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DEPARTMENT OF COMPUTER SCIENCES THE UNIVERSITY OF TEXAS AT AUSTIN

AUSTIN, TEXAS 78712

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FINAL TECHNICAL REPORT 1986-87

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A Year of Programming

Contract ONR N00014-86-K-0466

The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188



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A Year of Programming

Contractor: Department of the Navy

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Expiration Date of Contract: September 30, 1987

Co-principal Investigators:

James C. Browne and Jayadev Misra The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 Telephone: 512-471-9579

Personnel:

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Hamilton Richards, Coordinator Suzanne Kain Rhoads, Senior Administrative Associate Temporary clerical staff: B. Burson, Renate Dyke, R. Loyless

Expenditures 7/1/86-9/30/87:

 Salaries and Wages
 \$44,713.64

 Fringe Benefits
 9,653.68

 Other Expenses
 5,171.42

 Consultants
 6,879.95

 Consultants Travel
 2,912.31

 Overhead
 <u>30,506.00</u>

 Total
 \$99,837.00



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*The Year of Programming activities were augumented with funds from ONR N00014-86-K-0763 in the amount of \$488,038.

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YEAR OF PROGRAMMING

The 1987 University of Texas Year of Programming was established early in 1986, in response to a proposal by Profs. J. C. Browne and J. Misra, with the following goals:

- (>)) to advance the art and science of programming by bringing leading scientists together for discussions and collaboration '
- ~ 2 to disseminate among leading practitioners the best of what has been learned about the theory and practice of programming $\sim \alpha_r \lambda$

Upon acceptance of the proposal by the Office of Naval Research, a Year of Programming management committee was established, consisting of a dozen members of UT's Computer Sciences faculty and one representative each from MCC and Lockheed/Austin. A half-time coordinator (H. Richards) was appointed in August, but the half-time administrative associate (S. K. Rhoads) did not join the YoP office until November.

When the management committee proved too cumbersome for the frequent and intensive consultations which the early planning stages required, an executive subcommittee was formed, consisting of J. C. Browne, E. W. Dijkstra, C. A. R. Hoare, and H. Richards. Out of the executive subcommittee's weekly meetings came the decision that the Year of Programming's major effort would be a series of Programming Institutes, each composed of some combination of research seminars, tutorials, and workshops, whose influence would be extended beyond their immediate audience through the distribution of published proceedings and videotapes.

Accomplishments

The Year of Programming's goals have been substantially achieved by its accomplishments during 1986-87, which included a workshop and five Programming Institutes (described individually below), each devoted to a topic at computing's scientific frontier. Each institute was presented by six to a dozen or more of the leading scientists in its subject area, and drew an audience from industry, government, and academia numbering between 75 and 106 (except for one institute, which was limited by the availability of suitable computing equipment to 30).

These events have effectively brought into focus the state of knowledge concerning formal aspects of programming, have propagated that knowledge to a large, diverse, and influential audience from universities, industry, and government, and have stimulated critical evaluation

Year of Programming

of research directions for the URI in Formulation and Programming of Parallel and Distributed Computation at The University of Texas. The coordinated proceedings and videotapes of the Institutes provide an opportunity for further dissemination of this important body of knowledge (see Plans for next year's work, *infra*).

Workshop

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ם ק 0. Real-Time Systems Workshop (24-25 November) Director: Prof. A. K. Mok (UT Austin)

A small-scale workshop, involving about two dozen participants, met on the UT campus to bring together academic researchers and builders of real-time systems to enable researchers to assess their work's potential impact and to enable system builders to learn about current research and to influence its direction to advance the design of real-time systems. The workshop disclosed that there is a serious lack of communication between researchers and practitioners, but that recent advances in specification methodology, temporal logic, and scheduling theory may provide a theoretical groundwork for real-time-system design.

Programming Institutes

1. Concurrent Programming (23 February - 6 March) Scientific Director: Prof. C. A. R. Hoare (Oxford, visiting at UT Austin)

The first YoP institute was devoted to one of computing's most active subject areas---the formal description of concurrent computations. Since it was YoP's first major event, it was fortunate that its scientific director was a member of the YoP executive committee and was in residence at UT during all the preparations for it.

The institute's first week began with a one-day presentation by INMOS Corporation on their Transputer, a processor intended as a building block for multiprocessor systems. It continued with a four-day tutorial on Communicating Sequential Processes (CSP), a notation and methodology for programming concurrent computations developed by the institute's director.

The second week began with a three-day Research Seminar, at which ten of the field's leading scientists presented some of their latest work. Jayadev Misra and K. Mani Chandy, of UT-Austin, presented their new methodology for concurrent programming based on iterated assignments; David May, of INMOS Ltd., described an integrated- circuit manufacturer's use of formal methods; James Woodcock and He Jifeng, from Oxford University, presented several applications and extensions of CSP; Charles Seitz, of CalTech, described the architecture, design, and programming of concurrent message- passing systems; Alain Martin, also of CalTech,

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showed how concurrent-programming methodology can be used in the specification of VLSI circuits; Amir Pnueli, of the Weizmann Institute, presented some recent results in reasoning about concurrent systems using temporal logic; and Leslie Lamport, of Digital Equipment Corporation, lectured on the relationship between formal and informal methods and led, inspired, and moderated the discussion sessions that ended each day.

During the institute's final two days, the director and speakers were joined by a few invited observers to discuss their impressions of the preceding days and the institute's implications for the future of the discipline.

Four of the research seminar speakers presented evening lectures that were open to the public at no charge. Woodcock described the use of formal methods in software development at IBM's UK Laboratories, Lamport lectured on reasoning about concurrent programs, May described INMOS's formal verification of the floating-point-division section of a Transputer chip, and Seitz lectured on the effect on parallel architecture of the advent of VLSI technology.

2. Encapsulation, Modularization, and Reusability (1-10 April) Scientific Director: Prof. David Gries (Cornell)

The second institute addressed methods for dealing with the problems attending large software systems by constructing them of well-structured and reusable software components. It began with a four-day tutorial intended to bring the audience up to date on such topics as data abstraction, polymorphism, encapsulation, and modular programming, drawing on experience with such programming languages as Modula-2, Cedar/Mesa, Ada, and SmallTalk. The tutorial speakers were (in addition to Prof. Gries) Jurg Gutknecht (ETH Zürich), C. A. R. Hoare (Oxford, visiting at UT Austin), James Donahue (Olivetti Research Center), Gregory Andrews (Arizona), Alan Snyder (Hewlett-Packard), and Luca Cardelli (Digital Equipment Corporation).

Following the pattern of the previous institute, the tutorial was succeeded by a three-day Research Seminar. John Mitchell (Bell Labs) described the addition of modules to the programming language ML, and showed how modules and polymorphism can interfere with each other. Cliff Jones (Manchester) and He Jifeng (Oxford) both presented work on data types and data refinement; Prof. Jones showed how these ideas appear in the context of the Vienna Definition Method, whereas Dr. He explored the relationship between prespecification and simulation in data refinement. John Guttag (MIT) presented LARCH, a language for writing well-structured specifications. Jan Prins (Wisconsin) presented recent work (with Prof. Gries) on modules and encapsulation, and J. Donohue presented some new ideas on bringing object-oriented and procedural programming together. Finally, Edsger W. Dijkstra gave a presentation of "Batcher's Baffler," a concurrent sorting algorithm.

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The institute's final two days were devoted to a workshop attended by the speakers and a few invited observers. Most notable among the latter was Nax Mendler, a student of Robert Constable's at Cornell, who was invited on one day's notice when it was realized that his doctoral research, which was then practically complete, showed how two complementary approaches to encapsulation (one based on type theory and the other on proof theory) that had emerged during the research seminar could be brought together. This incident is offered as evidence that the Year of Programming has produced just the kind of scientific ferment and excitement that it was designed to bring about.

3. Logical Foundations of Functional Programming (8-12 June) Scientific Director: Dr. Gérard Huet (INRIA)

The third institute was shorter than either of its predecessors, lasting only a single week, but like them it offered both a tutorial and a research seminar. The tutorial, which was a three-day introduction to the French school of functional programming and type theory, was taught by Dr. Huet and his colleague Guy Cousineau (Ecôle Normale Supérieure, Paris). This was the first institute in which working computer systems were involved; a SUN workstation and video projector were used in the lecture hall for demonstrations of CAML software, and evening sessions on the UT campus gave institute attendants an opportunity to try their hand at CAML programming.

The week ended with a two-day research seminar on linear logic and constructive semantics. Jean-Yves Girard (Université Paris 7) gave two lectures on qualitative domains, coherent spaces, and linear logic, and in a third lecture presented his latest work on a geometry of interaction. Albert Meyer (MIT) presented a talk on computability, John Mitchell (Bell Labs) and André Scedrov (Pennsylvania) lectured on relationships between type theories, and Susumu Hayashi (Kyoto) dealt with program extraction. John Reynolds (Carnegie-Mellon) presented a demonstration that polymorphism is not set-theoretic.

4. Formal Specification and Verification of Hardware (8-17 July) Scientific Directors: Michael J. C. Gordon (Cambridge) and Warren A. Hunt Jr. (UT Austin)

The fourth institute departed from precedent in several ways. It had two directors, who organized the institute from opposite sides of the Atlantic, and it consisted almost exclusively of a tutorial. Moreover, it involved computer systems as an integral part of the institute, rather than as an optional adjunct, and it set a record for the volume of lecture notes provided to the participants.

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The institute was billed as a practical introduction to hardware specification and verification using two substantially different systems for machine-checked formal proofs: the Boyer-Moore Theorem Prover and the HOL Proof Assistant for Higher-Order Logic. The mornings were spent on lectures, and the afternoons on practical sessions using the two verification systems running on SUN workstations. Lecturing on HOL were Dr. Gordon, Tom Melham, and John Herbert, all from Cambridge University. The Boyer-Moore system was presented by Dr. Hunt and Matt Kaufmann, both at UT-Austin, with a supplementary lecture on Boyer-Moore logic by J Moore (also at UT-Austin).

The tutorial began with a three-day introduction to formal logic and to the SUN workstations and Unix. The remaining week was spent on learning to use the two verification systems, ranging from simple examples of formal specification (e.g., adders, counters) to advanced examples of verification (including the verification of the FM8501 cpu).

The course-evaluation questionnaires filled out by the students in the course reinforced the YoP office's impression that the institute's dependence on computing systems was a substantial liability. To begin with, the available population of SUNs and terminals (even during the summer term) limited the enrollment to 30 (students worked in pairs). Ensuring that the HOL software would run properly on UT's SUN-3s was difficult, requiring substantial efforts over three months to find and install the proper version of Franz Lisp and a last-minute scramble to correct a hardware design problem. Although the verification software itself was reasonably robust, the SUN/Uniz/Ethernet environment supporting them proved somewhat fragile, and the complexity of *emacs*, the Unix editor, proved troublesome.

Despite these difficulties, and thanks to the efforts of UT support staff and the cooperation of SUN Microsystems, Inc. in overcoming them, the students' evaluations of the institute were generally quite positive.

5. **Declarative Programming** (24-29 August) Scientific Director: Prof. David A. Turner (Kent)

The fifth institute returned to the format of the third one, with a three-day tutorial followed by a two-and-a-half day research seminar, and optional practical sessions on the UT campus in the evenings. Although the tutorial was taught by five lecturers— Samson Abramsky (Imperial College London), Richard Bird (Oxford University), John Hughes (University of Glasgow), Simon Thompson (University of Kent) and Prof. Turner — the obvious danger of fragmentation was nicely averted by the efforts of the director, who called his fellow instructors together for a daylong meeting early in July and then followed up with extensive correspondence to ensure the tutorial's coherence.

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The tutorial, which provided an introduction to lazy functional programming, consisted of lectures interspersed with programming sessions (conducted with pencil and paper) attended by the lecturers and several teaching assistants. Major topics included data types, polymorphism, recursion and induction, lists, domain theory, program synthesis, and several case studies.

At the research seminar, each of the tutorial speakers gave a presentation on his recent research. Abramsky showed how the standard theory of Ò-calculus can be extended to fit lazy functional languages. Hughes described *backward* analysis of functional programs, a technique that complements conventional (forward) techniques for such purposes as strictness analysis. Turner gave an account of his KAOS project, which is aimed at constructing an operating system of communicating processes written entirely in a functional notation. Thompson presented a method for analyzing the input-output behavior of systems defined in terms of functions on streams, and Bird described a calculus for deriving efficient implementations of programs involving lists.

The tutorial speakers were joined for the research seminar by six other scientists. Robert Cartwright, of Rice University, lectured on exact real arithmetic, and Peter Buneman (Pennsylvania) spoke on functional programming and databases. John Backus (IBM) addressed the problems of higher-order functions, input/output, and persistent files in a strict (i.e., non-lazy) functional language. Keshav Pingali (Cornell) presented a new data-structuring mechanism ("I-structures") intended as an efficient functional implementation of large data structures. Joseph Goguen (SRI) showed how higher-order functions can in many respects be replaced by a generic module facility, and David MacQueen (Bell Labs) described how type systems for functional programming languages are evolving to meet the demands placed on them by largescale programming.

This institute elicited particular enthusiasm among a group of UT graduate students, who circulated among themselves, and subsequently presented to the UT Department of Computer Sciences, a petition calling on the department "to make Functional Programming a more visible priority in the department... [through] recruitment of faculty engaged in research in the field [and] more formal contacts with private research and other departments...".

(6) **Specification and Design** (cancelled). Scientific Director: J. R. Abrial (Paris).

The sixth institute, scheduled for 14-25 September, had to be called off when, a week after the announced date for acceptance of applications, only a dozen applications had arrived. Although the cancellation was not widely publicized (the applicants were of course notified at once), the total number of applications received by 14 September was less than 20.

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The reasons for the sparsity of the turnout will never be known with certainty, but better communications among the organizers would have helped considerably. Perhaps September, when the American fall semester has just gotten under way, is not a good time for a gathering as long as two weeks; moreover, the announcements, mailed in July, may have found many of their recipients on holiday. Another factor, pointed out by one of the would-be speakers, is that M. Abrial is less widely known than some of the other YoP directors; those who know his work hold it in the highest regard, but M. Abrial has published comparatively seldom, and even in Europe his name is not particularly well known.

6. Formal Development of Programs and Proofs (26-30 October) Scientific Director: E. W. Dijkstra (Texas)

The final YoP institute is a week in the future as this is written. According to its director, "If the first [institutes] were for full orchestra, the last one may very well be for a chamber ensemble." The speakers "have been selected for their expertise in the judicious use of formal techniques and in the presentation and derivation of proofs and programs." Their presentations, which will occupy four and one half days, are offered as "intellectual recitals, to be listened to by way of mental preparation for the high-quality programming of the near future."

The speakers will be Roland Backhouse (Groningen), Wim Feijen (Eindhoven, visiting UT Austin), David Gries (Cornell), Alain Martin (CalTech), Joseph Morris (Glasgow), Martin Rem (Eindhoven), Jan van de Snepscheut (Groningen), and A. M. van Gasteren (Waalre, The Netherlands).

Following the public session, the speakers will gather for a workshop lasting a day and a half.

Statistical Summary

The attendees at the first five Programming Institutes (counting participation by a single person in two institutes as two participants) numbered 367; of these, 128 were graduate students and 8 were post-doctoral researchers. In addition, the number of scientists participating as lecturers and as scientific directors was 49.

Among the universities represented at the first five YoP institutes were the following (the number of attendees from each institute is also shown):

Brown	3	Maryland	3
CalTech	2	MIT	4
Carnegie-Mellon	6	Pennsylvania	6
Cornell	9	Stanford	2
Illinois	1	Wisconsin	3

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The list of YoP invitees and the list of YoP attendees for the first five Institutes are appended to this report.

Conclusions and Acknowledgments

By far the most important factor contributing to YoP's success was the caliber of the scientists who participated as directors and lecturers. This was due partially to the advice and counsel of the three leaders of the executive subcommittee in YoP's formative stages, and to their efforts and influence in recruiting their colleagues, but most importantly to the persuasiveness and negotiating skills of Dr. Hamilton Richards, the Director of the Year of Programming. The task of recruitment was eased by the resources placed at YoP's disposal by its sponsors, which made it clear that YoP was intent on recruiting the very best and was prepared to pay accordingly.

The staff of the YoP office — S. K. Rhoads and her assistant A. M. Mota — deserve a great deal of credit for their understanding of UT's administrative structure and procedures, for their dedication to YoP's success over many a late evening and working weekend, and for their diligence in organizing their own efforts and those of many part-time employees and student helpers to take care of the innumerable details that make an institute a success.

Among the infrastructural factors contributing to YoP's success was the availability of electronic mail, specifically, the Internet access provided by the university's DEC-20 and VAX/Unix computers. Without such a facility, cooperation among such geographically diverse groups on such tight schedules would have been impossible (though hardly conclusive, it is worth noting that the director of the cancelled sixth institute was the only YoP director not resident in Austin who was not accessible by electronic mail).

Another important contribution was the trio of Macintosh computers provided by the Department of Computer Sciences. The Macintosh text-preparation and database-management software has played a crucial role in the work of organizing and presenting the institutes (not to mention that of reporting on them).

A major concern from the YoP's early days was publicity — how to advertise the institutes to their potential audiences. An advertisement placed in the January 1987 issue of *Communications of the ACM* drew a disappointingly small response, no doubt partly because by the time it had to be submitted (in November), plans were still rather vague. Despite the small explicit response, however, the ad may well have prepared the CACM readership for the direct-mail and electronic bulletin-board campaigns that succeeded it.

Direct-mail advertising relied on the YoP mailing list, which has grown to 1700 names (500 with electronic-net addresses). Every institute announcement was distributed both by post and electronically; although a comprehensive analysis of results remains undone, our

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impression is that the applications received were about evenly divided between postal and electronic mail. The large number of applications received from people not on our mailing list shows that announcements' original recipients were conscientious in distributing them to colleagues.

An unexpectedly minor source of applications was the ARPAnet bulletin board. The disappointing response is explained in part by the moderator's refusal to allow the posting of complete announcements (despite the YoP's military sponsorship, all mention of fees was rigorously prohibited), and by the long delay (often exceeding a month) between an announcement's posting and its appearance.

No doubt the number of applications would have been considerably higher had we been able to advertise in conventional journals and technical magazines, but the lead time for conventional advertising is simply far too long for events which remain in a state of becoming organized down to the final days. Had the YoP been spread out over three or four years, such conventional approaches might have been valid, but since most of the institutes were practically full (up to limits of available space and other facilities), the main practical effect of such advertising would have been to increase the number of rejected applications (which was in fact approximately zero).

Activities for 1987-88

Most of the remaining effort on the Year of Programming will be directed towards publication of the Institutes' proceedings, both in traditional textual form and as videotapes, and towards vigorous development of continuing education programs using this material.

The textual proceedings are to be published in six volumes—one per institute—each edited by its institute's scientific director. Addison-Wesley Publishing Company has been selected to publish the series, and final agreement awaits only UT's approval. Several manuscripts have been received, the majority in machine-readable form. The current plan is for each volume editor to select the papers for his volume and to advise authors on matters of technical content and general style. The YoP office will be responsible for editing all manuscripts into a uniform format and typographic style, and for translating into LaTex manuscripts that are submitted as hard copy or other non-LaTex forms.

Current plans for publishing the videotapes call for a joint venture between UT and MPA Inc., an established Austin media services firm which performed the original taping of the lectures and proposes to contribute sufficient editing to produce technically clean documentaries from the raw tapes. The resulting tapes will be offered for purchase both as individual lectures and as complete Institute sets.



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List of Invitees and Attendees

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UT Year of Programming List of Invitees

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5s Imperial College London Dr. Samson Abramsky Prof. Gregory Andrews University of Arizona: Computer Science 2s Mr. John Backus IBM 5s Dr. Richard S. Bird **Oxford University 5**s Dr. Peter Buneman University of Pennsylvania 5s Dr. Luca Cardelli **DEC Systems Research Center** 2s **Rice University** Dr. Robert C. Cartwright **5**s **UT Austin: Computer Sciences** Prof. K. Mani Chandy **1s** Prof. Guy Cousineau Ecole Normale Supérieure 35 UT Austin: Computer Sciences Prof. dr. Edsger W. Dijkstra 10 Olivetti Research Center Dr. Jim Donahue 2s Université Paris 7 Prof. Jean-Yves Girard 3s Dr. Joseph A. Goguen SRI International **5**s Dr. Michael J. C. Gordon University of Cambridge: Computer Lab. 4d Prof. Mohamed G. Gouda **UT Austin: Computer Sciences** 10 **Cornell University: Computer Science Prof. David Gries** 2d ETH Zürich: Institut für Informatik **2**s Dr. Jurg Gutknecht M.I.T. Lab for Computer Science Prof. John Guttag 2s Prof. Susumu Havashi **Kyoto University** 3s Oxford University: Computing Laboratory Dr. Jifena He 1s.2s Prof. E. C. R.Hehner University of Toronto: Computer Science 20 University of Cambridge: Computer Lab. Dr. John Herbert **4**s University of Kent Mr. Stephen Hill 5t **UT Austin: Computer Sciences** Prof. C. A. R. Hoare 1**d** Mr. Gareth Howells University of Kent 5t Dr. Gérard Huet **INRIA** 3d Prof. R J M Hughes Glasgow University 5s Dr. Warren A. Hunt Jr. Computational Logic, Inc. **4**d Prof. Cliff Jones The University, Manchester: Computer Science 2s Dr. Matt Kaufmann Institute for Computing Science... **4s Digital Equipment Corp.-SRC** Dr. Leslie Lamport 1s Dr. David B. MacQueen AT&T Bell Laboratories 5s Prof. Alain J. Martin California Institute of Technology **1s** Dr. David Mav INMOS. Ltd. **1s** Mr. Thomas F. Melham University of Cambridge: Computer Lab. 4s **Cornell University** Mr. Nax Mendler 2w MIT Laboratory for Computer Science Prof. Albert R. Meyer 3s Prof. Javadev Misra UT Austin: Computer Sciences **1s** Dr. John Mitchell **Bell Laboratories** 2s Dr. J Strother Moore Computational Logic, Inc. 4s Prof. Ernst-Rudiger Olderog University of Kiel **1s** Prof. Keshav K. Pingali **Cornell University 5**s Prof. Gordon Plotkin University of Edinburgh 10 Prof. Amir Pnueli Weizmann Institute **1s** University of Wisconsin/Madison: Comp. Sci. Mr. Jan Prins 2s Prof. John Reynolds Carnegie-Mellon University 3s Prof. André Scedrov University of Pennsylvania 3s Prof. Fred B. Schneider **Cornell University** 10 Prof. Charles L.Seitz California Institute of Technology **1s Hewlett Packard Labs** 2s Dr. Alan Snyder Dr. Robert E .Strom IBM T. J. Watson Research Center 10

UT Year of Programming List of Invitees

Dr. Simon J. Thompson	University of Kent	5s
Prof. David A. Turner	University of Kent	5d
Prof. Jan L. A.van de Snepscheut	Rijksuniversiteit Groningen	10
Prof. Peter Wegner	Brown University: Computer Science	20
Dr. John Williams	IBM Almaden Research Center	20
Mr. Edward L. Wimmers	IBM	50
Dr. Pierre Wolper	Universite de Liege	10
Dr. Jim Woodcock	Oxford University: Computing Laboratory	1s

*Legend: 5s denotes 5th institute speaker.

s - speaker

- d director
- o observer
- t teaching assistant
- w workshop participant only

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Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987

Mr. Yeturu Aahlad The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 aahlad@sally.utexas.edu 512-471-9572

Mr. James H. Anderson The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188

Mr. Wayne Ashby The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 ARL@NGP.UTEXAS.EDU 512-835-3497

Mr. Nader Bagherzadeh The University of Texas at Austin Dept. of Electr. & Computer Engineering Austin, Texas 78712 nader@ngp.UTEXAS.EDU

Mr. Eugene Berger NL Industries 15510 Banff Dr. Houston, TX 77062 713-987-4605

Mr. David A. Brant The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 ARL@NGP.UTEXAS.EDU 512-835-3381



Mr. Robert L. Akers Computational Logic, Inc. 1300 West Lynn St. Austin, TX 78703 cmp.akers@R20.UTEXAS.EDU 512-478-7111

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Mr. Anish K. Arora The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.anish@R20.UTEXAS.EDU

Mr. Paul Baffes Ford Acrospace M4B 1150 Gemini Houston, TX 77258 713-483-8110

Mr. Rajive Bagrodia The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 rajive@sally.UTEXAS.EDU 512-471-9588

Mr. William R. Bevier The University of Texas at Austin Inst. for Computing Sci. & Computer Appl'ns Main 2100 Austin, Texas 78712 cmp.bevier@R20.UTEXAS.EDU 512-471-1901

Mr. Geoffrey Brown University of Texas at Austin Dept. of Elect. & Computer Engineering Austin, TX 78712 eeac736@ix2.UTEXAS.EDU

* * \$ * 5 *

Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987



Prof. James C. Browne The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ics.browne@r20.UTEXAS.EDU 512-471-9579

Dr. Gael Buckley The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.buckley@r20.UTEXAS.EDU 512-471-9723

Prof. K. Mani Chandy The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 nel@ratliff.UTEXAS.EDU 512-471-9549

Mr. Heng Chang FMC Corporation Central Engineering Labs 1205 Coleman, Box 580 Santa Clara, CA 95052 408-289-3162

Mr. Tam-Anh Chu M.I.T. Laboratory for Computer Science 545 Technology Square Cambridge, MA 02139 TCHU@XX.LCS.MIT.EDU 617-253-6078

Mr. James Crawford The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 jc@ratliff.UTEXAS.EDU 512-471-4753 Mr. Erik Brunvand Carnegie -Mellon University Department of Computer Science Schenley Park Pittsburgh, PA 15213 elb@vlsi.cs.cmu.edu 412-268-3076

Mr. David Burlingame Lockheed Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9743

Mr. Chung-Kuo Chang The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 chang@sally.UTEXAS.EDU 512-471-9575

Prof. Shiu-Kai Chin Syracuse University Dept. Electrical and Computer Engineering 111 Link Hall Syracuse, NY 13244-1240 chin@syr-sutcase.csnet

Mr. John W. Cobb The University of Texas at Austin Institute for Fusion Studies, Dept. of Physics R. L. Moore Hall 8.302 Austin, Texas 78712 512-471-1322

Mr. Thomas M. DeBoni The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 deboni@SALLY.UTEXAS.EDU

and the shear

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DODDA 103044 DAVIN LUUKA LANKA

Mr. Norman M. Delisle Tektronix, Inc. MS 50-662 P. O. Box 500 Beaverton, OR 97077 normd %tekcrl%tektronix.csnet@csnet-relay 503-627-6196

Prof. E. Allen Emerson The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 cs.emerson@R20.UTEXAS.EDU 512-471-9527

Mr. Stuart R. Faulk Naval Research Laboratory Code 5590 Washington, D.C. 20003 faulk@nrl-css.arpa 202-767-3212

Ms. Sue Fitzgerald Schlumberger Well Services 8311 North FM Road 620 Austin, TX 78726 512-331-3314

Mr. David Glaser Digital Equipment Corporation 200 Forest Street, MR01-2/M20 Marlboro, MA 01752 617-467-6597

Mr. David Goldschlag The University of Texas at Austin ICSCA MAI 2100 Austin, TX 78712 dmg@sally.UTEXAS.EDU 512-471-1901 Prof. dr. Edsger W. Dijkstra The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 512-471-1901

Mr. Morris Enfield MCC 3500 West Balcones Ctr. Dr. Austin, TX 78759 enfield@MCC 512-338-3477

Mr. Eric Fiene Motorola OE37 6501 William Cannon Drive West Austin, TX 78735-8598 512-440-2202

Dr. Ira Forman MCC 9390 Research Blvd. Kaleido II Building Austin, TX 78759 forman@mcc.com 512-338-3360

Mr. Ronald Goering The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 goering@im4u.utexas.edu

Prof. Mohamed G. Gouda The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.gouda@r20.UTEXAS.EDU 512-471-9532

Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987



Dr. Paul C. Grabow The University of Texas at Arlington Computer Science Engineering P. O. Box 19015 Arlington, TX 76019-0015 cs_grabow@uta.edu (csnet) 817-273-2348

Mr. Kenneth Gustafson Motorola, Inc. 1501 W. Shure Dr. Arlington Heights, IL 60004 312-590-5281

Dr. Jifeng He Oxford University Computing Laboratory 8-11 Keble Road Oxford Ox1 3QD United Kingdom julie%sevax.prg.oxford.ac.uk@Cs.Ucl.AC.UK

Dr. Wim H. Hesselink The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cmp.hesselink@r20.UTEXAS.EDU 512-471-1901

Prof. C. A. R. Hoare The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.rhoads@R20.UTEXAS.EDU 512-471-9522

Prof. Pei Hsia The University of Texas at Arlington Computer Science Department Arlington, TX 76019-0015 hsia@UTA.EDU 817-273-3610 Mr. William N. Graham The University of Texas at Austin Computation Center Austin, Texas 78712 512-471-3241 x 382

Dr. Scott B. Guthery Schlumberger Well Services 8311 North FM Road 620 Austin, TX 78726 guthery%ascvx5%slb-test.csnet@csnet-relay 512-331-3414

Mr. Carl Hesler Jr. Addison-Wesley Publishing Company Great Hills Corporate Center 9020 II Capitol of Texas Hwy., Suite 430 Austin, Texas 78759 512-346-2152

Mr. Fredrick Hill Sandia National Laboratories Division 5268 P. O. Box 5800 Albuquerque, NM 87185 FREHILL@SANDIA-2 505-846-6530

Dr. Charles Holland Office of Naval Research Code 1133 800 N. Quincy Street Arlington, VA 22217-5000 holland@RADMIS-ONR.ARPA 202-696-4302

Dr. Stephen Hufnagel The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 cs.hufnagel@r20.UTEXAS.EDU 512-835-3589

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Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987



Mr. Ravi Jain The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 rjain@fun.cs.utexas.edu 512-474-4711

Mr. Charanjit Singh Jutla The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 cs.jutla@R20.UTEXAS.EDU 512-471-4760

Mr. Edgar Knapp The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188

Mr. George Koehler The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 512-835-3495

Dr. Leslie Lamport Digital Equipment Corporation SRC 130 Lytton Avenue Palo Alto, CA 94301 lamport@src.DEC.COM 415-853-2170

Ms. Renee Loyless The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 renee@sally 512-471-9510 Prof. Bjarni Jonsson Vanderbilt University Department of Mathematics Nashville, TN 37205 615-322-6661

Mr. Donald A. Kassebaum The University of Texas at Austin Computation Center Austin, TX 78712 cc.kassebaum@r20.UTEXAS.EDU 512-471-3241

Mr. Jeffrey Kodosky National Instruments 12109 Technology Blvd Austin, TX 78727 512-250-9119

Prof. Vipin Kumar The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 kumar@sally.UTEXAS.EDU 512-471-9571

Prof. Christian Lengauer The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.lengauer@r20.UTEXAS.EDU 512-471-9557

Prof. Alain J. Martin California Institute of Technology Computer Science Department Pasadena, CA 91125 alain@vlsi.caltech.EDU 818-356-6549/6842

Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987

Dr. David May **INMOS** Limited 1000 Aztec West Almondsbury Bristol, BS12 43C United Kingdom

Mr. Gary McIntire Ford Aerospace M4B 1150 Gemini Houston, TX 77258 713-483-8110

Mr. James Mealy Nth Graphics 1807 C. West Braker Lane Austin, TX 78758 512-832-1944

Mr. Chuck Middleton **Nth Graphics** 1807 C. West Braker Lane Austin, TX 78758 512-832-1944

Prof. Jayadev Misra The University of Texas at Austin **Department of Computer Sciences** Taylor Hall 2.124 Austin, TX 78712-1188 cs.misra@r20.UTEXAS.EDU 512-471-9550

Prof. Al Mok The University of Texas at Austin **Department of Computer Sciences** Taylor Hall 2.124 Austin, Texas 78612-1188 mok@sally.utexas.edu 512-471-9542

Mr. Bob McBeth Lockheed Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9716

Mr. Nicholas F. McPhee The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mcphee@ratliff.UTEXAS.EDU

Prof. Sigurd Meldal University of Bergen Visiting -Stanford University ERL 456. CSL Stanford, CA 94305 meldal@shasta.stanford.edu 415-723-6027

Prof. Daniel Miranker The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 miranker@sally.utexas.edu 512-471-9541

Dr. David Mizell **USC Information Sciences Institute** 4676 Admiralty Way Marina del Rey, CA 90292-6695 mizell@venera.jsj.edu 213-822-1511

Ms. Ana Maria Mota The University of Texas at Austin **Department of Computer Sciences** Taylor Hall 2.124 Austin, TX 78712-1188 471-9526



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Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987

Mr. Thumrongrut Mungcharoen The University of Texas at Austin Department of Chemical Engineering CPE 3.406 Austin, TX 78712 auss@ngp.UTEXAS.EDU 512-471-5353

Dr. Linda Ness The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 linda@im4u.UTEXAS.EDU 512-471-9718

Prof. Ernst-Rudiger Olderog University of Kiel Department of Computer Science Kiel, West Germany

Mr. Trung Pham Lockheed Engineering & Management Services Co., Inc. 2400 Nasa Road 1, C 1B Houston, TX 77258 713-333-6239

Prof. Amir Pnueli Weizmann Institute Department of Applied Mathematics Rehovot, 76100 ISRAEL amir@wisdom

Dr. Colin Potts MCC 9390 Research Blvd. Kaleido II Building Austin, TX 78759 potts@MCC.COM 512-343-0978



KUNERAN PARADA

REFERENCE

222222

2

Mr. David A. Naumann c/o ISSI 12710 Research Blvd. Austin, TX 78750 cs.naumann@r20.UTEXAS.EDU 512-331-8866

Mr. Jimmy Niemann Electronic Data Systems 7223 Forest Lane Dallas, TX 75230 texsun!edsr!jen (use-nct) 214-661-6052

Mr. Anil Patel Nth Graphics 1807 C. West Braker Ln. Austin, TX 78758 512-832-1944

Prof. Gordon Plotkin University of Edinburgh Computer Science Department Kings Buildings Edinburgh EH9 3J2, SCOTLAND GDP%ECSVAX@UCL-CS

Prof. Sara Porat The University of Rochester Department of Computer Science Ray P. Hylan Building Rochester, NY 14627 porat@rochester.ARPA 716-275-5860

Dr. Nii Quaynor Digital Equipment Corporation MR01-1/L26 200 Forest Street Marlboro, MASS 01752 rhea::decwrl::antare::quaynor 617-467-2239

Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987

Mr. T. T. Ramgopal The University of Texas at Austin Dept. of Electr. & Computer Engineering Austin, TX 78712-1188 ramgopal@im4u.UTEXAS.EDU 512-471-9572

Ms. Suzanne Kain Rhoads The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 cs.rhoads@R20.UTEXAS.EDU 512-471-9526

Dr. Hamilton Richards Jr. The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.ham@R20.UTEXAS.EDU 512-471-9525

Mr. Mark Rosenbaum The BDM Corp. 1300 N. 17th Street Suite 950 Arlington, VA 22207 703-247-3300

1

Mr. Mark R. Scheevel MCC Parallel Processing 3500 West Balcones Center Drive Austin, TX 78759 scheevel@mcc.com 512-338-3411

Prof. Fred B. Schneider Cornell University Computer Science Department Upson Hall Ithaca, NY 14853-7501 fbs@gvax.cs.cornell.EDU 607-255-4052/4117



Mr. J. R. Rao The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ir@ratliff.UTEXAS.EDU

Dr. Michael D. Rice George Mason University Computer Science Department Fairfax, VA 22030 uucp:seismo!gmu90x!mrice 703-323-3884

Mr. Harald Richter Max-Planck-Institut Abteilung Informatik Boltzmannstr.2 8046 Garching, Federal Republic of Germany 089-3299-9244

Mr. Brian Sayrs Lockheed Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9709

Dr. Edward A. Schneider Odyssey Research Associates 1283 Trumansburg Rd. Ithaca, NY 14850-1313 Schneider@DOCKMASTER 607-277-2020

Ms. Sandra L. Schumacher Bell Communications Research 444 Hoes Ln. 1K318 Piscataway, NJ 08854 bellcore!ulloot!sandi 201-699-8195

8

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Dr. Herb Schwetman MCC 3500 West Balcones Center Drive Austin, TX 78759 hds@mcc.com 512-338-3428

Mr. Wade Shaw Lockheed Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9743

Dr. Rivi Sherman USC/Information Sciences Institute 4676 Admiralty Way Marina del Rey, CA 90291 rivi@venera.isi.edu 213-822-1511

Mr. Steven Siegfried Crav Research. Inc. 1345 Northland Drive Mendota Hts., MN 55120 uucp:ihnp4!cary!sos 612-681-5821

Mr. Stephen M. Sobek The University of Texas at Austin **Department of Computer Sciences** Taylor Hall 2.124 Austin, Texas 78712-1188 sobek@sally.UTEXAS.EDU 512-471-9572

Dr. Robert F. Sproull Sutherland, Sproull & Associates 4516 Henry Street Pittsburgh, PA 15213 sproull@vlsi.cs.cmu.edu 412-681-6625



Prof. Charles L. Seitz California Institute of Technology **Computer Science Department** 256-80 Pasadena, CA 91125 chuck@vlsi.caltech.EDU

Dr. Vincent Y. Shen 9390 Research Blvd. MCC Austin, TX 78759 shen@MCC.COM 512-338-3345

Dr. Steve Sherman Lockheed Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9720

Mr. Ambuj K. Singh The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ambujsin@sally.UTEXAS.EDU 512-471-4753

Dr. Robert J. Souza **Digital Equipment Corporation** ML03-5/U26 146 Main Street Maynard, MA 01754 bob%may18@decwrl.com 617-493-5805

Mr. Robert Strader Texas A&M University V-3-E Hensel College Station, TX 77840 BOB%LSR%TAMU@CSNET-RELAY 409-845-0299

Institute of Concurrent Programming Austin, Texas 23 February - 6 March 1987



Mr. Chris Tomlinson MCC Parallel Processing 3500 West Balcones Center Drive Austin, TX 78759 512-338-3765

Mr. James Villarreal Ford Aerospace M4B 1150 Gemini Houston, TX 77258 713-483-8110

Mr. Ralph F. Wachter Office of Naval Research Code 1133 800 N. Quincy Street Arlington, VA 22217-5000 Wachter@RADMIS-ONR

Dr. Winfried Wilcke IBM Research Mailstop 28-242 P. O. Box 218 Yorktown Heights, New York 10598 914-945-2059

Mr. Michael David Wolfe Center for Cybernetic Studies GSB 5.176E The University of Texas at Austin Austin, TX 78712 cs.wolfe@A20.CC.UTEXAS.EDU 512-471-4820



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Mr. Paul A. Suhler c/o Y. Van Olphen, Taylor Hall 2.124 Department of Computer Science The University of Texas at Austin Austin, Texas 78712-1188 suhler@im4u.UTEXAS.EDU

Prof. Jan L. A. van de Snepscheut Rijksuniversiteit Groningen Van Deyssellaan 90 9721 WX Groningen THE NETHERLANDS

Mr. Michael D. Vose The University of Texas at Austin Inst. for Computing Sci. & Computer Appl'ns Main Building 2100 Austin, Texas 78712 512-471-1901

Dr. John Werth The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.1243 Austin, TX 78712-1188 cs.werth@R20.UTEXAS.EDU 512-471-9853

Mr. S. H. Wilson Naval Research Laboratory Code 5590 Washington, D.C. 20375-5000 wilson@nrl-css 202-767-2518

Dr. Pierre Wolper Institute Montefiore, B28 Universite de Liege au Sart-Tilman 4000 LIEGE BELGIUM U502802@BLIULG11.bitnet

University of Texas

Institute of Concurrent Programming



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The University of Texas at Austin **Department of Computer Sciences**

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Austin, Texas

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1-10 April 1987

Mr. John Anderson Cognos Inc. Research Department 3755 Riverside Drive Ottawa, Ont. CANADA K1G 3N3 613-738-1440 x 6115

Mr. Anish K. Arora TheUniversity of Texas at Austin Department of Commputer Sciences Taylor Hall 2.124 Austin, TX 78712 cs.anish@r20.UTEXAS.EDU

Mr. Nader Bagherzadeh The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 nader@ngp

Mr. David A. Brant The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 arl@ngp.UTEXAS.EDU 512-835-3381

Mr. David Burlingame Lockheed Missiles & Space Co. ,Software Technology 2124 East St. Elmo Road 019601 B30-F Austin, TX 78744 512-448-9743

Dr. Luca Cardelli DEC Systems Research Center 130 Lytton Ave Palo Alto CA 94301 Iuca@src.dec.com (415) 853-2110

Prof. Gregory Andrews Department of Computer Science University of Arizona Tucson, Arizona 85721 andrews@arizona.edu 602 621-4239

\$181418_\$4815481648164816481648164816481848584858485848185858

Mr. L. Wayne Ashby The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 ARL@NGP.UTEXAS.EDU 512-835-3497

Mr. Rajive Bagrodia The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 rajive@sally.utexas.edu 512-471-9588

Ms. Joyce R. Brennan Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.brennan@r20.utexas.edu 512-471-9512

Mr. Peter Canning Hewlett-Packard 1501 Page Mill Road Palo Alto, CA 94304 canning@hplabs.hp.com 415-857-7508

Prof. K. Mani Chandy Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 nel@ratliff.UTEXAS.EDU 512-471-9549



Institute of Encapsulation, Modularization, and Reusability



Austin, Texas

1-10 April 1987

Mr. Albert Cheng Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cheng@sally.utexas.edu

Mr. Munir Cochinwala The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 munir@sally 512-471-3879

Mr. Mukesh Dalal Rutgers University Department of Computer Science Hill Center, Busch Campus Piscataway, NJ 08854 dalal@topaz.rutgers.edu 201-932-3999

Dr. Scott Danforth MCC 3500 West Balcones Center Drive Austin, TX 78759 danforth@mcc.com 512-338-3418

Prof. dr. Edsger W. Dijkstra Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 512-471-1901

Mr. S. R. Easwar Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 easwar@im4u.utexas.edu Mr. Paul C. Clements U.S. Naval Research Laboratory Code 5595 Washington, DC 20375 clements@nrl-css 202-767-3477

Mr. William Cook Brown University Department of Computer Science 151 Thayer Street Providence, RI 02906 wrc@cs.brown.edu 401-863-3264

Prof. Nell B. Dale The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ndale@ratliff 512-471-539

Mr. Thomas M. DeBoni The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 deboni@sally.UTEXAS.EDU 512-459-8680

Dr. Jim Donahue Director, Olivetti Research Center 5 Palo Alto Square, Suite 910 3000 El Camino Real Palo Alto, CA 94306 acornrc!jed@DECWRL.DEC.COM (415) 424-1197

Mr. Charles Fischler Naval Surface Weapons Center Code N42 Dahlgren, VA 22448 703-663-7981

Å

5

8

Ŋ

Ŗ

1 m

Institute of Encapsulation, Modularization, and Reusability



Austin, Texas

1-10 April 1987

Prof. Mohamed Gouda The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.gouda@r20.UTEXAS.EDU 512-471-9532

Prof. David Gries Computer Science, Upson Hall Cornell University, Ithaca, New York 14853 gries@gvax.cs.cornell.edu (607) 255-9207

Prof. John Guttag M.I.T. Lab for Computer Science 545 Technology Square-Pub.112 Cambridge, MA 02139 Guttag@larch.lcs.mit.edu (617) 253-6022

Prof. E. C. R. Hehner Computer Science Department 10 King's College Road, SF 2002 University of Toronto Toronto, Ontario M5S 1A4, CANADA hehner%toronto.csnet@CSNET-RELAY.ARPA (416) 978-6026

Walt Hill Hewlett-Packard Laboratories 1501 Page Mill Road Palo Alto, CA 94304 whill@hplabs.hp.com 415-857-7310

Prof. Daniel Hoffman University of Victoria Department of Computer Science Clearihue C205 Victoria, British Columbia V8W 2Y2 CANADA Ms. Erin Green Lockheed Missiles and Space Co. Software Technology Center 2124 East St. Elmo Road Austin, TX 448-9716 512-448-9731

Dr. Jurg Gutknecht Institut für Informatik E.T.H. 8092 Zürich, Switzerland mcvax!ethz!Gutknech@seismo.css.gov 011-41 (1) 256-2343

Dr. Jifeng He Oxford Univ. Computer Lab Programming Research Group 8-11 Keble Road Oxford OX1 3QD, England

Dr. W. H. Hesselink The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cmp.hesselink@r20.UTEXAS.EDU 512-471-1901

Prof. C. A. R. Hoare Department of Computer Sciences Taylor Hall 2.124 University of Texas Austin, Texas 78712 (512) 471-9522

Mr. Robert Holibaugh Carnegie-Mellon University Software Engineering Institute 580 S. Aiken Avenue Pittsburgh, PA 15232 rrh@sei.cmu.edu 412-268-6750

Institute of Encapsulation, Modularization, and Reusability



Austin, Texas

1-10 April 1987

Mr. Chua-Huang Huang The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.huang@r20.UTEXAS.EDU 512-471-9573

Mr. Neil Iscoe The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712 iscoe@im4u.UTEXAS.EDU

Prof. Gregory F. Johnson The University of Maryland Computer Science Department Room 4359 Computer & Space Sciences Bldg. College Park, Md 20742 johnson@mimsy.umd.edu 301-454-1463

Mr. Michael Jones Lockheed Missiles and Space Co. Software Technology Center 2124 East St. Elmo Rd. 0/96-01 B/30E Austin, TX 78744 512-448-9752

Mr. Markus Kaltenbach The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712 cs.kaltenbach@r20.UTEXAS.EDU

Mr. Edgar Knapp The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 knapp@ratliff Dr. Stephen P. Hufnagel The University of Texas at Austin Applied Research Laboratories P. O. Box 8029 Austin, TX 78713-8029 cs.hufnagel@r20.UTEXAS.EDU 512-835-3589

Mr. Ralph James Digital Equipment Corporation 8301-L Arrowridge Blvd. Charlotte, NC 28210 KUDZU::JAMES (digital e-net) 704-529-2092

Prof. Cliff Jones Computer Science Department The University Manchester M13 9PL, England Cliff%unix.computer-science.manchester.ac.uk@Cs. Ucl.AC.UK (61) 273-7121 ext 5018

Dr. Mark B. Josephs IBM T. J. Watson Research Center, 21-217 Route 134 Kitchawan Rd Yorktown Heights, NY 10598 MBJ@IBM.COM 914-945-1449

Ms. Youngmee Kim University of Texas at Dallas 7650 McCallum Blvd. #909 Dallas, TX 75252 kim@utd-cs 214-690-2156

Mr. Jeff Kodosky National Instruments 12109 Technology Blvd. Austin, TX 78727 512-250-9119

Institute of Encapsulation, Modularization, and Reusability



Austin, Texas

1-10 April 1987

Prof. Christian Lengauer The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.lengauer@r20.UTEXAS.EDU 512-471-9557

Ms. Rence Loyless The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 rence@sally.UTEXAS.EDU 512-471-9510

Mr. Robert J. McKenzie The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188

Mr. Nax Mendler Cornell University Department of Computer Science Ithaca, NY 14850

Prof. Jayadev Misra Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.misra@R20.UTEXAS.EDU 512-471-9550

Prof. Al Mok The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mok@sally.UTEXAS.EDU 512-471-9542

Mr. Mike Linda The University of Texas at Austin Applied Research Laboratory P. O. Box 8029 Austin, TX 78758-8029 512-835-3305

Mr. Peter Marks MCC 9390 Research Blvd Austin, TX 78759 marks@mcc.com 512-338-3349

Mr. Nicholas McPhee The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mcphee@ratliff.UTEXAS.EDU

Prof. Naftaly H. Minsky Rutgers University Department of Computer Science Hill Center, Busch Campus Piscataway, NJ 08854 minsky@rutgers.edu 201-932-2085

Dr. John Mitchell Bell Laboratories 600 Mountain Avenue Murray Hill, New Jersey 07974 jcm.mrkos%btl.csnet@CSNET-RELAY.ARPA (201) 582-3828

Ms. Ana Maria Mota The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ana@ratliff.UTEXAS.EDU 512-471-9523

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ß

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University of Texas Year of Programming Institute of Encapsulation, Modularization, and Reusability



Austin, Texas

1-10 April 1987

Prof. Hausi A. Muller University of Victoria Department of Computer Science Clearihue Building Victoria, B.C. Canada V8W 2Y2 hausi%vax-populi.UVic.cdn@ubc.csnet 604-721-7630

Dr. Linda A. Ness The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 linda@im4u 512-471-9718

Prof. Gordon Novak The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ai.novak@r20.UTEXAS.EDU 512-471-9569

Dr. Rex Page Amoco Production Company P. O. Box 3385 4502 East 41st Tulsa, OK 74102 918-660-3935

Dr. James M. Perry Carnegie-Mellon University Software Engineering Institute Pittsburgh, PA 15213 perry@SEI.CMU.EDU 412-268-7744

Mr. Jan Prins Computer Science Department University of Wisconsin/Madison 1210 W. Dayton Street Madison, WI 53706 prins@boursin.wisc.edu (608)-262-0765 Mr. David A. Naumann c/o ISSI 12710 Research Blvd. Austin, TX 78750 cs.naumann@r20.UTEXAS.EDU 512-331-8866

Prof. Dung X. Nguyen University of Houston Department of Computer Science 4800 Calhoun Road Houston, TX 77004 dnguyen@houston.csnet 713-749-4791

Mr. Sean W. O'Malley Software Productivity Consortium (SPC) 1880 Campus Commons Drive, North Reston, VA 22091 703-648-1880

Mr. Hal Perkins Cornell University Computer Science Department Upson Hall Ithaca, NY 14853 hal@gvax. cs.cornell.edu 607-255-4978

Ms. Toniann Pitassi AT&T Bell Laboratories 6200 East Broad Street Room 1B315 Columbus, OH 43206 ihoxb!cblpe!tp 614-860-7057

Mr. T. T. Ramgopal Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 ramgopal@im4u.utexas.edu

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Mr. Norman Ramsey Odyssey Research Associates 1283 Trumansburg Road Ithaca, New York 14850 oravax!norman@cu-arpa.cs.cornell.edu 607-277-2020

Mr. Vempaty N. Rao Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 vnrao@im4u.utexas.edu

Dr. Hamilton Richards The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.ham@r20.UTEXAS.EDU 512-471-9525

Mr. Mark Saaltink I. P. Sharp Assoc., Ltd. Suite 600 265 Carling Avenue Ottawa, Ontario K15 351 CANADA saaltink@dockmaster 613-236-9942

Dr. Steve Sherman Lockheed Missiles & Space Co. Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9720

Mr. Munindar Paul Singh The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.msingh@r20.UTEXAS.EDU Mr. Josyula R. Rao Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 jr@ratliff.utexas.edu

Ms. Suzanne Kain Rhoads The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.rhoads@r20.UTEXAS.EDU 512-471-9526

Mr. Gerhard Rossbach Springer-Verlag 815 De La Vina Street Santa Barbara, CA 93101 rossbach@ucsbcsl.ucsb 805-963-7960

Mr. Brian Sayrs Lockheed Missiles & Space Co. Software Technology Center 2124 East St. Elmo Road Austin, TX 78744 512-448-9709

Mr. Ambuj Singh The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78731-1188 ambujsin@sally 512-471-4753

Dr. W. James Sneeringer 5014 Lakeview Dr. Austin, TX 78732 512-469-7209



A CALL STORE



<u>、</u>

University of Texas Year of Programming Institute of Encapsulation, Modularization, and Reusability

Austin, Texas

Dr. Alan Snyder Hewlett Packard Labs 1501 Page Mill Rd. Palo Alto, California 94304 snyder@hplabs.HP.COM (415) 857-8764

Mr. Ramachandran Sriram Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 sriram@im4u.utexas.edu

Mr. Douglas Surber Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188

Mr. Brian Twichell The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 twitchell@im4u 512-471-9721

Dr. Dennis M. Volpano MCC Software Technology Program 3500 West Balcones Center Dr. Austin, TX 78759 volpano@mcc.arpa 512-338-3782

Mr. Robert Wasilausky Naval Ocean Systems Center Code 423 San Diego, CA 92152-5000 wasilausky@NOSC 619-2252083 1-10 April 1987

Mr. Kiran Somalwar Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 kiran@sally.utexas.edu

Mr. Sakthikumar Subramanian The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 sakthi@sally.utexas.edu

Ms. Mary A. Tompkins Lockheed Missiles & Space Co. Software Technology Center, 0/T2-32 2124 East St. Elmo Road Austin, TX 78744

Mr. Larry Van Sickle The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.vansickle@r20.UTEXAS.EDU 512-471-9589

Mr. Douglas K. Walker The University of Texas at Austin Applied Research Labs P. O. Box 8029 Austin, TX 78758-8029 512-343-2877

Prof. Peter Wegner P.O. Box 1910 Computer Science Dept., 151 Thayer Street Brown University Providence RI 02906 pw@cs.brown.edu 401-863-3311

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Austin, Texas

1-10 April 1987

Dr. John Werth The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.werth@r20.UTEXAS.EDU 512-471-9583

Ms. Carolyn West MCC 3500 West Balcones Center Drive Austin, TX 78759 west@mcc.com 512-338-3708

Dr. John Williams IBM Almaden Research Center 650 Harry Road San Jose, California 95120-6099 williams@ibm.com 408 927-1888

Dr. Pamela Zave AT&T Bell Laboratories 600 Mountain Avenue Room 3D-426 Murray Hill, NJ 07974 ames!ucbcad!ucbvax.berkeley.edu!allegra!pamela 201-582-3080 Dr. Laurie Werth The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.laurie@r20.UTEXAS.EDU 512-471-9535

Mr. Matt Wilding Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 wilding@bun.utexas.edu

Prof. Salih Yurttas Texas A & M University Department of Computer Science College Station, TX 77843 409-845-5475

Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

Dr. Hassan Ait-Kaci MCC 35.00 W. Balcones Center Drive Austin, TX 78759 hassan@mcc.com 512-338-3354

Mr. Patrick Simon Arnold Hewlett-Packard Laboratories Filton Road Stoke Gifford Bristol BS12 6QZ ENGLAND psa%hplb.csnet@RELAY.CS.NET 0272 799910 x 4120

Ms. Laura Jean Babbitt Western Washington University Department of Computer Sciences Bellingham, WA 98225 8348310@wwu.edu

Prof. Alfred E. Borm Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.borm@R20.UTEXAS.EDU 512-471-9543

Mr. Ernie Cohen The University of Texas at Austin Department of Computer Science's Taylor Hall 2.124 Austin, TX 78712-1188 atp.cohen@r20.UTEXAS.EDU 512-471-9709

Prof. Guy Cousineau LIENS École Normale Supérieure 45 rue d'Ulm Paris, 75005-France



Mr. Robert L. Akers Computational Logic, Inc. 1717 West 6th Suite 290 Austin, TX 78703 cmp.akers@r20.UTEXAS.EDU 512-478-7111

Mr. Anish K. Arora The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712 cs.anish@r20.UTEXAS.EDU 512-471-5925

Mr. Eli Blevis Queen's University Department of Computing and Information Science Goodwin Hall Kingston, Ontario, CANADA K7L 3N6 eli%QUCIS.BITNET@wiscvm.wisc.edu

Mr. Shan-Jon Chao University of Alabama at Birmingham Computer and Information Sciences Campbell Hall Birmingham, AL 35294 chao%uab.csnet@RELAY.CS.NET 205-934-2213

Mr. Frank J. Corley University of Chicago Department of Computer Science Chicago, IL 60637 corley@anubis.uchicago.edu 312-702-6032

Mr. Thomas M. Deboni The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Tx 78712-1188 deboni@sally.UTEXAS.EDU

b

Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

Prof. André H. Deutz Cornell University Department of Mathematics White Hall Ithaca, NY 14853 607-255-4640

Mr. Lars W. Ericson Courant Institute 251 Mercer Stret New York, NY 10012 ericson@nyu.arpa 212-460-7496

Dr. William M. Farmer The MITRE Corporation Burlington Road, A040 Bedford, MA 01730 farmer%faron@mitre-bedford.ARPA 617-271-2749

Ms. Amy Felty University of Pennsylvania Department of Computer and Information Science Philadelphia, PA 19104 felty@linc.cis.upenn.edu 215-898-8508

Prof. Jean-Yves Girard Groupe de Logique Mathématique UER de Mathématiques Université Paris 7, 3 place Jussieu Paris, 75005-France

Mr. Joao Repas Goncalves Indiana University Nutts Apts. D101 Bloomington, IN 47401 joao@iucs.cs.indiana.edu Mr. Dominic Duggan Dept. of Computer Science University of Maryland College Park, MD 20742 den@brillig.umd.edu 301-454-1516

Mr. Larry Joe Evans Shell Information Center 1500 Old Spanish Trail Houston, TX 77054 713-795-3011

Dr. Joseph H. Fasel Los Alamos National Laboratory C-10 Mail Stop B296 Los Alamos, NM 87545 jhf@lanl.gov 505-667-7158

Mr. Arthur Flatau Computational Logic, Inc. 1717 West 6th Suite 290 Austin, TX 78703 cmp.flatau@r20.UTEXAS.EDU 512-478-7111

Prof. Robert Glueck Institut für Praktische Informatik TU Vienna Argentinierstr. 8/180 1040 Vienna, Austria mcvax!vipvax!rufus@seismo.CSS.GOV (0222) 58 8 01 / 4463

Prof. John W. Gray University of Illinois Department of Mathematics 1409 W. Green Street Urbana, IL 61801 gray@b.cs.uiuc.edu 217-333-1468





P

University of Texas Year of Programming Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

Prof. Susumu Hayashi Research Institute for Mathematical Sciences, Kyoto University, Sakyo, Kyoto 606, JAPAN suh@SAIL.STANFORD.EDU (075) 721-2111 ext. 7244 or 7220

Dr. Wim H. Hesselink Rijksuniversiteit Groningen Vakgroep Informatica, P. O. Box 800 9700 AV Groningen The NETHERLANDS wim%guvaxin.uucp@seismo.css.gov

Lt. Michael L. Hilton RADC/COES Griffiss AFB, NY 13441-5700 hilton@radc-tops20.arpa 315-330-7794

Mr. James Hook Odyssey Research Associates, Inc. 1283 Trumansburg Road Ithaca, NY 14850-1313 jgh@svax.cs.cornell.edu 607-277-2020

Mr. Chua-huang Huang The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.huang@r20.UTEXAS.EDU 512-471-9573

Dr. Warren A. Hunt Jr. Computational Logic, Inc. 1717 West 6th Suite 290 Austin, TX 78703 cl.hunt@R20.UTEXAS.EDU 512-478-7111 Prof. James Hearne Western Washington University Computer Science Department Bond Hall Bellingham, Washington 98225 hearne%wwu.csnet@CSNET-RELAY.ARPA 206-676-3797

Dr. Walt Hill Hewlett-Packard Laboratories 1501 Page Mill Road Palo Alto, CA 94304-1181 whill%hplabsc@hplabs.HP.COM 415-857-7310

Prof. C. A. R. Hoare Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 512-471-9522

Prof. Frederick A. Hosch University of New Orleans Department of Computer Sciences New Orleans, LA 70148 fahcs%uno.bitnet@wiscvm.wisc.edu 504-286-6594

Dr. Gérard Huet Groupe "FORMEL" INRIA Domaine de Voluceau - Rocquencourt 78153 Le Chesnay CEDEX FRANCE "mcvax!inria!margaux!huet"@seismo.CSS.GOV

Mr. Charanjit Singh Jutla The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.jutla@r20.UTEXAS.EDU 512-471-4760





PERSONA DISCURPTING NUMBER NOT

TAURAN TITUN DEPENDEN DITERI

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Ans LIN

Ms. Deborah L. Knox 2970 Turbot Drive Madison, WI 53713 "ihnp4!isucs!knox@seismo.CSS.GOV"

Ms. Debra S. Lane University of California at Irvine Information and Computer Science Department Irvine, CA 92717 dlane@ics.uci.edu 714-856-4049

Mr. Pat Lincoln MCC 3500 W. Balcones Center Drive Austin, TX 78759 lincoln@mcc.com 512-338-3717

Prof. Donald W. Loveland Duke University Department of Computer Science North Bidg. Durham, NC 27706 dwl@cs.duke.edu 919-684-3048

Prof. David F. Martin Computer Science Dept. Room 3532 Boelter Hall UCLA Los Angeles, CA 90024 dmartin@CS.UCLA.EDU 213-825-2091, -1322

Prof. Carl McCrosky University of Saskatchewan Department of Computational Science Commerce Building Saskatoon, CANADA S7N 0W0 "ihnp4!skorpio!mccrosky@seismo.CSS.GOV" 306-652-3136

Mr. Aaron Larson Honeywell Sytems and Research Center MN65-2100 3660 Technology Drive Minneapolis, MN 55418 612-782-7308

Mr. James Lipton Dept. of Mathematics White Hall Cornell University Ithaca, NY 14853 W4AJ%Cornella.bitnet@wiscvm.wisc.edu (607)-255-4013

Ms. Renee Loyless The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 renee@sally.UTEXAS.EDU 512-471-9510

Mr. Norman C. McCain Jr. The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-7:38 cs.mccain@r20.UTEXAS.EDU

Prof. Albert R. Meyer M.I.T. Lab. for Computer Science NE43-315 Cambridge, MA 02139 meyer@THEORY.LCS.MIT.EDU

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Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

Prof. Prateek Mishra SUNY Department of Computer Science Stony Brook, NY 11794 mishra%sbcs.csnet@relay.cs.net 510-632-8450

Prof. A1 Mok The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mok@sally.UTEXAS.EDU 512-471-9542

Mr. David A. Mundie Incremental Systems Corporation 319 South Craig Street Pittsburgh, PA 15213 412-621-8888

Mr. Neal Nelson Oregon Graduate Center Department of Computer Science and Engineering 19600 NW Von Neumann Beaverton, OR 97006 nealn%ogcvax.csnet@relay.cs.net 503-690-1121 x 7391

Mr. Atsushi Ohori University of Pennsylvania Moore School/D2 Dept. of Computer Science and Information Science Philadelphia, PA 19104 ohori@cis.upenn.edu 215-898-9510

Prof. Keshav Pingali Cornell University Department of Computer Science 4502 Upson Hall Ithaca, NY 14850 pingali@gvax.cs.cornell.edu 607-255-7203



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24442222 2522222 L L444222 2224200

Dr. John Mitchell Bell Laboratories 600 Mountain Avenue Murray Hill, New Jersey 07974 jcm.mrkos%btl.csnet@CSNET-RELAY.ARPA (201) 582-3828

Ms. Ana Maria Mota The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ana@ratliff.UTEXAS.EDU 512-471-9523

Mr. David Naumann ISSI 12710 Research Blvd. Austin, Tx 78750 cs.naumann@r20.UTEXAS.EDU 512-331-8866

Mr. Daniel A. Nesmith Carnegie-Mellon University Department of Mathematics Pittsburgh, PA 15213-3890 nesmith@K.CS.CMU.EDU 412-268-2547

Mr. Dirk Ourston Lockheed Software Technology Center O/96-01, Bldg. 30E 2124 East St. Elmo Road Austin, TX 78744

Dr. Antonio Pizzarello Honeywell-Bull, Z-10 Deer Valley Computer Park Black Canyon Hwy. Phoeniz, AZ 85029 602-862-5281

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University of Texas Year of Programming

Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

Mr. Robert A. Pollack The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.pollack@r20.UTEXAS.EDU

Mr. Josyula R. Rao The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 jr@ratliff.UTEXAS.EDU

Ms. Suzanne Kain Rhoads The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.rhoads@r20.UTEXAS.EDU 512-471-9526

Dr. Eugene J. Rollins Carnegie-Mellon University Computer Science Department 5000 Forbes Avenue Pittsburgh, PA 15213 rollins@theory.cs.cmu.edu 412-268-5684

Mr. Brian Sayrs Lockheed Software Technology Center O/96-01, Bldg. 30E 2124 East St. Elmo Road Austin, TX 78744 cs.sayrs@R20.UTEXAS.EDU 512-448-9709

Prof. Philip J. Scott University of Pennsylvania Department of Mathematics Philadelphia, PA 19104 (On sabbatical from Univ.of Ottawa, Dept. of Mathematics, Ottawa, Ont., Canada) Phil@cis.upenn.edu 215-898-5969



Dr. Garrel Pottinger Odyssey Research Associates, Inc. 1283 Trumansburg Road Ithaca, NY 14850-1313 oravax!garrel@cu-arpa.cs.cornell.edu 607-277-2020

Prof. John Reynolds Computer Science Department Carnegie-Mellon University Schenley Park Pittsburgh, PA 15213 John.Reynolds@A.CS.CMU.EDU (412) 268-3057

Dr. Hamilton RichardsJr. The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.ham@r20.UTEXAS.EDU 512-471-9525

Mr. Shyam Sundar Sarkar The University of Texas at Dallas Department of Computer Science Richardson, TX 75080 shyam@utd-cs.csnet 214-690-2195

Prof. André Scedrov University of Pennsylvania Department of Mathematics 33rd & Walnut Streets Philadelphia, PA 19104 Andre@cis.upenn.edu

Mr. Stuart M. Shieber SRI International EJ 231 333 Ravenswood Avenue Menlo Park, CA 94025 shieber@stripe.sri.com 415-859-4593

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Institute on Logical Foundations of Functional Programming Austin, Texas 8-12 June 1987

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Dr. Michael K. Smith Computational Logic 1717 West 6th Suite 290 Austin, TX 78703 cmp.mksmith@r20.UTEXAS.EDU 512-478-7111

Mr. Sakthi Subramanian The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 sakthi@sally.UTEXAS.EDU

Prof. Carolyn Talcott Stanford University Department of Computer Science Stanford, CA 94305 clt@sail.stanford.edu 415-723-0936

Dr. Dennis M. Volpano MCC Software Technology Program 3500 West Balcones Center Dr. Austin, TX 78759 volpano@mcc.com 512-338-3782

Prof. John Werth The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.werth@r20.UTEXAS.EDU 512-471-9583

Dr. Kent Wittenburg MCC 3500 West Balcones Center Drive Austin, Texas 78759 kent@mcc.com 512-338-3626



Prof. Donald F. Stanat University of North Carolina Department of Computer Science New West Hall Chapel Hill, NC 27514 stanat@cs.unc.edu 919-962-6511

Mr. Douglas N. Surber Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.surber@R20.UTEXAS.EDU

Prof. Yung Hyang Tsin University of Windsor School of Computer Science Windsor, Ontario CANADA N9B 3P4 253-4232 x 3001

Mr. Ralph F. Wachter Office of Naval Research Code 1133 800 N. Quincy Street Arlington, VA 22217-5000 rfw@aplvax.arpa

Mr. Duminda Wijesekera Cornell University Department of Mathematics White Hall Ithaca, NY 14853 W4AJ%Cornella.bitnet@wiscvm.wisc.edu 607-2722107

Prof. Charles T. Wright lowa State University Dept. of Electrical Engineering and Computer Engineering Ames, Iowa 50011 wright%iowa-state.csnet 515-294-3571 1222250

KARZANAN

MARSEN.

100 CO 100

K

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Institute on

Logical Foundations of Functional Programming 8-12 June 1987



Mr. Jonathan Young Yale University Department of Computer Science 101/2 Hillhouse Avenue, Box 2158 New Haven, CT 06511 young-jonathan@yale.arpa 203-432-1286

Austin, Texas

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University of Texas Year of Programming Institute on Hardware Specification and Verification Austin, Texas 8-17 July 198

Dr. Martin Abadi Digital Equipment Corporation Systems Research Center 130 Lytton Ave. Palo Alto, CA 94301 ma@SRC.DEC.COM 415-853-2196

Mr. Andrew Bailey Plessey Research Roke Manor Ltd. Roke Manor, Romsey, Hants SO51 0ZN ENGLAND amb%idec.stc.co.uk@CS.UCL.AC.UK (44) 794 515222 x2219

Dr. Geoffrey Brown School of Electrical and Computer Engineering Phillips Hall Cornell University Ithaca, NY 14853-5401

Dr. Tam-AnhChu M.I.T. Lab. for Computer Science 545 Technology Square #253 Cambridge, Mass. 02139 tchu@XX.LCS.MIT.EDU (617) 253-6078

Dr. Charles B. Cross Code 5593 Naval Research Laboratory Washington, D.C. 20375-5000 cross@nrl-css.arpa (202) 767-3490

Dr. Michael J. C. Gordon University of Cambridge Computer Laboratory Corn Exchange Street Cambridge CB2 3QG ENGLAND mjcg%computer-lab.cambridge.ac.uk@Cs.Ucl.AC.UK 8-17 July 1987

Mr. Parosh Abdulla Department of Computer Science Uppsala University Lagerhyddvagen 2; hus 1 751 20 Uppsala, SWEDEN "enea!kuling!parosh@seismo.CSS.GOV" 18 - 18 31 63

Mr. Alex Bronstein Margaret Jacks Hall Computer Science Dept. Stanford University Stanford, California 94305 bronstein@sushi.stanford.edu 415-723-4338

Dr. Shiu-KaiChin 111 Link Hall Dept. of Electrical & Computer Engineering, Syracuse University Svracuse, New York 13244-1240 Chin%syr.csnet@RELAY.CS.NET 315-423-3776

Mr. Jeffrey V. Cook The Aerospace Corporation 2350 East El Segundo Blvd El Segundo, California 90245-4691 jvc@aero2.aero.org (213) 336-5555

M. Dominique Jean Gascuel Laboratoire d'Informatique Ecole Normale Supérieure 45, rue d'Ulm 75005 PARIS, FRANCE gascuel%FRULM63.bitnet@wiscvm.wisc.edu 33 1 43291225-3766

Dr. John Herbert University of Cambridge Computer Laboratory Corn Exchange Street Cambridge CB2 3QG ENGLAND jmjh%computer-lab.cambridge.ac.uk@Cs.Ucl.AC.UK



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Hardware Specification and Verification Austin, Texas 8-17 July 1987

Institute on

Prof. C. A. R. Hoare Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 512-471-9522

Dr. MattKaufmann Inst. for Computing Science & Computer Apps. 2100 Main Building The University of Texas at Austin Austin, Texas 78712 cmp.kaufmann@R20.UTEXAS.EDU 512-471-1901

Mr. Tony Larsson Linkoping University Department of Computer and Information Science S-581 83 Linkoping SWEDEN "enea!liuida.UUCP!tla@seismo.CSS.GOV" 013-281832

Dr. BethLevy The Aerospace Corporation 2350 East El Segundo Blvd. El Segundo, California 90245-4691 blevy@aero2.aero.org 213-336-5914

Ms. Renee Loyless Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 renee@sally.UTEXAS.EDU 512-471-9510

Prof. David F. Martin **Computer Science Department** Room 3532 Boelter Hall University of California at Los Angeles Los Angeles, California 90024 dmartin@cs.ucla.edu 213-825-2091, ...-1322



Dr. Warren A. Hunt Ir. Computational Logic, Inc. 1717 West Sixth Street, Suite 290 Austin, Texas 78703-4776 cl.hunt@R20.UTEXAS.EDU 512-322-9951

Mr. Willem A. Koulman Lincoln Laboratory / MIT A-026 244 Wood Street Lexington, Mass. 02173 617-863-5500 x4687

Mr. Tim Leonard BXB1-1/E11 **Digital Equipment Corporation** 85 Swanson Road Boxboro, Mass. 01719-1326 leonard%eagle1.DEC@decwrl.DEC.COM 617-264-5363

Mr. Paul Loewenstein Fairchild Semiconductor Corporation MS 30-9896 4001 Miranda Avenue Palo Alto, California 94304 "spar!parfs6!paul@decwrl.DEC.COM" 415-858-4851

Prof. Glenn MacEwen **Computing and Information Science** Good win Hall Queen's University Kingston, Ontario K7L 3N6 CANADA macewen%qucis.bitnet@wiscvm.wisc.edu 613-545-6052

Mr. Thomas F. Melham University of Cambridge Computer Laboratory Corn Exchange Street Cambridge CB2 3QG ENGLAND tfm%computer-lab.cambridge.ac.uk@Cs.Ucl.AC.UK (44) 223 334618

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TEXAUSTIN

University of Texas Year of Programming

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'n

Institute on Hardware Specification and Verification Austin, Texas 8-17 July 1987

Dr. J Strother Moore Computational Logic, Inc. 1717 West Sixth Street, Suite 290 Austin, Texas 78703-4776 cl.moore@R20.UTEXAS.EDU 512-322-9951

Mr. K. Muthukumar Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 muthu@ratliff.utexas.edu 512-471-4760

M. Nicolas Paris Laboratoire d'Informatique **Ecole Normale Supérieure** 45. rue d'Ulm 75005 PARIS, FRANCE paris%FRULM63.bitnet@wiscvm.wisc.edu 33 1 43291225-3766

Dr. NiiQuaynor High Performance Systems, MRO-1/L26 **Digital Equipment Corporation** 200 Forest Street Mariboro, Mass. 01752 quaynor%inanna.DEC@decwrl.DEC.COM 617-467-2239

Ms. Suzanne KainRhoads **Department of Computer Sciences** Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.rhoads@R20.UTEXAS.EDU 512-471-9526

Ms. JaneSinclair Programming Research Group Oxford University 11 Keble Road Oxford OX1 3OD ENGLAND (44) 865 273847

Ms. Ana Maria Mota Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 ana@ratliff.UTEXAS.EDU 512-471-9523

Mr. Stephen GOwen Hewlett Packard Research Labs Filton Foad Stoke Gifford Bristol. ENGLAND sgo%hplb.csnet@RELAY.CS.NET (44) 272 799910

Dr. CarlPixley MCC 3500 West Balcones Center Drive Austin, Texas 78759 pixley@MCC.COM

Dr. Joy Reed Programming Research Group Oxford University 11 Keble Road Oxford OX1 3QD ENGLAND (44) 865 273847

Dr. HamiltonRichardsJr **Department of Computer Sciences** Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 cs.ham@R20.UTEXAS.EDU 512-471-9525

Mr. SakthiSubramanian Department of Computer Sciences Taylor Hall 2.124 The University of Texas at Austin Austin, Texas 78712-1188 sakthi@sally.utexas.edu 512-471-7316





0000

Institute on Hardware Specification and Verification Austin, Texas 8-17 July 1987

Mr. Simon Turner Plessey Research Roke Manor Ltd. Roke Manor, Romsey, Hants SO51 0ZN ENGLAND (44) 794 515222

Mr. Malcolm StuartWalker British Aerospace (Box F3C) Downshire Way, Bracknell, Berkshire RG12 1QL ENGLAND (44) 344 483222 Mr. Tom Verhoeff Eindhoven University of Technology Dep t. of Mathematics and Computing Science Main Building HG 7.22, Den Dolech 2 5612 AZ EINDHOVEN, THE NETHERLANDS "mcvax!eutrc3!wstomv@seismo.CSS.GOV" +31 40 47 41 25 or +31 40 47 39 02

Prof. MaxWarshauer Department of Mathematics Southwest Texas State University San Marcos, Texas 78666 mlw@MCC.COM 512-245-2551

π

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Dr. Samson Abramsky Department of Computer Science Imperial College Queens Gate London SW7 2AZ ENGLAND sa%doc.ic.ac.uk@NSS.CS.UCL.AC.UK (+44) 1 589 5111

Mr. Guy Argo **Glasgow University** Computer Science Department 14 Lilybank Gardens Glasgow G12 8QQ SCOTLAND gargo@cs.glasgow.ac.uk (+44) 41 339 8855 x 4256

Mr. John Backus IBM 91 Saint Germain Avenue San Francisco, CA 94114 backus@ibm.com 415-545-2060

Mr. Michael Barnett The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mbarnett@sally.UTEXAS.EDU 512-338-3275

Mr. Claude R. Baudoin Fairchild Semiconductor Corp. 4001 Miranda Avenue, MS 30-9896 Palo Alto, CA 94304-1270 baudoin%parfs2%spar@decwrl.dec.com 415-858-4783

Mr. Hemant K. Bhargava Wharton School University of Pennsylvania 3620 Locust Walk #1300 Philadelphia, PA 19104-5936 bhargava40@wharton.upenn.edu 215-898-7211

Mr. Robert L. Akers Computational Logic, Inc. 1717 West 6th Street Suite 290 Austin, TX 78703 cli!akers@sally.utexas.edu 512-322-9951

Ms. Laura Jean Babbitt Western Washington University 3640 Agate Bay Lane Bellingham, WA 98226 8348310%wwu.edu@RELAY.CS.NET 206-676-6005

Dr. Paul A. Bailes University of Queensland Department of Computer Science St. Lucia Queensland, 4067, AUSTRALIA paul%uqcspe.oz@seismo.css.gov

Prof. Don Batory The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 dsb@orbit.CS.UTEXAS.EDU 512-471-9711

Mr. William R. Bevier The University of Texas at Austin **ICSCA** Main Building 2100 Austin, TX 78712 cli!bevier@sally.utexas.edu 512-471-1901

Dr. Richard S. Bird **Oxford University** Programming Research Group 8-11 Keble Road Oxford OX1 3QD ENGLAND bird%prgv.ox.ac.uk@NSS.CS.UCL.AC.UK (+44) 865 273840

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Mr. David A. Brant The University of Texas at Austin Applied Research Laboratories 10,000 Burnet Road Austin, TX 78758 512-835-3381

Prof. Homer Carlisle Texas A&M University Computer Science Department College Station, TX 77843-3112 carlisle@TAMLSR 409-845-5481

Mr. In Jun Choi The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 injun@mothra.cs.utexas.edu 512-837-4467

Prof. James A. Davis Iowa State University Department of Electrical and Computer Engineering 253 Coover Hall Ames, Iowa 50011 davis@iowa-state 515-294-8307

prof. dr. Edsger W. Dijkstra Department of Computer Sciences The University of Texas at Austin Austin, Texas 78712-1188 512-471-1901

Mr. Dominic Duggan University of Maryland Department of Computer Science College Park, MD 20742 den@brillig.umd.edu (301) 454-2002/1516

Mr. Tom Blenko Unisys Corp. Paoli Research Center Central Ave. and Rt. 252 Paoli, PA 19301 blenko@bigburd.prc.unisys.com 215-648-7316

Dr. Peter Buneman Department of Computer and Information Science University of Pennsylvania 200 South 33rd Street Philadelphia, PA 19104-6389 peter@CIS.UPENN.EDU

Dr. Robert C. Cartwright Department of Computer Science Rice University Houston, Texas77005 cork@rice.EDU (415) 494-4497

Mr. Tony Cox Amoco Production Company Research Center 4502 East 41st Street Tulsa, OK 74102 uucp;-!seismo!okstate!apctrc!ztlc02 918-660-3769

Mr. Thomas M. DeBoni The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 deboni@sally.UTEXAS.EDU 512-471-7316

Mr. Glenn P. Downing MCC 9390 Research Blvd. Austin, TX 78759 downing@mcc.com 512-338-3327

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Dr. Joseph H. Fasel Los Alamos National Laboratory C-10, Mail Stop B296 Los Alamos, NM 87545 jhf@lanl.gov 505-667-7158

Dr. Alex Feldman Odyssey Research Associates 1283 Trumansburg Road Ithaca, NY 14850-1313 Oravax!alex@cu-ARPA.CS.CORNELL.EDU 607-277-2020

Prof. Arthur C. Fleck The University of Iowa Department of Computer Science 101 MacLean Hall Iowa City, IA 52242 fleck@cs.uiowa.edu 319-335-0713

Mr. Robert Glueck Institut fuer Praktische Informatik TU Vienna Argentinierstr. 8/180 A-1040 Vienna, AUSTRIA rufus@vipvax.UUCP (0222) 58 8 01/4463

Mr. David Goldschlag The University of Texas at Austin ICSCA Main Building 2100 Austin, TX 78712 cli!dmg@sally.utexas.edu 512-471-1901

Mr. Stephen Hill Computer Laboratory University of Kent Canterbury, Kent CT2 7NF ENGLAND sah%ukc.ac.uk@NSS.CS.UCL.AC.UK Ms. Patricia K. Fasel Los Alamos National Laboratory C-10, Mail Stop B296 Los Alamos, NM 87545 pkf@lanl.gov 505-667-3533

Mr. Arthur Flatau Computational Logic, Inc. 1717 W. 6th, Suite #290 Austin, TX 78703-4776 cli!flatau@sally.utexas.edu 512-322-9951

Dr. Northrup Fowler III Rome Air Development Center Griffiss AFB, NY 13441-5700 Fowler@RADC-MULTICS.ARPA (315) 330-7794

Dr. Joseph A. Goguen SRI International EL 372 333 Ravenswood Avenue Menlo Park, CA 94025 goguen@csl.sri.com 415-859-5454

Prof. Hector J. Hernandez Texas A&M University Department of Computer Science College Station, TX 77843-3112 hector@TAMLSR 409-845-4259

Lt. Michael L Hilton RADC/COES Griffiss AFB, NY 13441-5700 HILTON@RADC-TOPS20.ARPA (315) 330-7794

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Prof. Chi Fai Ho Cal. State University Department of Mathematics and Computer Science Hayward, CA 94542 bbdr0bf@calstate.bitnet (or ho@csuh.uucp) 415-881-3997

Ms. Wanda Holmes Texas Air Control Board 6330 Hwy. 290 East Austin, TX 78723 512-451-5711

Mr. Gareth Howells University of Kent Computer Laboratory Canterbury, Kent CT2 7NF ENGLAND wgjh%ukc.ac.uk@NSS.CS.UCL.AC.UK +44 227 764000 x 3824

Dr. Warren Hunt Jr. Computational Logic, Inc. 1717 West 6th Street, Suite 290 Austin, TX 78703-4776 cli!hunt@sally.utexas.edu 512-322-9951

Prof. Roy T. Jacob Jr. North Texas State University Department of Computer Sciences Denton, TX 76203 uucp: (convex,infoswx)!ntvax!jacob 817-565-2372

Dr. Roy Jenevein The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712 jenevein@sally.UTEXAS.EDU 512-835-3570 Prof. C. A. R. Hoare Oxford University Programming Research Group 8-11 Keble Road Oxford OX1 3QD ENGLAND (+44) 865 273840

Ir. Rob Hoogerwoord Dep t. of Mathematics and Computing Science Eindhoven University of Technology Den Dolech 2 5600 AA Eindhoven The Netherlands WSINROBH%HEITHE5.BITNET@wiscvm.wisc.edu (+31)-40-474564

Prof. R J M Hughes Department of Computer Science Glasgow University Glasgow G12 8QQ SCOTLAND rjmh%cs.glasgow.ac.uk@CS.UCL.AC.UK (+44) 41 339 8855

Mr. Ramachandran Iyer Washington State University Computer Science Department #1039 Pullman, WA 99164-1210 60874863%WSUVM1.BITNET@wiscvm.wisc.edu 509-335-6636

Mr. Ravi Jain The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 rjain@fun.utexas.edu

Mr. Stefan Kaes Technische Hochschule Darmstadt Fachbereich Informatik Magdalenenstrabe 11c D-6100 Darmstadt, West Germany EARN/BITNET Snelting@DDADVS1 06151/163414

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Mr. Thomas A. Kiesler University of Missouri-Kansas City Computer Science Department 4747 Troost Street Kansas City, MO 64110 816-276-1193

Prof. Deborah L. Knox University of Wisconsin-Milwaukee Department of Electrical Engr. & Computer Science P. O. Box 784 Milwaukee, WI 53201 knox@csd4.milw.wisc.edu 414-963-4677

Prof. Christian Lengauer University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.lengauer@r20.UTEXAS.EDU 512-471-9557

Ms. Renee Loyless The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, Texas 78712-1188 renee@sally.UTEXAS.EDU 512-471-9510

Prof. Robert S. Maier University of Arizona Department of Mathematics Tucson, AZ 85721 "amethyst!rsm@arizona.edu" 602-621-2617

Dr. Randy Michelsen Los Alamos National Laboratory MS B 296 Los Alamos, NM 87545 rem@lanl.gov 505-667-0789 Mr. Edgar Knapp University of Texas at Austin Department of Computer Science Taylor Hall 2.124 Austin, TX 78712-1188 knapp@ratliff.UTEXAS.EDU

Mr. Jeffrey Kodosky National Instruments 12109 Technology Blvd. Austin, TX 78727 512-250-9119

Mr. P. D. Lincoln MCC 3500 West Balcones Cntr. Drive Austin, TX 78759 lincoln@mcc.com 512-338-3717

Dr. David B. MacQueen AT&T Bell Laboratories Room 2C-322 600 Mountain Avenue Murray Hill, NJ 07974 dbm%btl.csnet@relay.cs.net 201-582-7691

Mr. Norman McCain The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.mccain@R20.UTEXAS.EDU

Prof. Jayadev Misra University of Texas at Austin Department of Computer Science Taylor Hall 2.124 Austin, TX 78712-1188 cs.misra@r20.UTEXAS.EDU 512-471-9550

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Prof. Al Mok University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 mok@sally 512-471-9542

Mr. K. Muthukumar The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 muthu@ratliff.UTEXAS.EDU 512-471-4760

Prof. Edward W. Page Clemson University Department of Computer Science Nursing Building Clemson, SC 29634-1906 epage@tecnet-clemson.ARPA 803-656-2398

Prof. Keshav K. Pingali Cornell University Department of Computer Science 4502 Upson Hall Ithaca, NY 14853

pingali@gvax.cs.cornell.edu 607 255 7203

Dr. Alfred J. Reich Lockheed Austin Division 0/T2-32 B/30E 6800 Burleson Rd. Austin, TX 78744 512-448-5178

Ms. Suzanne Kain Rhoads The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.rhoads@r20.UTEXAS.EDU 512-471-9526 Ms. Ana Maria Mota The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ana@ratliff.UTEXAS.EDU 512-471-9523

Mr. David Naumann The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.naumann@R20.UTEXAS.EDU 512-331-8866

Mr. Benjamin Pierce Computer Science Dept. Carnegie Mellon Univ. Pittsburgh, PA 15213 bcp@gandalf.cs.cmu.edu (412) 268-3046

Mr. Michael G. Redding Naval Surface Weapons Center Code N42 Dahlgren, VA 22448-5000 703-663-7951

Dr. Gyorgy E. Revesz IBM T. J. Watson Research Center P. O. Box 704 Yorktown Heights, NY 10598 revesz@IBM.COM 914-789-7871

Dr. Hamilton Richards Jr. The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.ham@r20.UTE> AS.EDU 512-471-9525

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Mr. Shyam Sundar Sarkar Texas Instruments Inc., Database Systems Branch Computer Science Center P. O. Box 655474, M/S 238 Dallas, TX 75266 sarkar@ti-csl.csnet 214-995-0308

Ms. Rea Simpson Lawrence Livermore Lab L-306, Bldg. 218 Rm 277 7000 East Avenue Livermore, CA 94550 simpson@lll-crg.arpa 415-423-0910

Ms. Lauren L. Smith Department of Defense 9800 Savage Road Fort George Meade, MD 20755-6000 Ils@mimsy.umd.edu 301-859-6695

Prof. Donald F. Stanat University of North Carolina Department of Computer Sciences Sitterson Hall Chapel Hill, NC 27514 stanat@unc 919-962-1937

Dr. Byron Tate Schlumberger Well Services Austin Systems Center 8311 North FM 620 Road Austin, TX 78726 tate@asc.SINET 512-331-3264

Mr. Steven Tighe MCC 3500 West Balcones Center Dr. Austin, TX 78759 tighe@mcc.com.arpa 512-338-3410 Mr. Patric Savage Shell Development Co. 3737 Bellaire Blvd. Houston, TX 77001-0481 713-663-2384

Mr. Ambuj K. Singh The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 ambujsin@sally.UTEXAS.EDU 512-471-4753

Dr. Michael K. Smith Computational Logic, Inc. 1717 West 6th Street Suite 290 Austin, TX 78703-4776 cli!mksmith@sally.utexas.edu 512-322-9951

Mr. Douglas Surber The University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.surber@R20.UTEXAS.EDU

Dr. Simon J. Thompson Computing Laboratory University of Kent Canterbury Kent CT2 7NF ENGLAND sjt%ukc.ac.uk@NSS.CS.UCL.AC.UK (+44) 227 764000 ext 3820

Prof. David A. Turner Computing Laboratory University of Kent Canterbury Kent CT2 7NF ENGLAND dat%ukc.ac.uk@NSS.CS.UCL.AC.UK (+44) 227 764000 ext 627

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Prof. Jan Tijmen Udding Groningen University Department of Mathematics and Computer Science Nettelbosje 2 9747 AE Groningen, The Netherlands jtu@guvaxin.UUCP 31-50-633943

Mr. Michael D. Vose University of Texas at Austin ICSCA 2100 Main Building Austin, TX 78712 cli!vose@sally.utexas.edu 512-471-1901

Prof. John Werth University of Texas at Austin Department of Computer Sciences Taylor Hall 2.124 Austin, TX 78712-1188 cs.werth@r20.UTEXAS.EDU 512-471-9583

Prof. Charles Wright Iowa State University Electrical Engr. & Computer Engineering Ames, Iowa 50011 wright@iowa-state 515-294-3571

Mr. Ken Zink MCC 3500 West Balcones Center Drive Austin, TX 78759 zink@MCC.COM Dr. Dennis M. Volpano MCC Software Technology Program 3500 West Balcones Center Dr. Austin, TX 78759 volpano@mcc.com 512-338-3782

Prof. Peter Wegner Brown University Department of Computer Science 151 Thayer Street Providence, R.I. 02912 pw@cs.brown.edu 401-863-3311

Mr. Edward L. Wimmers IBM Almaden Research Department K53/803 650 Harry Road San Jose, CA 95120-6099 wimmers@ibm.com 408-927-1882

Mr. Richard M. Wright Lockheed Missiles and Space Co. 0/96-01 B/30E 2100 East St. Elmo Road Austin, TX 78744 512-448-9741

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