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L. Turner
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THE TEAM WORKSHOPS: A SHORT HISTORY*

Larry R. Turner
APS Accelerator Division
Argonne National Laboratory
Argonne, Illinois 60439, USA

The introduction of the TEAM Newsletter seems an appropriate occasion to look back over the three cycles and five years of the TEAM (Testing Electromagnetic Analysis Methods) Workshops. This note reviews the origins, the three cycles of workshops, and the problems. The workshops are summarized in Table 1.

Origins of the Workshops

Early in 1985, Sam Berk of the Office of Fusion Energy, U.S. Department of Energy, suggested that the development and validation of 3-D eddy current codes would benefit from the compilation of benchmark problems that could be used to validate the codes and from a series of workshops for the comparison of solution methods and codes. (Two years later, at the first International Symposium on Fusion Nuclear Technology in Tokyo, Sam Berk proposed the acronym TEAM for the workshops.)

Community response to the idea was judged through two questionnaires and a general meeting of interested people held at Fort Collins, Colorado in June 1985 during COMPUMAG-Colorado. From that response came three ideas that were incorporated into the workshops:

(1) Inclusion of both 2-D and 3-D problems,
(2) Publication of the proceedings of each workshop, and
(3) Several regional workshops followed by a global workshop.

At a three-day planning meeting at Argonne National Laboratory (ANL) in November 1985, eleven participants from five countries defined the goals, format, schedule and problems for the workshops. The goals were stated as:

> The ultimate goal is to show the effectiveness of numerical techniques and associated computer codes in solving electromagnetic field problems, and to gain confidence in their predictions. The workshops should also provide cooperation between workers, leading to an interchange of ideas.

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The nature of the workshops and problems was stated as:

> Participants will compare their computed results for one or more problems. The problems include transient and steady-state ac magnetic fields, close and far boundary conditions, magnetic and nonmagnetic materials. All the problems are based either on experiments or on geometries that can be solved analytically.

First Round of Workshops (1986-1987)

Six problems (1 through 6 in the list below) were selected for the first round. In each case, the field was to be found at specified points, and global quantities--currents, stored energy, forces, and power dissipation--were to be found as well. For transient problems, these were found at specified points; for steady-state problems, amplitudes and phases were found. Each problem had an assigned mesh; assigned meshes were discontinued in subsequent rounds as being too restrictive. An attempt was made to have results presented in tables and graphs with uniform format, but success varied in achieving this practice.

Five regional workshops were followed by a global workshop in Graz, Austria immediately before COMPUMAG-Graz.

Rutherford Appleton Laboratory, 27 March 1986. The workshop followed a seminar on eddy current computation. There were 32 participants from seven countries. Despite the short time since the organizational meeting at ANL in November 1985, and although many participants had received the problems only a few weeks before the workshop, there were presentations and discussions of four of the six problems. There were also suggestions for clarifications of the problems, for new problems, and for improvements in the workshop format.

Argonne National Laboratory, 23-24 June 1986. There were fifteen participants from four countries. From these first two workshops, the trend continued that workshops organized in conjunction with other meetings were better attended than those that were not. There were ten presentations on three problems. Beginning with ANL, part of the workshop activity was to prepare a summary of the different results for each problem.

Tokyo Electric Power Company, 20-21 October 1986. There were 62 participants, 50 from Japan and others from France, Sweden, Poland, Korea, UK, and USA. Akihisa Kameari of Mitsubishi Atomic Power Industries summarized the Japanese solutions to all six problems. The success of this workshop demonstrated the value of TEAM.

Ecole Centrale de Lyon, 18-19 November 1986. Thirty-six persons from seven European countries attended. The participants prepared tables of results for problems 1, 2, 5, and 6 from this workshop and from Tokyo.

Georgia Institute of Technology, 12-13 January 1987. Six solutions were compared for problem 6; there were also solutions to problems 2 and 5. There were ten participants from the US, Japan, Canada, and UK.

Technical University of Graz, 20-21 August 1987. The major activity of this global workshop was the presentation of summaries of solutions to the six problems, which were later published as a double issue (March and June 1988) of the journal COMPEL. There were 44 participants from eleven countries. There were also reports on the Tokyo, Atlanta, and Lyon workshops and many suggested problems for future workshops. The participants indicated approval of the workshops and a desire that they continue.

Results. One goal of the workshops was to "provide cooperation between workers, leading to an interchange of ideas." That goal was clearly achieved; the workshops identified key codes and code-developers in Japan, Europe, and America. In terms of ranking different methods, the first round began to show when approximate methods, e.g. codes with only two components of current, do or do not give satisfactory results, and how much computer time can be saved by using such methods.

The problems continue to be useful. At every computational conference, we see people using TEAM problems to illustrate new methods.

Second Round of Workshops (1988-1989)

Immediately following the Graz workshop, a planning meeting chose problems and venues for another round of workshops. All of the original problems were judged to be solved adequately with the possible exception of problem 5, where there was some discrepancy between the experimental results and the numerical solutions. Six new problems (7 through 12) were added. Some of the new problems were intended to come nearer to actual application areas, such as nondestructive testing.

Regional Workshops were held in Vancouver, Capri, Paris, and Baltimore, followed by a global workshop in Okayama the week after COMPUMAG-Tokyo. From discussions at these workshops came a more formal structure for the workshops plus a broadening of the workshops to include magnetostatics and other topics as well as eddy currents.

University of British Columbia, 18-19 July 1988. The workshop followed the Intermag conference in Vancouver. Twenty-four participants attended from six countries. There were solutions to all six new problems, including problem 10 with non-linear materials. Extensions and clarifications to the problems were adopted, and were included in the proceedings of the workshop.

Capri, 5-6 October 1988. The workshop was held jointly with a meeting on the industrial applications of eddy current codes on 7 October. There were 41 participants from six countries, with good distribution among universities, industries, and national and international laboratories. There were ten presentations on problems 3, 5, 7, 8, 11, and 12. Controversy about the experimental and numerical results for problem 8, the signal in a differential coil above a slit in a plate, began in this workshop and continued through the Paris, Baltimore, and Okayama workshops that followed. The proceedings were published by the Commission of the European Communities, as were the proceedings of the Paris workshop the following spring.

La Roche Dieu, Bievres, 20-22 March 1989. The meeting was hosted by Electricite de France and was held jointly with a meeting on the application of eddy-current computations. There were 52 participants from eight European countries. There were 14 presentations on problems 3, 4, 5, 6, 7, 8, 11, and 12, including new numerical and experimental results on problem 8. Four new test problems were also suggested, and there was considerable discussion on the future of the workshops.

John Hopkins University, Baltimore, 3-4 April 1989. The workshop followed the Intermag conference in Washington, D.C. There were twelve participants from five countries. There were presentations on problems 3, 4, 7, 8, 10, and 11. Discussion of problem 8 and the future of the workshops continued.

Okayama University, 11-13 September 1989. The workshop was held in conjunction with the International Symposium on 3-D Electromagnetic Field Analysis (3DMAG) and followed COMPUMAG-Tokyo. There was an unprecedented attendance of 243 participants from 19 countries--comparable to all previous workshops put together. There were summaries of solutions for the seven problems (5 and 7 through 12), 44 individual presentations on solutions, summaries of the four regional workshops, and more than eight suggestions for future problems. The summaries of the seven problems were published as the September 1990 issue of COMPEL. The individual presentations on the problems, the suggested new problems, and papers presented at the 3DMAG symposium were published as Supplement A to COMPEL.

Results. The TEAM workshops are beginning to demonstrate which methods and formulations are appropriate for which problems, depending on such considerations as boundary conditions, ratio of conducting to nonconducting elements, multiple connections, and current flow between regions with different conductivity. The groups at Okayama University and the Technical University of Graz in particular have been active in solving the same problem with different approaches and comparing the solutions.

Some of the problems of the second round (5, 7, and 11) were readily solved and will no longer be treated at the workshops, but others still require more attention.

Third Round of Workshops (1990-1991)

The success of the Okayama workshop clearly demonstrated the value of continuing the TEAM workshops. Plans were made before, during, and after Okayama (most noticeably at the Oxford workshop) to give some new directions to TEAM.

The Organization of the TEAM Workshops. The COMPUMAG ISC (International Steering Committee), meeting in Tokyo in April 1989, agreed to oversee the TEAM workshops and appointed a chairman for the workshops (Giorgio Molinari) and vice chairmen for Japan and America (Takayoshi Nakata and Larry Turner).

At Okayama about sixty people attended a luncheon meeting to discuss the future of the workshops. There was agreement about expanding the workshops to magnetostatics, high-frequency, and other areas, but disagreement about whether problems should be many or few, practical (complex geometry) or academic (simple geometry). Twenty-seven people attended a dinner meeting to begin planning for the third round of workshops. Workshops were suggested for Oxford, Toronto, and other places. Joint TEAM/ACES (Applied Computational Electromagnetics Society) workshops were explored. In choosing problems for the third round, some wanted to define all the problems on the spot; others wanted to wait for more input. For the Oxford workshop, problems 8, 10, and 12 were retained, and a new magnetostatics problem was adopted as problem 13.

Workshop in Oxford, 23-25 April 1990. The workshop followed the Intermag Conference in Brighton. There were over 60 participants from ten countries, making it the largest workshop outside Japan. There were 16 presentations on the four problems specified (8, 10, 12, and 13).

Several additional organizational decisions were made at the Oxford workshop. A planning board was selected, consisting of 12 chairmen of workshops of the first through third rounds plus the chairman and two vice-chairmen earlier chosen by the COMPUMAG ISC. Planning for the TEAM newsletter was approved. Two additional problems were selected for the third round, bringing the total to six. Dates and other details were approved for the regional workshops in Graz, Toronto, and Sendai, and the global workshop was scheduled for Sorrento after COMPUMAG-Sorrento.

The Toronto and Sorrento workshops, and probably the Sendai workshop as well, will be joint ACES/TEAM workshops.

Problems: Description and Status.

Problems 1 through 6 were treated in the first round of workshops. Problems 5 and 7 through 12 were treated in the second round. Problems 8 through 10 and 12 through 14 are being treated in the third round.

Problem 1, The FELIX Cylinder Experiment. A hollow aluminum cylinder with axis perpendicular to a uniform magnetic field that decays exponentially with time. Based on an experiment. Status: adequately solved in the first round.

Problem 2, Infinitely Long Cylinder in a Sinusoidal Field. Similar to problem 1, but solvable with a steady-state 2-D code. An analytical solution is available. Status: adequately solved in the first round.

Problem 3, The Bath Plate with Two Holes. A coil with sinusoidal excitation above a conducting ladder. Based on an experiment. Status: adequately solved in the first round. Problem 7 is a similar problem, but with a thicker conductor.

Problem 4, The FELIX Brick Experiment. A rectangular aluminum brick with a rectangular hole in a uniform magnetic field that decays exponentially with time. Based on an experiment. Status: adequately solved in the first round.

Problem 5, The Bath Cube. Four identical aluminum cubes are enclosed within a laminated iron box under a laminated iron pole. A sinusoidal magnetomotive force (mmf) is applied between the pole and box. A near-boundary problem, based on an experiment. Status: Because of some ongoing discrepancies between experimental and numerical results, it was augmented somewhat and kept for the second round, in which it was adequately solved.

Problem 6, The Hollow Sphere. A hollow sphere in a uniform sinusoidally varying magnetic field. There is an analytical solution. The problem may be solved either as a 3-D or as a 2-D (axisymmetric) problem. Status: adequately solved in the first round.

Problem 7, Plate and Hole. This is effectively a new version of the Bath plate, but with a much thicker conductor. A 3-D multiply-connected problem, with experimental solution. Status: adequately solved in the second round.

Problem 8, Coil above Crack. A conducting metal plate has a "crack" of defined dimensions. The probe has one inducing solenoid and two receptive solenoids. The differential impedance of the probe is to be found as a function of position. Based on a nondestructive testing (NDT) experiment. Two additional groups performed this experiment during the second round. Status: Agreement between numerical computations and experiment (and among computations, and among experiments) improved over the course of the second round, but the problem was retained for the third round.

Problem 9, Coil Moving in a Cylinder. A coil with ac excitation moves in a metal tube. Different velocities for the coil present different degrees of difficulty for the problem. Status: There was only one attempt to solve the problem in the second round. It has been simplified, so that there is an analytical solution, and was retained for the third round.

Problem 10, Plate over a Coil. A steel plate (nonlinear permeability) is located above a coil with transient excitation. The problem requires substantial computer time. Status: retained for the third round because only a few people had solved it in the second round.

Problem 11, Sphere in a Step Field. The sphere geometry is identical to that of problem 6. The step field is a challenging transient problem. There is an analytical solution. Status: adequately solved in the second round.

Problem 12, Cantilevered Beam in Crossed Fields. A coupled problem with moving conductor. The motion of the beam causes the current and deflection to be quite different from the uncoupled case. Based on a FELIX experiment. Status: Almost all the solutions in the second round treated the beam deflection with a one or two parameter model. The problem was retained for the third round with the deflection to be treated numerically.

Problem 13, Nonlinear Steel Channels. Two steel channels are located antisymmetrically with respect to a central steel sheet and a coil with dc excitation. Status: a new problem, with four solutions presented at the Oxford workshop.

Problem 14, Eddy Current Losses In Euratom LCT Coil. Based on extensive experiments on the currents induced in the coil case by pulsed coils. Status: a new problem, adopted at the Oxford workshop.

TABLE 1

THE TEAM WORKSHOPS

Dates	Site	Chairman
27 March 1986	Rutherford Appleton Lab., UK	Chris Emson, RAL
23-24 June 1986	Argonne National Lab., IL	Larry Turner, ANL
20-21 October 1986	Tokyo, Japan	Kinzo Miya, U. of Tokyo - Takayoshi Nakata, Okayama U
18-19 November 1986	Lyon, France	Alain Nicolas, ECDL
12-13 January 1987	Atlanta, GA	Kent Davey, Georgia Tech
20-21 August 1987	Graz Austria	Larry Turner, ANL
18-19 July 1988	Vancouver, BC	Larry Turner, ANL
5-6 October 1988	Capri, Italy	Raffaele Albanese, U. of Salerno Vincenzo Corcorese, U. of Reggio Calabria Raffaele Martone, U. of Salerno Guglielmo Rubinacci, U. of Naples
20-22 March 1989	Paris, France	Jean-Claude Verite, EDF Alain Bossauit, EDF Jacques Cahouet, EDF Yves Crutzen, JRC-Ispra
3-4 April 1989	Baltimore, MD	Nathan Ida, U. of Akron
11-13 September 1989	Okayama, Japan	Takayoski, Nakata, Okayama U

23-25 April 1990	Oxford, UK	Jim Diserens, RAL Chris Emson, Vector Fields Dave Rodger, Bath U.
10-12 October 1990	Graz, Austria	Kurt Richter, TUG Werner Rucker, TUG Oszkar Biro, TUG
25-26 October 1990	Toronto, Ontario	Harold Sabbagh, Sabbagh Associates
31 Jan.-1 Feb 1991	Sendai, Japan	Toshiyuki Takagi, Tohoku U.
15-16 July 1991	Sorrento, Italy	No yet chosen