

## **Nick McKeown**

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### **Employment**

**Stanford University, Associate Professor of Electrical Engineering and Computer Science (2002- )**

**Stanford University, Assistant Professor of Electrical Engineering and Computer Science (1995- 2002)**

Researching techniques for high speed networks, including high speed Internet routing and architectures for high speed switches. Currently working on the analysis and design of cell scheduling algorithms, memory architectures, switch and router architectures, traffic analysis, lookup and classification.

**Nemo Systems Inc, CEO and Co-Founder (2003-)**

Co-founded Nemo Systems in 2003, to build semiconductors for networking systems.

**Abrizio Inc, now part of PMC-Sierra, (1998-2001)**

Co-founded Abrizio Inc in August 1997; took two year leave from Stanford to work as CTO of Abrizio from June 1998 to August 2000. Abrizio was established as a fabless semiconductor company building high-performance switching silicon for IP routers, ATM switches and TDM cross-connects that form the core of the Internet. Abrizio was acquired by PMC-Sierra (British Columbia, Canada) in August of 1999.

**Hewlett-Packard Labs, Bristol, UK (1986-89)**

Low Cost Alternatives to FDDI, optical collision detection schemes, ATM switches, optical amplifiers and high-performance computer I/O, encryption algorithms.

### **Consultancy**

Served as consultant to: Cisco Systems (1994-1995) as architect of next generation, high-performance router (the GSR 12000); and many other networking and semiconductor companies.

### **Academic Background**

<i>Place of Study</i>	<i>Degree</i>	<i>Dates</i>
University of California, Berkeley	PhD	May 1995
University of California, Berkeley	MS	May 1992
University of Leeds, England	BEng	May 1986

**Phd Thesis:** Scheduling Cells in an Input-Queued Cell Switch.

**Adviser:** Professor Jean Walrand, University of California, Berkeley.

## **Awards**

1. Ada Lovelace Medal, British Computer Society, 2005.
2. Fellow of the Royal Academy of Engineering (UK).
3. STMicroelectronics Faculty Development Scholar, 2003-2006.
4. IEEE Communications Society Stephen O. Rice Prize Paper Award in the Field of Communications Theory, 2000.
5. Charles Lee Powell Fellowship, 2000-2001.
6. Alfred P. Sloan Fellow, 1997-1999.
7. Robert N. Noyce Faculty Scholar, Stanford 1997-1999.
8. Undergraduate Scholarship from GEC-Marconi, 1981-1985.
9. IEE Undergraduate Scholarship, 1985-1986.
10. University Award for outstanding achievement, Leeds 1986.
11. University Award for instrumentation and control, Leeds 1986.
12. British National Engineering Scholarship, 1982-1986.

## **Professional Activities**

1. Editor for Switching and Routing, IEEE Transactions on Communication, 1997-2000.
2. Editor for IEEE Transactions on Networking, 2000-2003.
3. Guest Editor for IEEE Communications Magazine, December 2000.
4. Guest Editor for IEEE Networks Magazine, January 2001.
5. Guest Editor for IEEE Micro Magazine, January/February 1999.
6. Guest Editor for IEEE JSAC Special Issue, June 1999.
7. Program Committee Member, ACM Sigcomm, 1998-2002.
8. Member of Technical Advisory Committee for ACM Sigcomm, 1999-present.
9. Chair of Technical Advisory Committee for ACM Sigcomm, 2003-present.
10. Program Committee Co-chair, Hot Nets III, 2003.
11. Program Committee Co-chair, Hot Interconnect VI, 1998.
12. Program Committee member, IEEE Infocom 1998.
13. Local Organizer Co-chair, Hot Interconnects V, 1997.
14. Program Committee member, Hot Interconnects V, 1997.
15. Conference Chairman of Gignet '97, London, June 1997.
16. Program Committee member, IEEE LAN/MAN Workshop, 1996.
17. Organized Workshop on High Speed Switching & Routing, Stanford, September 1996.
18. Senior Member, IEEE.

## Publications

### Journal Publications

1. Isaac Keslassy, Rui Zhang-Shen, Nick McKeown, "**Maximum Size Matching is Unstable for Any Packet Switch**" *IEEE Communications Letters*, Vol. 7, No. 10, pp. 496-498, Oct. 2003.
2. Sundar Iyer and Nick McKeown, "**Using Constraint Sets to Achieve Delay Bounds in CIOQ Switches**" *IEEE Communication Letters*, pp. 275-277, 2003.
3. Pablo Molinero-Fernández, Nick McKeown, "**The performance of circuit switching in the Internet**" *OSA Journal of Optical Networking*, Vol. 2, No. 4, March 2003
4. Sundar Iyer, Nick McKeown, "**Analysis of the Parallel Packet Switch Architecture**", *IEEE/ACM Transaction on Networking*, pp. 314-324, April 2003.
5. Pablo Molinero-Fernandez, Nick McKeown, "**The Performance of Circuit Switching in the Internet**", *OSA Journal of Optical Networking*, Vol. 2, No. 4, pp. 83-96, March 2003.
6. Sundar Iyer, Supratik Bhattacharya, Nina Taft, Christophe Diot, "**An Approach to Alleviate Link Overload as Observed on an IP Backbone**". *To appear in proceeding of IEEE INFOCOM*, San Francisco, CA, March 2003.
7. Pablo Molinero-Fernandez, Nick McKeown, Hui Zhang, "**Is IP going to take over the world (of communications)?**", to appear in *ACM Computer Communications Review*, January 2003.
8. Sundar Iyer, Nick McKeown, "**Maximum Size Matchings and Input Queued Switches**", *Proceedings of the 40<sup>th</sup> Annual Allerton Conference on Communication, Control, and Computing*, Monticello. IL, Oct. 2002.
9. Sundar Iyer, Rui Zhang, Nick McKeown, "**Routers with a Single Stage of Buffering**" *Computer Communications Review*, Vol. 32, No. 4, Oct. 2002.
10. Devavrat Shah, Sundar Iyer, Balaji Prabhakar, and Nick McKeown; "**Analysis of a Statistics Counter Architecture**", *IEEE Micro Magazine*, Vol. 22, No. 1, pp. 76-81, January-February 2002.
11. Pablo Molinero-Fernandez and Nick McKeown; "**TCP Switching: Exposing Circuits to IP**", *IEEE Micro Magazine*, Vol. 22, No. 1, pp. 82-89, January-February 2002.
12. Sundar Iyer and Nick McKeown; "**On the Speedup Required for a Multicast Parallel Packet Switch**", *IEEE Communications Letters*, Vol. 5, No. 6, pp. 269-271, June, 2001.
13. Pankaj Gupta and Nick McKeown; "**Algorithms for Packet Classification**", *IEEE Network*, Vol. 15, No. 2, pp. 24-32, March-April 2001.
14. Pankaj Gupta and Nick McKeown; "**Packet Classification using Hierarchical Intelligent Cuttings**", *IEEE Micro Magazine*, Vol. 20, No. 1, pp 34-41, January-February 2000.
15. Balaji Prabhakar and Nick McKeown; "**On the Speedup Required for Combined Input and Output Queued Switching**", *Automatica*, Vol. 35, No. 12, pp. 1909-29, December, 1999.

16. Nick McKeown, Adisak Mekkittikul, Venkat Anantharam and Jean Walrand; **“Achieving 100% Throughput in an Input-Queued Switch (extended version)”**, *IEEE Transactions on Communications*, Vol. 47, No. 8, pp. 1260-1267, August, 1999.
17. Shang-tse Chuang, Asish Goel, Nick McKeown and Balaji Prabhakar; **“Matching Output Queueing with a Combined Input Output Queued Switch”**, *IEEE JSAC Special Issue on Switches and Routers*, Vol. 17, No. 6, pp 1030-1039, June, 1999.
18. Pankaj Gupta and Nick McKeown; **“Design and Implementation of a Fast Crossbar Scheduler”**, *IEEE Micro Magazine*, Vol. 19, No. 1, pp. 20-28, January-February, 1999.
19. Nick McKeown; **“iSLIP: A Scheduling Algorithm for Input-Queued Switches”**, *IEEE Transactions on Networking*, Vol. 7, No. 2, April, 1999.
20. Nick McKeown and Thomas E. Anderson; **“A Quantitative Comparison of Scheduling Algorithms for Input-Queued Switches”**, *Computer Networks and ISDN Systems*, Vol. 30, No. 24, pp. 2309 - 2326, December, 1998.
21. Nick McKeown; **“A Fast Switched Backplane for a Gigabit Switched Router”**, *Business Communications Review*, December 1997.
22. Ritesh Ahuja, Balaji Prabhakar and Nick McKeown; **“Multicast Scheduling Algorithms for Input-Queued Switches”**, *IEEE Journal of Selected Areas in Communications*, Vol. 15, No. 5, pp. 855-866, June, 1997.
23. Nick McKeown, Martin Izzard, Adisak Mekkittikul, Bill Ellersick and Mark Horowitz; **“The Tiny Tera: A Small High-Bandwidth Packet Switch Core”**, *IEEE Micro Magazine*, Vol. 17, No. 1, pp. 26 - 33, January-February 1997.
24. Richard J. Edell, Nick McKeown, Pravin Varaiya; **“Billing Users and Pricing for TCP Traffic”**, *IEEE Journal of Selected Areas in Communications*, Vol. 13, no. 7, pp. 1162-75, September, 1995.
25. Nick McKeown, Pravin Varaiya and Jean Walrand; **“Scheduling Cells in an Input-Queued Switch,”** *IEEE Electronics Letters*, pp. 2174-5. December 1993.
26. Nick McKeown, Richard Edell and My T Le; **“The Bay Bridge: A High Speed Bridge/Router”**, *IFIP Transactions of Protocols for High Speed Networks III*, Vol. C-9, pp. 203-218, November 1993.
27. Steven E. Schladover, Charles A. Desoer, J. Karl Hedrick, Masayoshi Tomizuka, Jean Walrand, Wei-Bin Zhang, Donn H. McMahon, Huei Peng, Shahab Sheikholeslam and Nick McKeown; **“Automatic Vehicle Control Developments in the PATH Program”**, *IEEE Transactions on Vehicular Technology*, Vol. 40, No.1, pp. 114-130, February 1991.

### Conference Papers

1. Nick McKeown , **“Optics inside Routers”** *ECOC 2003, Rimini, Italy, September 2003.*
2. Isaac Keslassy, Shang-Tse Chuang, Kyoungsik Yu, David Miller, Mark Horowitz, Olav Solgaard, Nick McKeown, **“Scaling Internet Routers Using Optics”** *ACM SIGCOMM Aug. 2003, Karlsruhe, Germany.*
3. Pablo Molinero-Fernandez, Nick McKeown and Hui Zhang, **“Is IP going to take over the world (of communications)?”**, *ACM HotNets-I, Princeton, NJ, October 2002.*

4. Sundar Iyer, Rui Zhang, Nick McKeown, “**Routers with a Single Stage of Buffering**”, Proceedings of ACM SIGCOMM, September 2002, Pittsburgh, PA.
5. Isaac Keslassy and Nick McKeown; “**Maintaining Packet Sequence in a Two Stage Switch**”, *IEEE Infocom 2002*, June 2002, New York, NY.
6. Giancarlo Iannaccone, Christophe Diot, Ian Graham and Nick McKeown; “**Monitoring Very High Speed Links**”, *ACM Sigcomm Internet Measurement Workshop IMW 2001*, pp. 267-271, November 2001, San Francisco, CA.
7. Isaac Keslassy and Nick McKeown; “**Analysis of Scheduling Algorithms that Provide 100% Throughput in Input-Queued Switches**”, *Proceedings of the 39th Annual Allerton Conference on Communications, Control, and Computing*, pp. 593-602, October 2001, Monticello, Illinois.
8. Nick McKeown, Costas Calamvokis, and Shang-tse Chuang, “**A 2.5Tb/s Switch Core with LCS Interface**”, *Hot Chips 13*, August 2001, Stanford, CA.
9. Pablo Molinero-Fernandez and Nick McKeown; “**TCP Switching: Exposing circuits to IP**”, *Proceedings Hot Interconnects IX*, pp. 43-48, August 2001, Stanford, CA.
10. Devavrat Shah, Sundar Iyer, Balaji Prabhakar and Nick McKeown; “**Analysis of a Statistics Counter Architecture**”, *Hot Interconnects IX*, pp. 107-111, August 2001, Stanford, CA.
11. Anna Gilbert, Nick McKeown and Youngmi Joo; “**Congestion Control and Periodic Behavior**”, *11th IEEE Workshop on Local and Metropolitan Area Networks*, pp. 26-29, March 2001, Boulder, CO.
12. Sundar Iyer and Nick McKeown; “**Making Parallel Packet Switches Practical**”, *IEEE Infocom*, Vol. 3, pp. 1680-1687, March 2001, Anchorage, Alaska.
13. Sundar Iyer, Ramana Rao Kompella, and Nick McKeown; “**Analysis of a Memory Architecture for Fast Packet Buffers**”, *IEEE Workshop on High Performance Switching and Routing*, pp. 368-373, May 2000, Dallas, Texas.
14. Pankaj Gupta and Nick McKeown; “**Dynamic Algorithms with Worst-case Performance for Packet Classification**”, *Proceedings of IFIP Networking*, pp. 528-539, May 2000, Paris, France.
15. Sundar Iyer, Amr A. Awadallah, and Nick McKeown; “**Analysis of a Packet Switch with Memories Running Slower than the Line Rate**”, *Proceedings of IEEE Infocom 2000*, Vol. 2, pp.529-537, March 2000, Tel-Aviv, Israel.
16. Pankaj Gupta and Nick McKeown, “**Packet Classification on Multiple Fields**”, *Proceedings Sigcomm 1999*, pp. 147-160, September 1999, Harvard University, MA.
17. Pankaj Gupta and Nick McKeown, “**Packet Classification using Hierarchical Intelligent Cuttings**”, *Proceedings of the Hot Interconnects VII*, pp. 27-31, August 1999, Stanford, CA.
18. Shang-tse Chuang, Ashish Goel, Nick McKeown and Balaji Prabhakar; “**Matching Output Queueing with a Combined Input Output Queued Switch**”, *Proceedings of IEEE Infocom 1999*, Vol. 3, pp. 1169-1178, March 1999, New York, NY.
19. Pankaj Gupta and Nick McKeown; “**Design and Implementation of a Fast Crossbar Scheduler**”, *Proceedings of Hot Interconnects VI*, pp. 77-84, August 1998, Stanford, CA.

20. A. Hung, G. Kesidis and N. McKeown; **“ATM Input-Buffered Switches with the Guaranteed-Rate Property”**, *IEEE International Symposium on Computer and Communications '98*, pp. 331- 335, June 1998, Athens, Greece.
21. Pankaj Gupta, Steven Lin, and Nick McKeown; **“Routing Lookups in Hardware at Memory Access Speeds”** *Proceedings of IEEE Infocom 1998*, Vol. 3, pp. 1240 - 1247, April, 1998, San Francisco, CA.
22. Adisak Mekkittikul and Nick McKeown; **“A Practical Scheduling Algorithm to Achieve 100% Throughput in Input-Queued Switches”**, *Proceedings of IEEE Infocom '98*, Vol. 2, pp. 792 - 799, March 1998, San Francisco, CA.
23. Youngmi Joo and Nick McKeown; **“Doubling Memory Bandwidth for Network Buffers”**, *Proceedings of IEEE Infocom 1998*, Vol. 2, pp. 808 - 815, March 1998, San Francisco, CA.
24. Nick McKeown, Balaji Prabhakar and Mingyan Zhu; **“Matching Output Queueing with Combined Input and Output Queueing”**, *Proceedings of the 35th Annual Allerton Conference on Communication, Control, and Computing*, pp. 595-603, September 29 - October 1, 1997, Allerton, IL.
25. Steven Lin and Nick McKeown; **“A simulation study of IP switching”**, *Proceedings of ACM Sigcomm '97*, Vol. 27, No. 4, pp. 15-24, September 1997, Cannes, France.
26. George Kesidis and Nick McKeown; **“Output-buffer ATM Packet Switching for Integrated-Services Communication Networks”**, *Presented at ICC '97*, pp. 1684-1688, August 26 -29th, 1997, Montreal, Canada.
27. Ken K. -Y. Chang, William Ellersick, Shang-Tse Chuang, Stefanos Sidiropoulos, Mark Horowitz, Nick McKeown, Martin Izzard; **“A 2Gb/s Asymmetric Serial Link Architecture for High-Bandwidth Packet Switches”**, *Proceedings of Hot Interconnects V '97*, pp. 171-179, August 1997, Stanford, CA.
28. Nick McKeown, Martin Izzard, Adisak Mekkittikul; **“The Tiny Tera: A Small High-Bandwidth ATM Switch”**, *Proceedings of SPIE '96*, Vol. 29, No.17, pp. 387-397, November 1996, Boston, MA.
29. Adisak Mekkittikul and Nick McKeown; **“A Starvation-Free Algorithm for Achieving 100% Utilization in an Input-queued Switch”**, *Proceedings of International Conference on Computer Communications '96*, pp. 226-231, October 1996.
30. Nick McKeown, Martin Izzard, Adisak Mekkittikul, Bill Ellersick, Mark Horowitz; **“The Tiny Tera: A Small High-Bandwidth Packet Switch Core”**, *Proceedings of Hot Inteconnects IV*, pp. 161-173, August 1996, Stanford, CA.
31. Nick McKeown, Venkat Anantharam and Jean Walrand; **“Achieving 100% Utilization in an Input-queued Switch”**, *Proceedings of IEEE Infocom '96*, Vol. 1, pp. 296-302, March 1996.
32. Nick McKeown and Balaji Prabhakar; **“Scheduling Multicast Cells in an Input-queued Switch”**, *Proceedings of IEEE Infocom '96*, Vol. 1, pp. 271-8, March 1996, Reston, VA.
33. Balaji Prabhakar, Nick McKeown and Jean Mairesse; **“Tetris Models for Multicast Switches”**, *Proceedings of the Princeton Conference*, Vol. 1, pp. 216-221, March 1996, Princeton, NJ.

34. Adisak Mekkittikul, D. Sadot, L.G. Kazovsky, Nick McKeown; **“8 Tb/s ATM Interconnection through optical WDM networks”**, *High-Speed Semiconductor Laser Sources*, Vol. 2684, pp. 186-98, 1-2 February, 1996, San Jose, CA.
35. Balaji Prabhakar and Nick McKeown; **“Designing a Multicast Scheduler”**, *Proceedings of the 33rd Annual Allerton Conference on Communication, Control, and Computing*, pp. 984-993, October 1995, Monticello, Illinois.
36. Richard Edell, Nick McKeown, Pravin Varaiya; **“Billing Users for TCP”**, invited paper of the *Proceedings of the 3rd Intl. Conf. on Telecommunications. Systems Modeling and Analysis*, pp. 135-41, March 1995, Nashville, TN.
37. Nick McKeown, Jean Walrand; **“A Fast Scheduling Algorithm for Input-Queued Switches”**, *Proceedings of 7th IEEE LAN/MAN Workshop*, pp. 450-456, March 1995, Marathon, FL.
38. Nick McKeown, Richard Edell, and My Le; **“The Bay Bridge: A High Speed Bridge/Router”**, *IFIP Workshop*, May 1992, Stockholm, Sweden.

#### Unpublished papers available:

1. Nick McKeown, Fouad Tobagi; **“Bridges, Switches and Routers,”** Available on request.
2. Nick McKeown, Richard Edell, and My T. Le; **“Architecture and Performance of The BayBridge: A High Speed Bridge/Router between FDDI and SMDS.”** Available on request.
3. My T. Le, Nick McKeown, and Richard Edell; **“A High Performance SMDS Interface at STS-3c Rate,”** Available on request.
4. Karl Petty and Nick McKeown; **“XDistribute: A Process Distribution System,”** Available on request.
5. Nick McKeown; **“Scheduling Algorithms for Input-Queued Cell Switches,”** *Ph.D. Thesis, University of California at Berkeley*, May 1995. Reprint available on request.

#### Hewlett-Packard Technical Reports externally available include:

1. Nick McKeown; **“Segmentation and Reassembly for Cell-Based Misordering Networks,”** Hewlett-Packard Technical Report, 1991.
2. Nick McKeown; **“Constraints on Receiver Design for a Q-Star Network,”** Hewlett-Packard Technical Report, 1989.
3. Nick McKeown; **“Collision Detection for Passive Star LANs,”** Hewlett-Packard Technical Report, 1989.
4. Nick McKeown; **“Q-Star: A Protocol for High Speed Passive Star LANs,”** Hewlett-Packard Technical Report, 1988.

#### Invited Talks

1. **“Circuit Switching in the core”**, OpenArch 2003, San Francisco, April 2003.
2. **“High Performance Routers”**, Colloquium Series at University of Pennsylvania, March 2003.

3. "Internet Infrastructure Teaching Tools", Sigcomm Education Workshop, August 2002, Pittsburgh.
4. "Scalable Routers", Keynote talk at IEEE HPSR 2002, Kobe, Japan, May 2002.
5. "High Performance Routers", Invited talk, IEE London, UK, October 2001.
6. "Do Optics and Routers Belong Together?" Keynote address, Opticomm 2001, August 2001, Denver, Colorado.
7. "Network Algorithms", Tutorial at Sigcomm 2001, August 2001, San Diego, CA.
8. "How Scalable is the capacity of (Electronic) IP routers?", Invited Talk at OFC 2001, March 2001, Stanford, CA.
9. Invited Speaker at NSF Workshop, UC Irvine, October 2000.
10. Invited Speaker at NREN NGI Workshop, NASA, August 2000.
11. Top-Gun Lecturer, Colloquium Series of University of Virginia, December 1999.
12. "High Performance Packet-Switches" Tutorial at ACM SIGCOMM'99, Harvard University.
13. "High Performance Packet Switch Design" Tutorial at Hot-Interconnects 7, August '99, Stanford University.
14. Invited Speaker at the NSF Workshop on Internet Research, January 1999.
15. Invited Speaker at the IBM Workshop on Intelligent Internet Infrastructure, March 1999.
16. Invited Colloquium at Washington University in St. Louis, July 1998.
17. "How to build a terabit router," Invited Talk at the Ninth Annual IEEE Workshop on Interconnections Within High Speed Digital Systems, Santa Fe, May 1998.
18. Gigabit Networking Workshop '98, San Francisco, March 1998.
19. Invited talk at MIT LIDS Colloquium, Boston, February 1998.
20. Keynote Speaker, Next Generation Networks, Washington, D.C., November 1997.
21. "High-speed Switching and Routing for the Internet," Invited Talk at the Eighth Annual IEEE Workshop on Interconnections Within High Speed Digital Systems, Santa Fe, May 1997.
22. Invited talk at Multimedia Networking Workshop, Lausanne, Switzerland, 1996.
23. "The merging of IP + ATM: Hardware Issues," Invited Talk at Washington University Workshop, November 1996.
24. "High Speed Switching & Routing," Invited Departmental Colloquium at the University of Utah, May 1996.

## Patents

1. Nick McKeown and Costas Calamvokis (PMC Sierra/Abrizio) "Interchanging crossbar", U.S. Patent applied for.
2. Costas Calamvokis, Nick McKeown, and Paul Ries (PMC Sierra/Abrizio) "Distributed multicast scheduling", U.S. Patent 6,856,622, Feb 2005.
3. Nick McKeown et al. (PMC-Sierra/Abrizio) "Packet-switch system", U.S. Patent 6,647,019, Nov 2003.

4. Amr A. Awadallah and Nick McKeown (Stanford) "Voice-Mail to E-Mail Agent Providing Access to Multiple Heterogeneous Voice-Mail Systems" U.S. Patent applied for, June 1999.
5. Nick McKeown (Abrizio) "Streamline LANS" U.S. Patent applied for.
6. Nick McKeown (Stanford), Balaji Prabhakar (Hewlett-Packard), "Algorithm for matching output queueing", U.S. Patent 6,351,466, Feb 2002.
7. Nick McKeown (Stanford), Balaji Prabhakar (Hewlett-Packard), Ritesh Ahuja, "Apparatus and Method for Processing Multicast Cells in an Input-Queued Multicast Switch", U.S. Patent 5,923,644, July 1999.
8. Nick McKeown (Cisco Systems); "Combined Unicast and Multicast Scheduling," U.S. Patent 6,212,182, April 2003.
9. Nick McKeown (Berkeley); "Method and apparatus for scheduling cells in an input-queued switch," U.S. Patent 5,500,858, March 1996.
10. Nick McKeown (Hewlett-Packard); "Method and Apparatus for Exchanging Data Within a Digital Communications System (Q-Star)", U.S. Patent 5,206,638, April 1993.
11. Nick McKeown (Hewlett-Packard); "Network Transceiver (Optical Collision Detection)," U.S. Patent 5,063,612, November 1991.