford Appleton Laboratory on running an EASE Community Club in visualisation.
- To make recommendations on a programme of activities to benefit all those involved in visualisation in the academic research community.
- To maintain knowledge of methods and techniques in visualisation and of their implementation in hardware and software.
- To identify requirements and make recommendations for the provision of new visualisation facilities.
- To encourage interchange of ideas and methodologies between engineers and visualisation providers.
- To liaise with the Advisory Group On Computer Graphics (AGOCG) and appropriate national and international groups.
- To report to the Visualisation Community Club at least annually.
- To report through relevant subject committees to the Engineering Research Commission on the activities of the community club and the provision and use of existing computing facilities for visualisation at least annually.

Appendix II - Visualisation Community Club Events

1. Visualisation Community Club Inaugural Meeting (meeting)

Venue: Rutherford Appleton Laboratory

Date: Friday, 11 October 1991

Chairman: Dr. D R S Boyd (RAL)

Speakers: Dr. D R S Boyd (RAL), Mrs. R Popovic (RAL), Dr. K Refson (University of Oxford), Dr. P Milne (University of Strathclyde), Mr. M Graves (Guy's Hospital), Prof. I M Smith (University of Manchester), Mr. N Wiseman (NERC Computer Services), Mr. J R Gallop (RAL), Dr. K W Brodlie (University of Leeds)

Attendance: 49 (42 Academic, 7 Industrial)

2. Effective Use of Colour and Hardcopy and Video Facilities in Visualisation (seminar)

Venue: Rutherford Appleton Laboratory

Date: Tuesday, 17 March 1992

Chairman: Mr. J R Gallop (RAL)

Speakers: Mr. L W McDonald (Crosfield), Prof. J Landsdown (Middlesex Polytechnic), Mr. R L Middleton (Edinburgh University Computing Service), Mr. C D Osland (RAL), Mike Lamming (Xerox EuroPARC), Mrs. M M Hindmarsh (Newcastle University), Dr. D Clarke (I-MEDIA)

Attendance: 62 (51 Academic, 11 Industrial)

3. Visualisation in Engineering (meeting)

Venue: University of Sheffield

Date: Thursday, 28 May 1992

Chairman: Prof. J Swithenbank (University of Sheffield)

Speakers: Prof. J Swithenbank (University of Sheffield), Mr. M Sabin (FECS), Mr. W Roberts (Hydraulics Research Ltd.), Dr. D Catherall (Royal Aerospace Establishment), Prof. E T Woodburn (UMIST), Mr. N Simpson (Rolls-Royce, Derby), Mr. J Cox (University of Manchester), Mr. M Fuller (University of Sheffield), Mr. P Hall (University of Sheffield)

Attendance: 43 (39 Academic, 4 Industrial)

4. Data in Visualisation (workshop)

Venue: University of Manchester

Date: Thursday 15 and Friday 16 October 1992

Chairmen: Mr. W T Hewitt and Mr. S Larkin (both from University of Manchester)

Speakers: Prof. R B Haber (University of Illinois at Urbana-Champaign, USA), Dr. K W Brodlie (University of Leeds), Dr. A M Mumford (Loughborough University of Technology), Dr. J Owen (University of Leeds), Dr. A Steer (Nuclear Electric Plc), Mr. M Mead (RAL), Mr. S Larkin (University of Leeds).

Attendance: 27 (25 Academic, 2 Industrial)

5. Visualisation Software (meeting)

Venue: Rutherford Appleton Laboratory

Date: Wednesday, 11 November 1992

Chairman: Dr. K W Brodlie (University of Leeds)

Speakers: Dr. K W Brodlie (University of Leeds), Dr. R J Hubbard (University of Manchester), Dr. T David (University of Leeds), Dr. D Watson (IBM UK Scientific Centre), Dr. D Morris (University of Leeds and Silicon Graphics Inc.), Mr. S Larkin (University of Manchester), Mr. G Banecki (NAG Ltd.)

Panel Session Speakers: Mr. J R Gallop (RAL), Dr. I Curington (AVS Inc.), Dr. D Watson (IBM UK Scientific Centre), Dr. D Morris (University of Leeds and Silicon Graphics Inc.)

Attendance: 50 (46 Academic, 4 Industrial)

Appendix III - Proceedings of Meetings, Workshops and Seminars

For each of the meetings and seminars listed (except the Inaugural Meeting) the collected papers and view graphs have been collected under a single cover. A full report on the event is attached to the event proceedings.

There is also a full report on the "Data in Visualisation" workshop which lists recommendations and conclusions made during the workshop. It is also possible to order a set of handouts from the Inaugural Meeting together with a copy of the report on presentations and the discussion session of the meeting.

Visualisation in Engineering and Visualisation Software meetings were recorded on video. For information on edited versions of these videos see Appendix V.

These materials are available free to all members of the academic community and for a fee to industrials.

1. Visualisation Community Club Inaugural Meeting, handouts, 11 October 1992
2. Effective Use of Colour and Hardcopy and Video Facilities in Visualisation, Proceedings, 17 March 1992
3. Visualisation in Engineering, Proceedings, 28 May 1992
4. Report on Data in Visualisation Workshop, 15-16 October 1992
5. Visualisation Software, Proceedings, 11 November 1992

The copies of Proceedings can be obtained by sending a request to vcc@uk.ac.rl.inf or by contacting *Mrs. Virginia Jones*:

- **phone:** 0235 445121 (attended a.m. - answerphone p.m.)
- **letter:** Rutherford Appleton Laboratory
Informatics - R1
Chilton, Didcot
Oxon OX11 0QX

Appendix IV - Video Records

1. "Visualisation in Engineering", Video Proceedings No 1 (available).
2. "Visualisation Software", Video Proceedings No 2 (to be available shortly).
3. "Video Collection", Issue 1 (to be available shortly).

The copies of Video Records can be obtained by sending a request on vcc@uk.ac.rl.inf or by contacting *Mrs. Virginia Jones*:

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Informatics - R1
Chilton, Didcot
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Appendix V - Steering Group Reports, Newsletter Articles, Mailshots and Publications

Visualisation Community Club Steering Group Reports

- VCCSG/P01/91 Membership of the Visualisation Community Club Steering Group, *Mrs. R Popovic*, 20 November 1991
- VCCSG/P02/91 Background to Current SERC Activities in Visualisation, *Dr. D R S Boyd*, 19 November 1991
- VCCSG/P03/91 Role of the Visualisation Community Club and its Steering Group, *Mrs. R Popovic*, 20 November 1991
- VCCSG/P04/91 Report of the Visualisation Community Club Inaugural Meeting on 11 October 1991., *Mrs. R Popovic*, 20 November 1991
- VCCSG/P05/91 Report on IEEE Visualization 91., *Mr. J R Gallop*, 19 November 1991
- VCCSG/P06/91 Report on current Visualisation Community Club Technical Activities, *Mr. J R Gallop*, 19 November 1991
- VCCSG/P07/91 Discussion of the Future Programme of the Visualisation Community Club, *Mrs. R Popovic*, 19 November 1991
- VCCSG/P08/91 Using Colour in Computer Graphics, *Prof. F R A Hopgood*, January 1991
-
- VCCSG/P03/92 Report on Progress in Organising Visualisation Community Club Events, *Mrs. R Popovic*, 24 February 1992
- VCCSG/P05/92 Report on Visit to International AVS Centre and First International AVS Conference, *Mr. J R Gallop*, 20 February 1992
- VCCSG/P06/92 Report on Current Visualisation Community Club Technical Activities, *Mr. J R Gallop*, 19 February 1992
- VCCSG/P07/92 Options for the Support Service Provision, *Mr. J R Gallop*, 31 March 1992
- VCCSG/P08/92 Report on Funding from ISC under IT Training Initiative to Produce Teaching Materials for Graphics and Visualisation, *Mr. W T Hewitt*, 24 February 1992
- VCCSG/P10/92 AGOCG's Visualisation Coordinator, *Mr. S Larkin*, 30 March 1992
- VCCSG/P12/92 Report on Past Events, *Mrs. R Popovic*, 1 June 1992
- VCCSG/P13/92 Report on Progress in Organising "Data in Visualisation" Workshop, *Mr. S Larkin*, 1 June 1992
- VCCSG/P14/92 Report on Progress in Organising "Visualisation Software" Meeting, *Mrs. R Popovic*, 1 June 1992
- VCCSG/P15/92 Discussion of the Future Visualisation Community Club Events, *Mrs. R Popovic*, 1 June 1992
- VCCSG/P16/92 Report on Current Visualisation Community Club Technical Activities, *Mr. J R Gallop*, 1 June 1992
- VCCSG/P17/92 Report on "Visualisation Surgery" Service, *Mr. J R Gallop*, 22 May 1992
- VCCSG/P18/92 Report on Progress in Writing "Getting Started in Scientific Visualisation" Document, *Mr. J R Gallop*, 28 May 1992
- VCCSG/P19/92 Report on AGOCG's Visualisation Activities, *Mr. S Larkin*, 1 June 1992

- VCCSG/P20/92 Report on Eurographics Workshop on Visualisation in Scientific Computing, *Mr. J R Gallop*, 22 May 1992
- VCCSG/P23/92 Report on Progress in Organising “Visualisation Software” Meeting, *Dr. K W Brodlie and Mrs. R Popovic*, 23 September 1992
- VCCSG/P25/92 Discussion of the Future Visualisation Community Club Events, *Mrs. R Popovic*, 23 September 1992
- VCCSG/P26/92 Review of Visualisation Community Club Technical Support, *Mr. J R Gallop*, 23 September 1992
- VCCSG/P27/92 Report on “Visualisation Surgery” Service, *Mr. J R Gallop*, 22 September 1992
- VCCSG/P28/92 Report on Progress in Writing “Getting Started in Scientific Visualisation” Document, *Mr. J R Gallop*, 22 September 1992
- VCCSG/P29/92 Production of a Video Record of Club’s Meetings, Seminars, Annual Video and Video Collection, *Dr. K W Brodlie, Mr. J R Gallop and Mrs. R Popovic*, 23 September 1992
- VCCSG/P31/92 Report on AGOCG’s Visualisation Activities, *Mr. S Larkin*, 14 July 1992
- VCCSG/P32/92 Report on Inaugural Meeting of the UK AVS User Group, *Mr. J R Gallop*, 22 September 1992
- VCCSG/P34/92 Membership of the Steering Group, *Mrs. R Popovic*, 30 November 1992
- VCCSG/P35/92 Report on “Data in Visualisation” Workshop - summary, *Mr. J R Gallop*, 30 November 1992
- VCCSG/P36/92 Report on “Data in Visualisation” Workshop, *Mr. W T Hewitt and Mr. S Larkin*
- VCCSG/P37/92 Report on “Visualisation Software” Meeting, *Dr. K W Brodlie and Mrs. R Popovic*, 30 November 1992
- VCCSG/P38/92 Report on Progress in Organising “3D Visualisation” Meeting, *Mr. W T Hewitt, Mr. J R Gallop and Mrs. R Popovic*, 30 November 1992
- VCCSG/P39/92 Future Events, *Mrs. R Popovic*, 30 November 1992
- VCCSG/P40/92 Review of Visualisation Community Club Technical Support, *Mr. J R Gallop*, 30 November 1992
- VCCSG/P41/92 Report on Progress in Writing “Getting Started in Scientific Visualisation” Document, *Mr. J R Gallop*, 30 November 1992
- VCCSG/P42/92 Production of a Video Record of Club’s Meetings, Seminars, Annual Video and Video Collection, *Dr. K W Brodlie, Mr. J R Gallop and Mrs. R Popovic*, 30 November 1992
- VCCSG/P44/92 Report on AGOCG’s Visualisation Activities, *Mr. S Larkin*, 26 October 1992
- VCCSG/P45/92 Report on “Visualization 92’ Conference, *Prof. F R A Hopgood, Dr. D R S Boyd and Mrs. R Popovic*, 26 October 1992
- VCCSG/M01/91 Minutes, *Mrs. R Popovic*, 19 December 1991
- VCCSG/M01/92 Minutes, *Mrs. R Popovic*, 10 April 1992
- VCCSG/M02/92 Minutes, *Mrs. R Popovic*, 10 July 1992
- VCCSG/M03/92 Minutes, *Mrs. R Popovic*, 16 October 1992
- VCCSG/M04/92 Minutes, *Mrs. R Popovic*, December 1992

Visualisation Community Club Articles in the EASE Engineering Computing Newsletter

1. Visualisation in EASE, *Mr. J R Gallop*, ECN 33 (July 1991)
2. Visualisation Community Club: Inaugural Meeting, *Mr. P L Popovic*, ECN 34 (September 1991)
3. Visualisation Community Club Inaugural Meeting, *Mrs. R Popovic*, ECN 36 (January 1992)
4. "Visualisation Surgery" Service, *Mrs. R Popovic*, ECN 39 (July 1992)
5. Data in Visualisation Workshop, Manchester, 15-16 October, Call For Papers, *Mr. W T Hewitt and Mr. S Larkin*, ECN 39 (July 1992)
6. EASE Visualisation Community Club - Video Record, *Dr. K W Brodlie*, ECN 40 (September 1992)
7. Visualisation Community Club Meeting Reports: Effective Use of Colour, Hard-copy and Video Facilities in Visualisation, *Mrs. R Popovic*, ECN 40 (September 1992)
8. Visualisation Community Club Meeting Reports: Visualisation in Engineering Meeting, *Mrs. R Popovic*, ECN 40 (September 1992)
9. Visualisation Community Club, *Mrs. R Popovic*, ECN 41 (November 1992)

Visualisation Community Club Mailshots

1. Mailshot, May 1992
 - Visualisation Surgery Service;
 - Regional Visualisation Seminars organized by University of Manchester;
 - Announcement of a new electronic mail service for visualisation;
 - Survey on data requirements for visualisation;
 - Evaluation of Visualisation Systems - AGOCG Technical Report.
2. Mailshot, August 1992
 - an announcement of the CHEST deal for AVS;
 - an announcement of the inaugural meeting of the UK AVS User Group;
 - an announcement of a book on PHIGS.

Visualisation Community Club Publications

1. "Getting Started in Visualisation", *Mr. J R Gallop*.
2. "Review of Current Graphical User Interface Design Tools", *Dr L Sastry*.
3. "Evaluation of DVX-Designer", *Dr L Sastry*.
4. "Evaluation of X-Designer", *Dr L Sastry*.

The copies of most Reports, Articles, Mailshots and Publications can be obtained by sending a request on vcc@uk.ac.rl.inf or by contacting *Mrs. Virginia Jones*:

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- **letter:** Rutherford Appleton Laboratory
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Chilton, Didcot
Oxon OX11 0QX

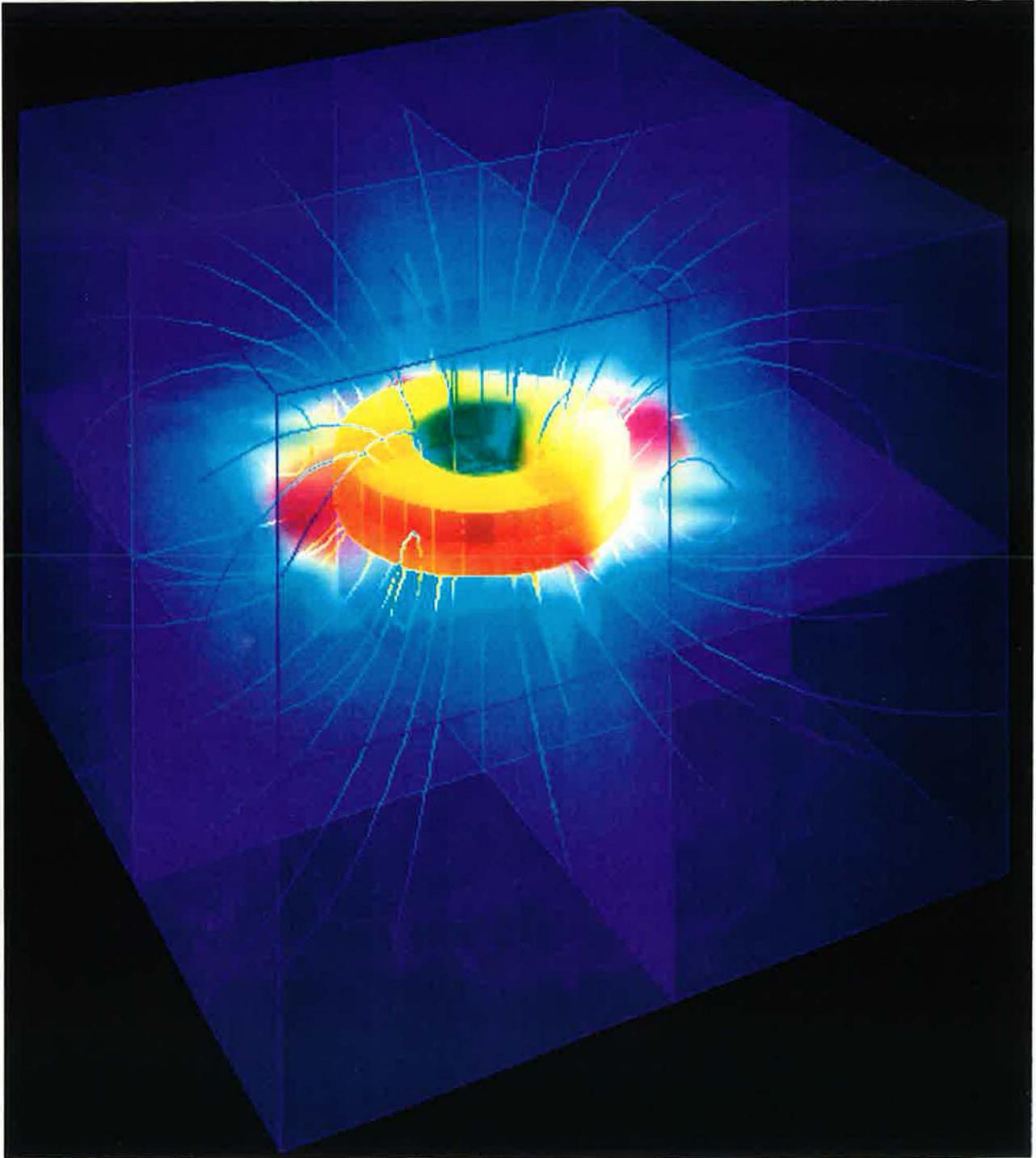


Figure 1: Simulated Eletromagnetic data estimates the magnetic field around a coil carrying an electric current. The data consists of 3D vectors in and around the magnetic material. In this example, the data is divided into magnetic material (where the geometry is rendered opaque) and the surrounding air (rendered as a transparent box) where both are coloured according to the magnitude of the vectors (from blue for small to red for large magnitude). Streamlines are used to represent the magnetic field lines. Since the solution has 8-way symmetry it is possible to mirror the rendered geometry to produce a more complete visualisation. Data courtesy of Vector Fields Ltd. and interactive visualisation developed in the Informatics department at RAL. For more details see section 5.4.

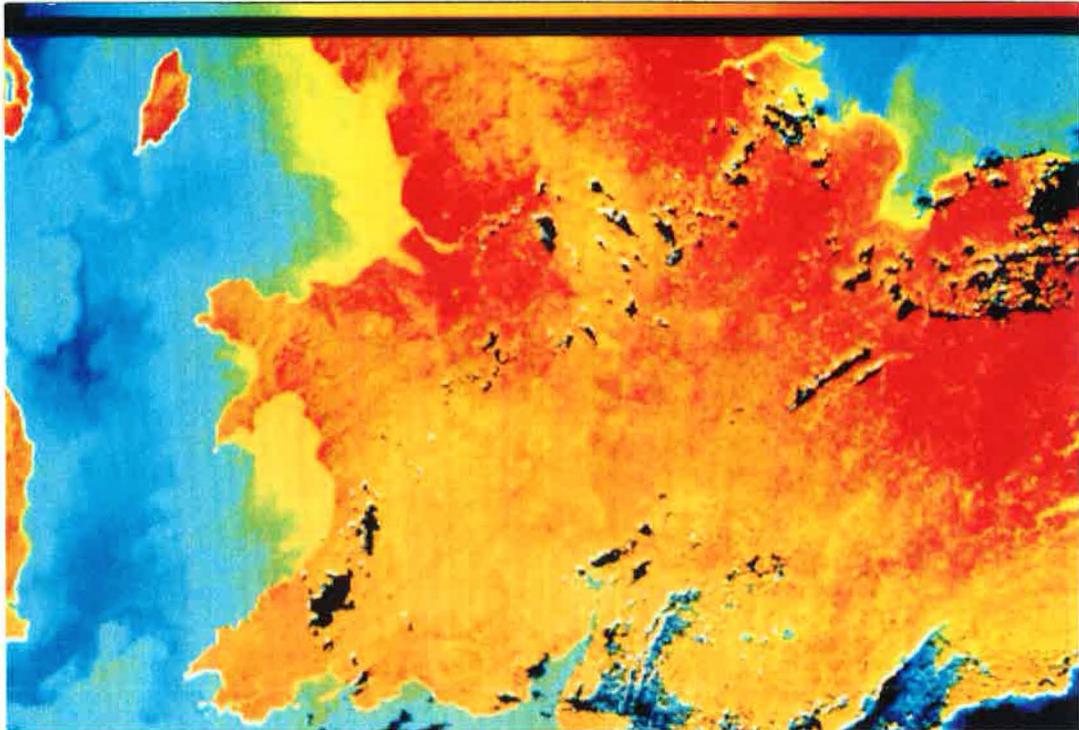


Figure 2: Image (courtesy ESA/SERC/RAL) of sea and land surface temperatures as seen from space. False colour shows temperatures varying from blues (cold) to reds (warm). Identified cloud pixels are masked black. Data processing by RAL Space Science, interactive visualisation by RAL Informatics. For more details see section 5.4.



Figure 3: Simulation of the flame front inside a diesel engine. This is a single frame from an animation showing the progress of a flame, estimated by the mass fraction of burnt fuel, in the prechamber (coloured blue for low to red for high levels of burnt fuel) of a diesel engine. The flame is rendered as a red isosurface and the prechamber is rendered transparently so the isosurface can be visible. (Interactive visualisation courtesy of Charles Hill from Imperial College).

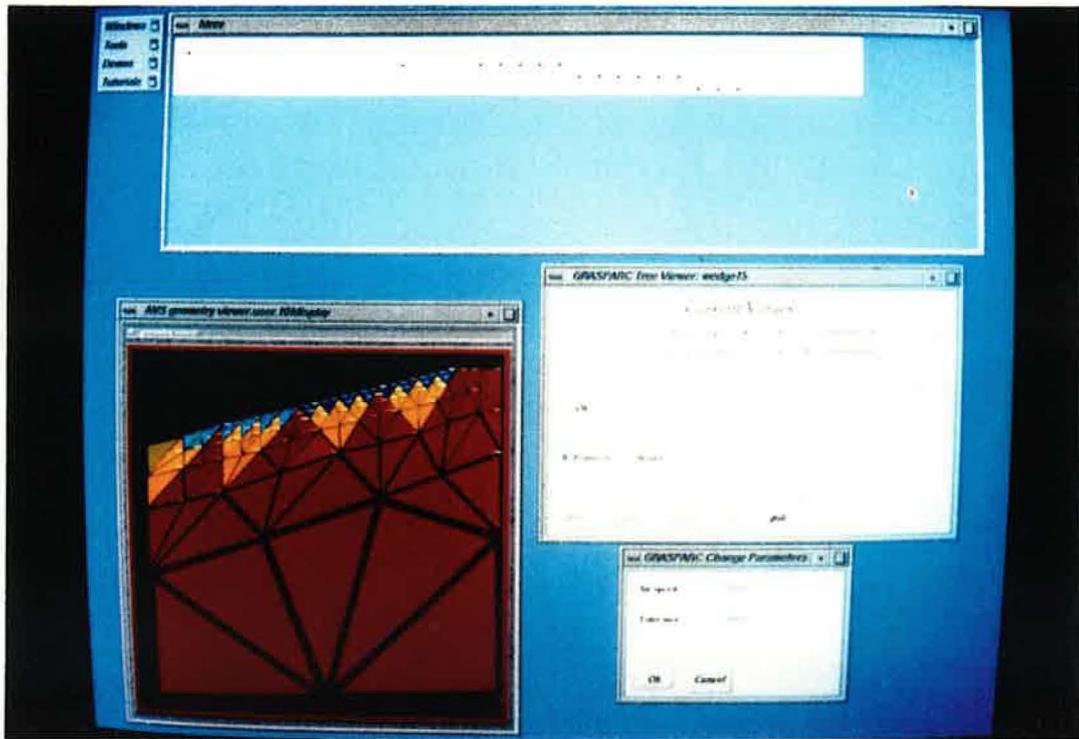


Figure 4: The GRASPARC project is looking at the use of visualisation to help the mathematical modeller. The system integrates numerical, graphical and data management components into a single problem-solving environment. The picture shows the study of air flow over a wedge: a series of experiments are carried out for different air speeds and different solution tolerances. These experiments form a tree structure - as shown in the top window. The modeller can navigate the tree to visualise previously calculated solutions, or backtrack to an earlier node to repeat an experiment with a different parameter setting - as is being done here.

The system is general enough to support different numerical components - here use is being made of the SPRINT differential equation solvers developed jointly by University of Leeds and Shell Research - and different graphical components - here AVS is being used.

The partners in the SERC/DTI project are NAG Ltd, University of Leeds and Quintek Ltd.

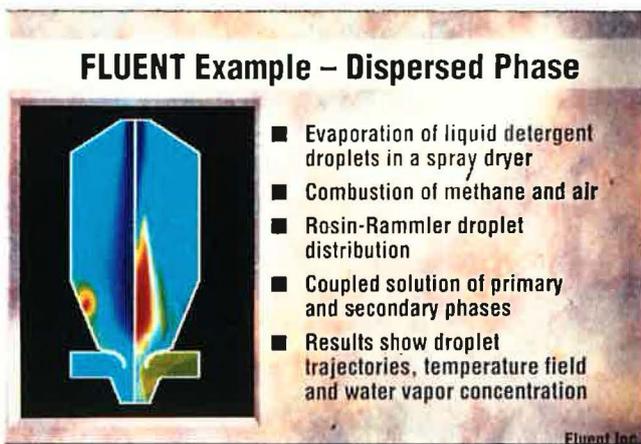


Figure 5: Courtesy of Prof. J Swithenbank.

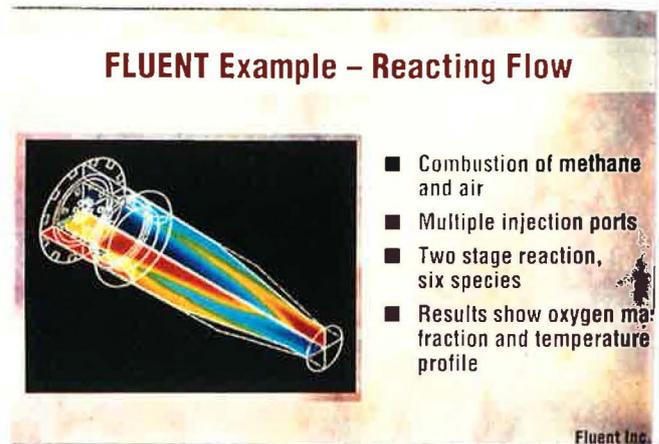


Figure 6: Courtesy of Prof. J Swithenbank

A Prototype AVS Reader for FLOW3D

This work was carried out by Mr S Larkin, Computer Graphics Unit, Manchester Computing Centre, University of Manchester, and involved developing a prototype reader for Harwell's FLOW3D system. The reader allowed the results from simulation using FLOW3D to be imported into the Application Visualisation System (AVS). The AVS software was then used to visualise the data using the various visualisation techniques available.

The figures below show output from AVS produced from a sample dataset which represents the turbulent flow of air through a cylinder which has obstructions placed inside its length.

Thanks must go to Dr I P Jones, CFDS, Harwell Labs, for kindly supplying the sample datasets and supporting the initial work. The current version of the FLOW3D package now has facilities to output a format which can be imported directly into the AVS software.

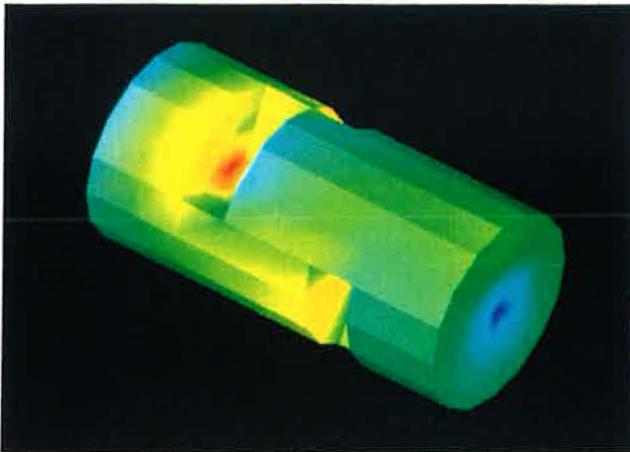


Figure 7: shows the cylinder structure with the scalar data component pressure mapped onto the surface. The colour-map used to colour the surface ranges from blue for low pressure to red at high pressure.

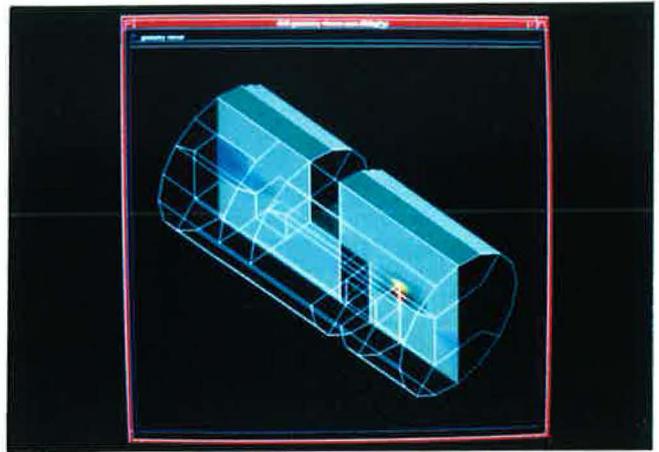


Figure 8: shows the same structure as Figure 7 but a cropping tool in AVS has been used to reveal the inner detail.

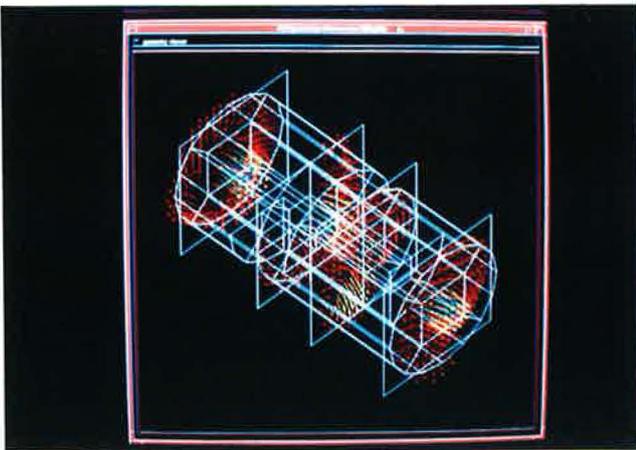


Figure 9: shows four planar probes positioned along the length of the cylinder to examine the vector data component velocity. The probes have small arrows indicating the direction of the velocity and are coloured according to the magnitude. Again a colourmap has been used ranging from blue to red hue for low to high magnitudes.

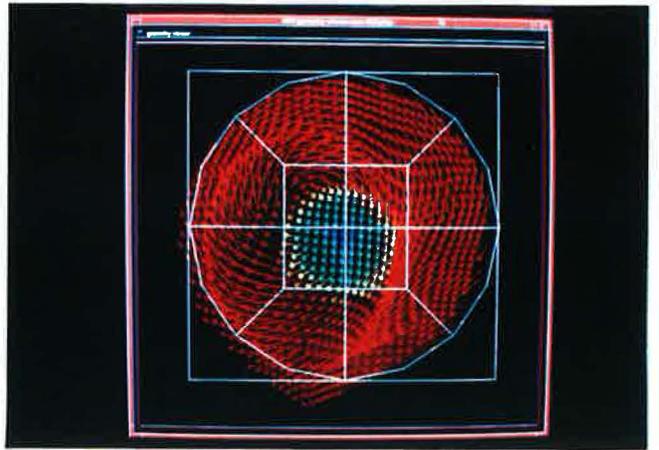


Figure 10: shows a front view of the scene in Figure 9 and it can be clearly seen from this the clockwise movement of the air as it passes through the cylinder.

