Heterogeneous Modeling and Design

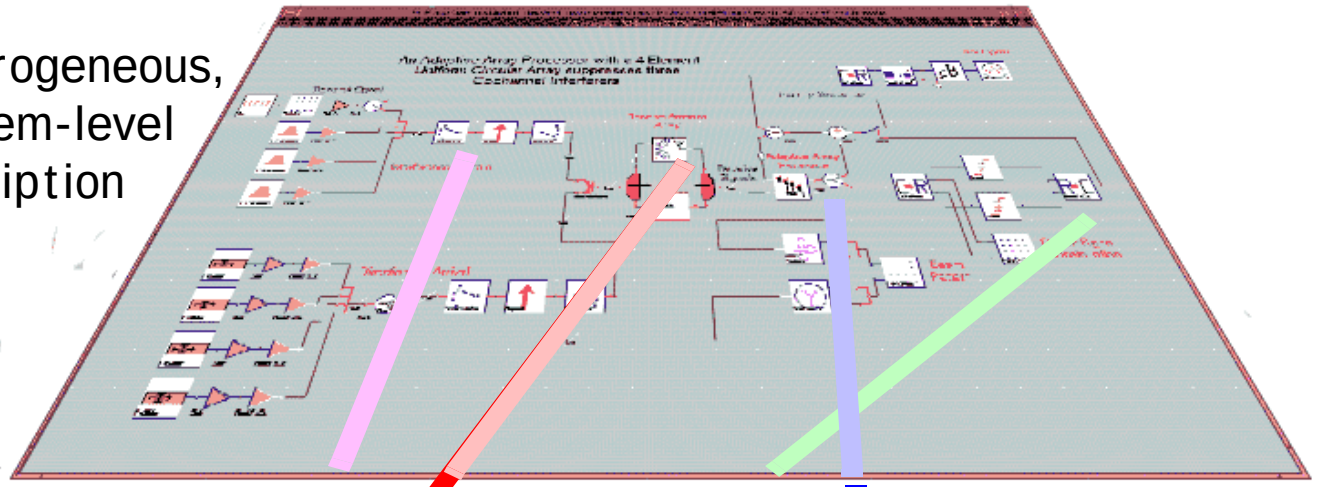
- Edward A. Lee (PI) -

Staff
Christopher Hylands
Fiona Sinclair
Mary P. Stewart

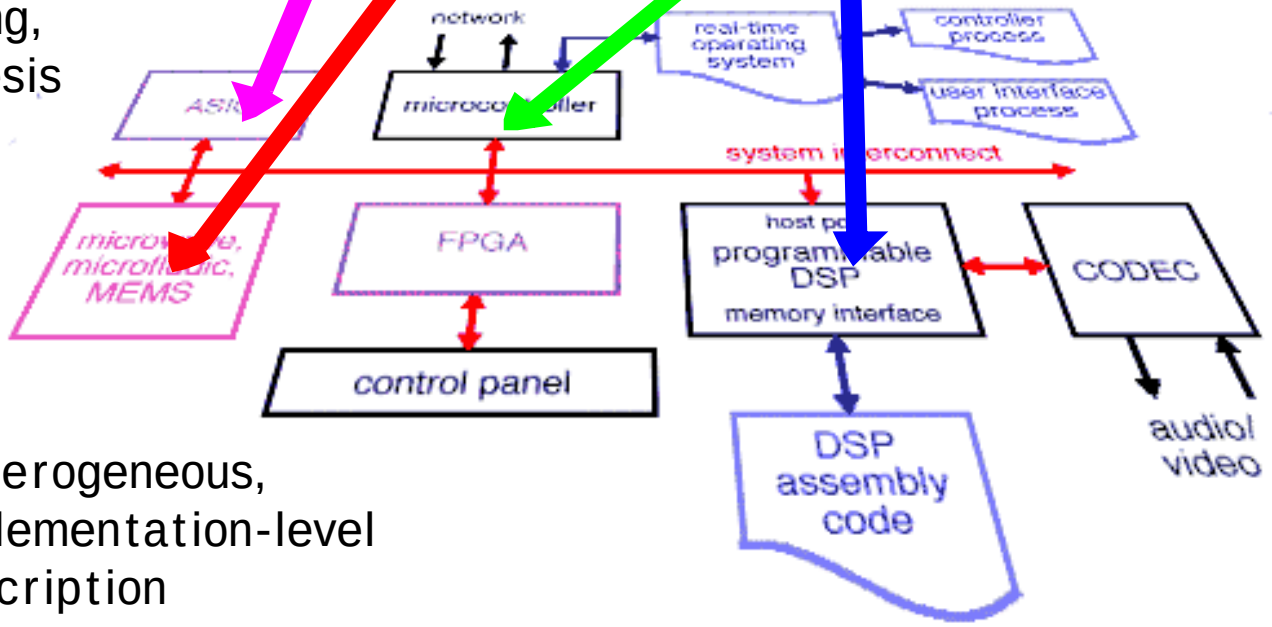
Postdoctoral Researchers
Praveen K. Murthy
H. John Reekie

Graduate Students
John Davis, II
Ron Galicia
Mudit Goel
Michael Goodwin
Bilung Lee
Jie Liu
Neil Smyth
Michael C. Williamson
William Wu
Yuhong Xiong

Heterogeneous, problem-level description



Modeling, mapping, synthesis



Heterogeneous, implementation-level description

Approach

- Theory and techniques for mixing diverse models of computation, e.g. mixed signal, hybrid systems, discrete and continuous events.
- Software architecture for modular, distributed, and heterogeneous design, modeling and visualization tools.
- Theory and software for domain-specific modeling of composite concurrent systems.
- Use of programming language concepts (semantics, type theories, and concurrency theories) for modeling and design of composite systems.
- Emphasis on visual representations.

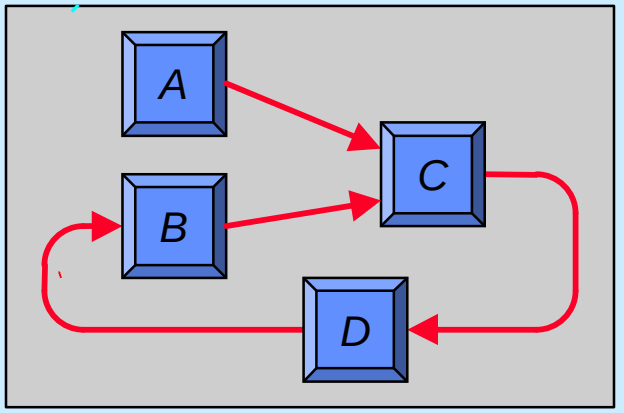
Schedule

December 1996 to December 1999

- Phase 1 (18 months): Infrastructure
  - modular, deployable design tools architecture
  - domain specific modeling techniques
  - heterogeneous interaction semantics
- Phase 2 (18 months): Modeling and Design
  - process-level type system
  - system-level validation techniques
  - system-level design visualization

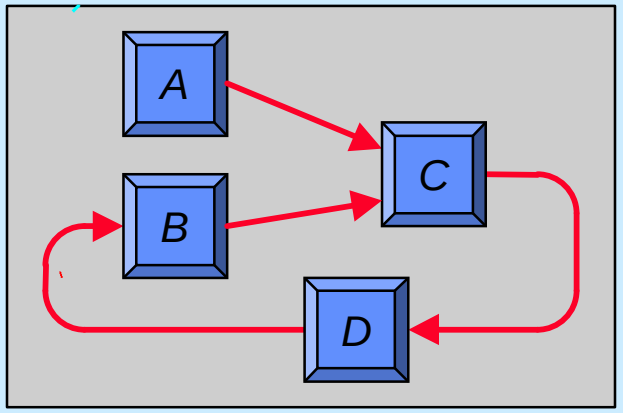
Models of Computation

- Analog computers (differential equations)
- Discrete time (difference equations)
- Discrete-event systems
- Synchronous-reactive systems
- Sequential processes with rendezvous
- Process networks
- Dataflow
- Finite state machines



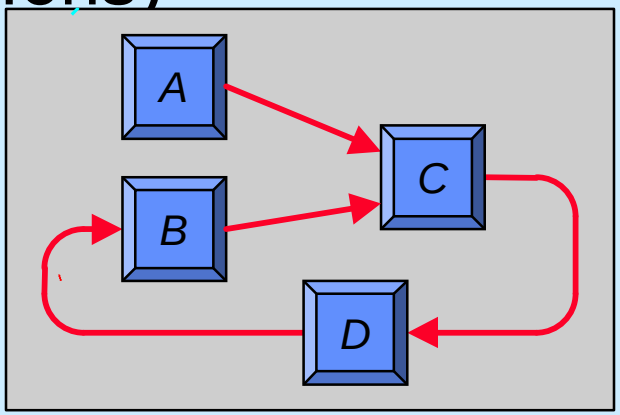
Shared Properties

- Strengths and weaknesses (no silver bullet)
- Domain-specific
- Modular
- Amenable to visual syntaxes
- Hierarchical
- Concurrent (except FSMs)
- Abstract



Issues Being Addressed

- Semantics (what is a behavior)
- Determinacy (how many behaviors are there)
- Simulation (finding a behavior)
- Analysis (finding properties of behaviors)
- Compositionality (encapsulating subsystems)
- Synthesis (translation to implementation)
- Design (choosing implementations)
- Heterogeneity



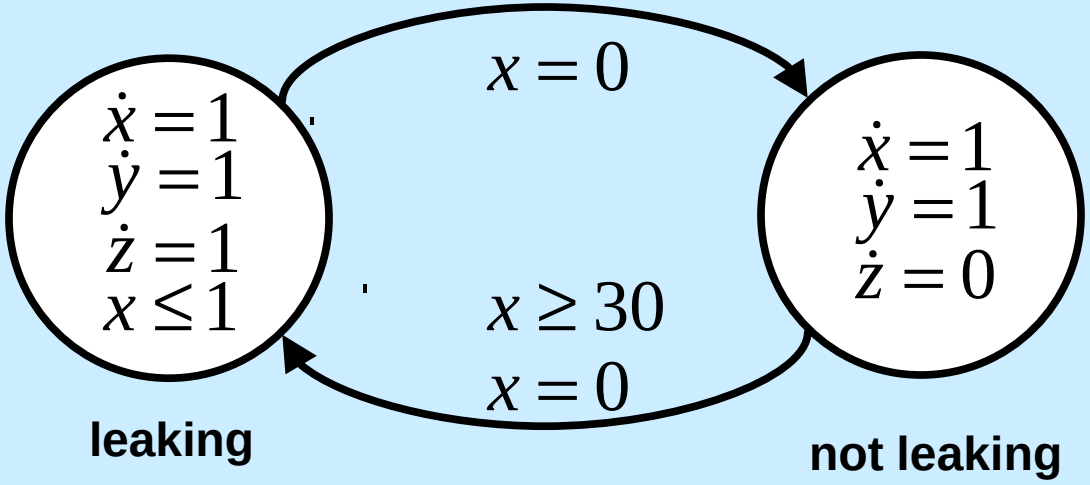
Examples Requiring Heterogeneity

- MEMS device with a discrete controller (differential equations plus discrete-event models)
- Modal models, with regimes of operation (differential equations plus finite-state machines)
- Mixed signal systems (differential equations plus discrete-time and/or discrete-event systems)
- Hardware/software systems (differential equations, discrete-events, discrete-time, finite-state machines, dataflow, rendezvous, process networks, ...)

Hybrid Systems

A discrete program combined with an analog system.
A combination of automata and analog computers.

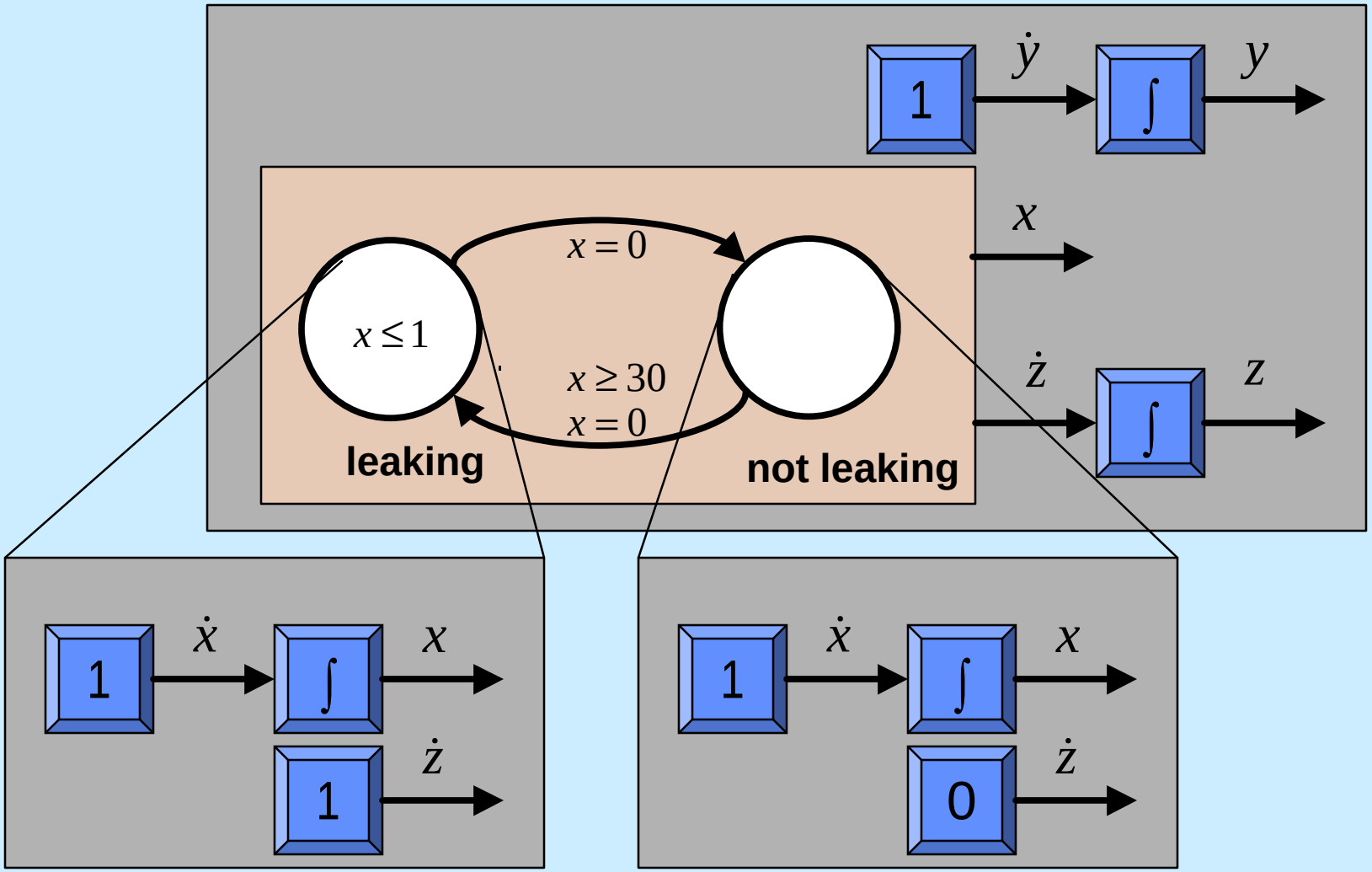
Traditional syntax (classic example: leaking gas burner):



Here, the differential equations hardly look like a concurrency model, but in fact they are.

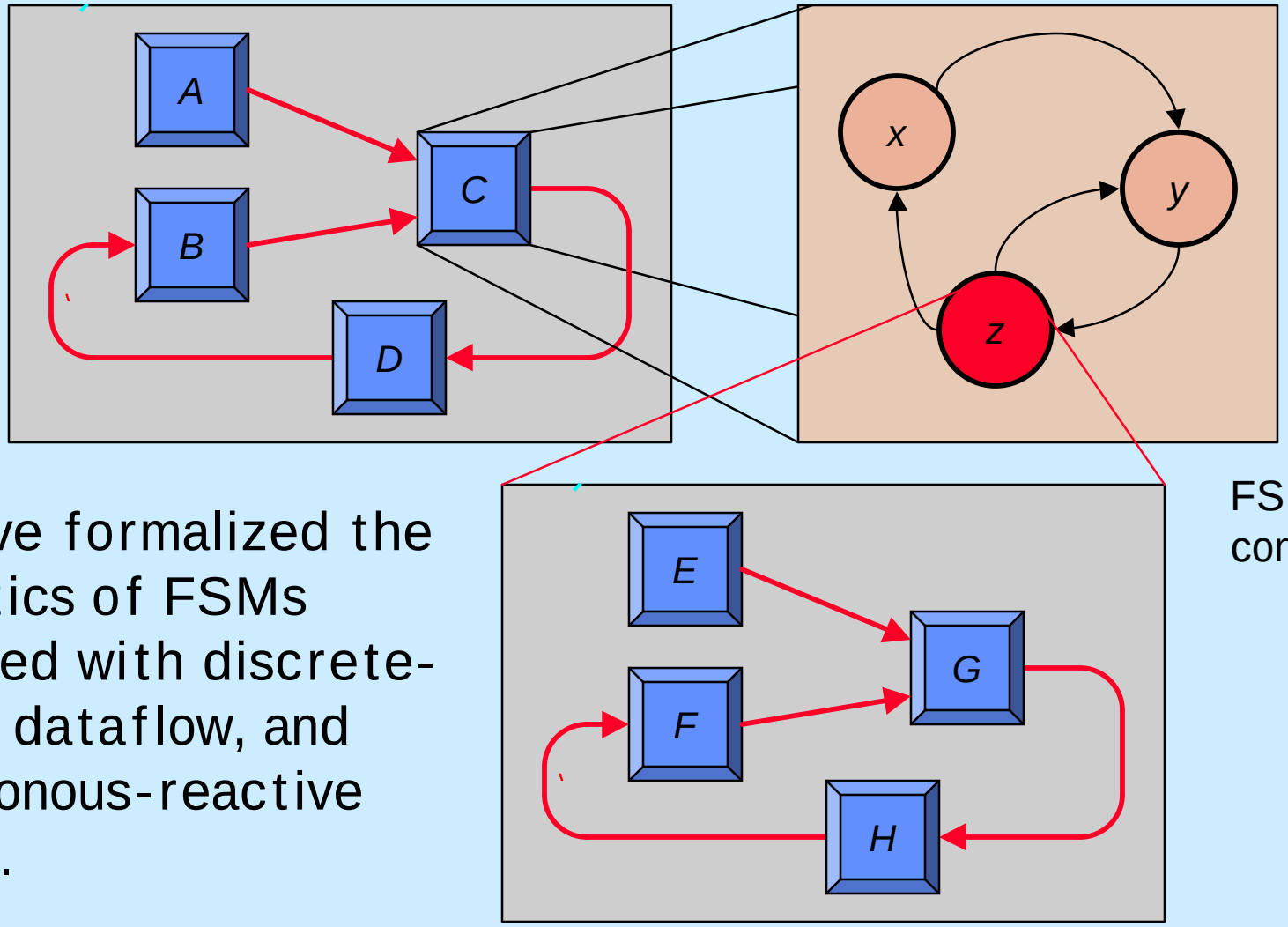
Alternative View of Hybrid Systems

Analog computers hierarchically combined with automata.
Classic example (leaking gas burner):



Generalized Hybrid Systems

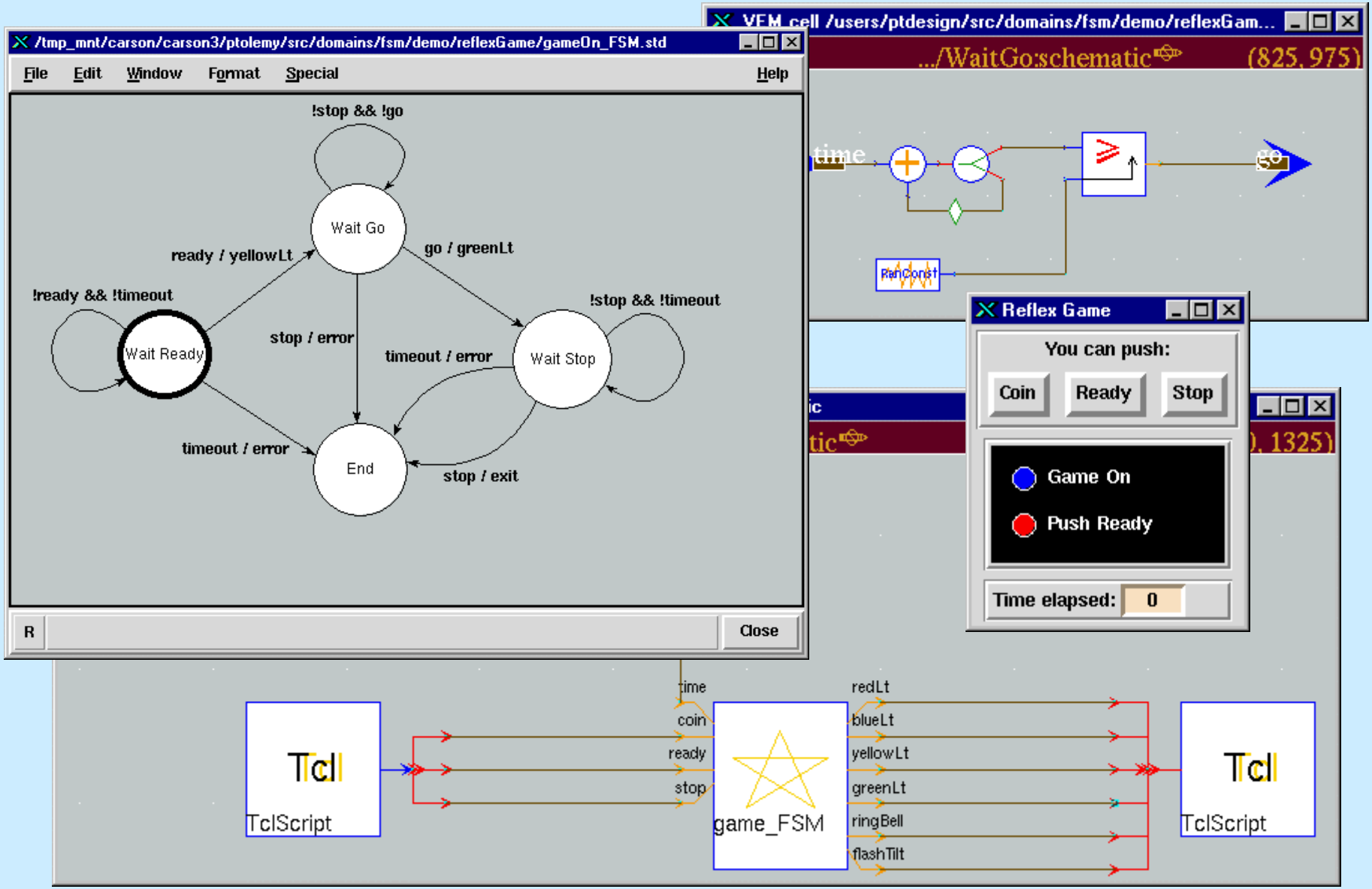
Choice of domain here determines concurrent semantics



FSM for control

We have formalized the semantics of FSMs combined with discrete-event, dataflow, and synchronous-reactive models.

Ptolemy Prototype



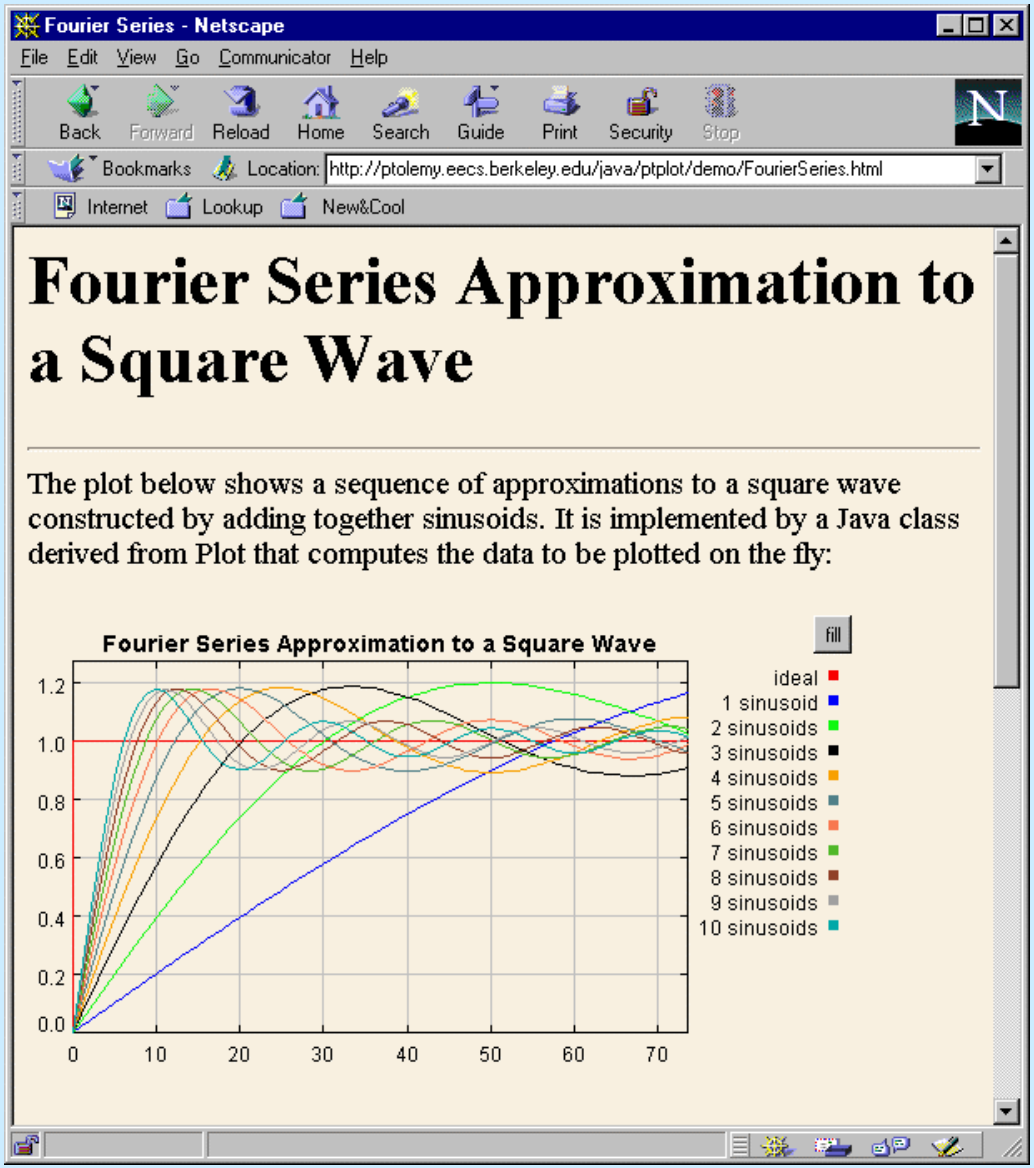
Modular Tools Architecture

- Use Java and Itcl
- Split Ptolemy into Java packages
- Split Tycho into Itcl packages
- Make everything network aware
- Use object modeling
- Use the model-view design pattern
- Use object-request broker technology
- Experiment with reflection, remote method invocation, etc.

First Released Java Module

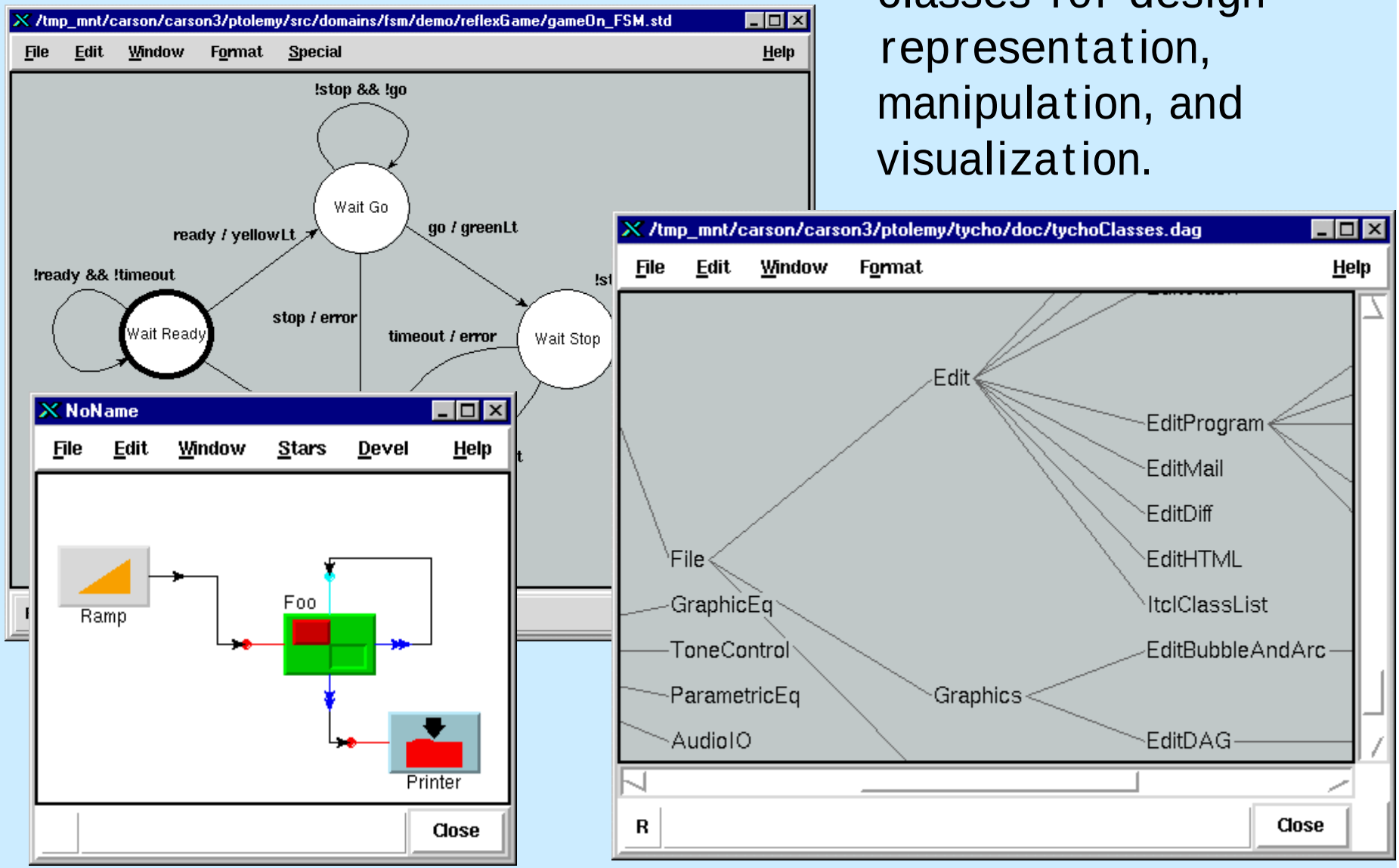
PtPlot is a Java package for interactive, animated signal plotting on the web.

We have used it to learn about Java applets as an interchange and modularization format, and will distribute Ptolemy modules similarly.



Tycho

Tycho is suite of Itcl classes for design representation, manipulation, and visualization.



Software Engineering

- Code rating system: red, yellow, green, blue.
- Author/reviewer division of responsibilities.
- Automated test suites (scripted, in Tcl).
- Code coverage measurements.
- Integrated documentation.
- Tycho support.

The Ptolemy group has a tradition of emphasizing code and documentation quality.

Major Accomplishments so Far

- Semantics for hierarchical interaction of finite-state controllers with several models of computation.
- Demonstration of a client-server, web-based mechanism supporting Ptolemy simulations.
- Construction of a network-integrated, scripted design management environment (Tycho).
- Design of an "information model" and an associated "model-view" software architecture (Tycho).
- Demonstration of a Java-threads-based process networks modeling environment.
- Release on the net of our first Java module, a multipurpose signal plotter.
- Java/Tycho integration.
- A well-attended Ptolemy miniconference.

Top Three Research Challenges for the next year

- Simulation and synthesis of generalized hybrid systems.
- Modular software architecture design, implementation, and deployment.
- Generalizing pairwise interaction semantics - common principles and software architecture support.

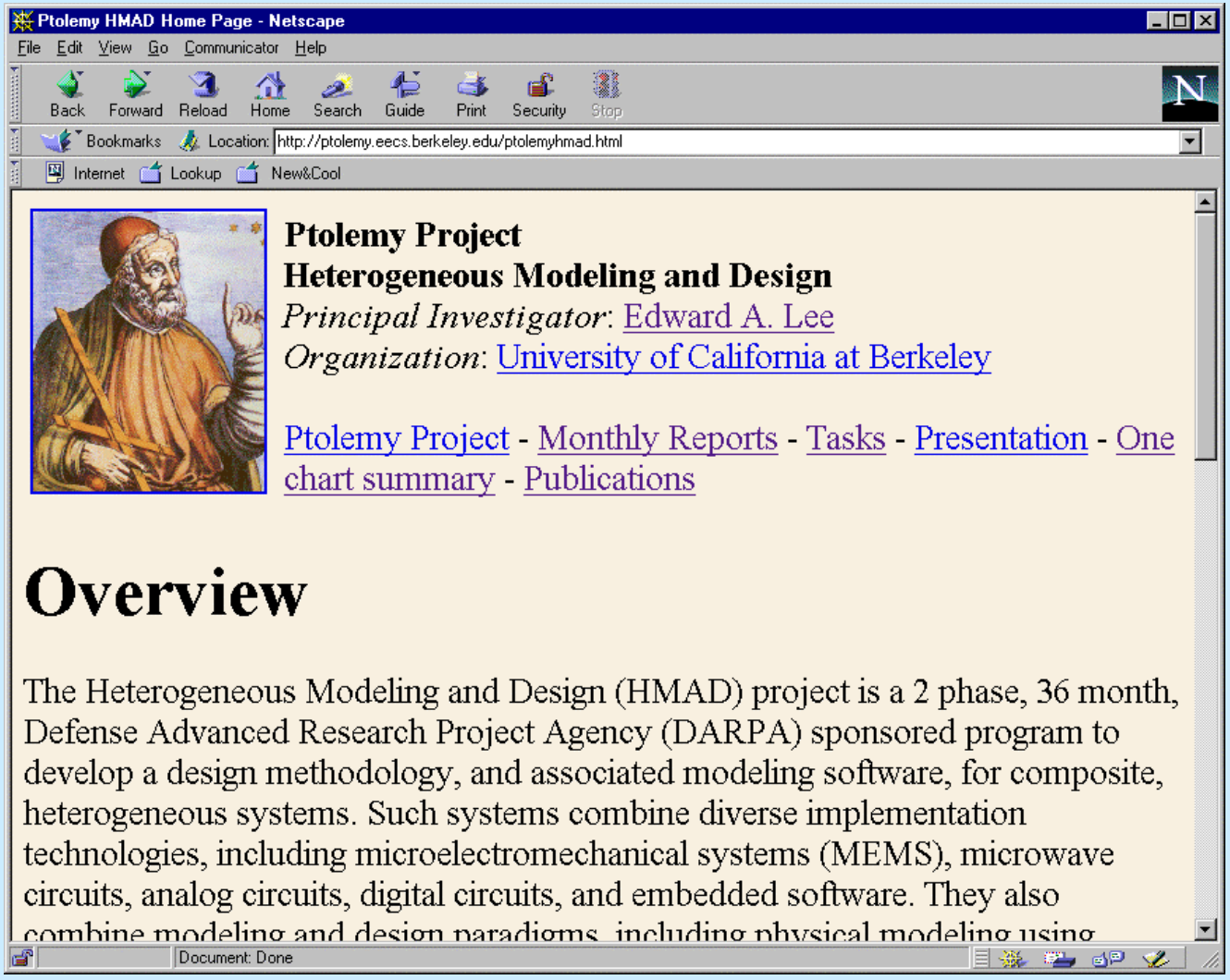
How Results may be Used

- In 1 year:
  - C++ Ptolemy & HP and Cadence commercializations used in modeling and design of composite systems.
  - Java Ptolemy modules and Tycho on the web and used in specialized ways by researchers.
- In 5 years:
  - Widespread use of Java Ptolemy modules for modeling, simulation, publication, dissemination, and commercial and non-commercial distribution and sharing of designs.
  - Acceptance of modular, distributed software architecture for design tools.
- In 10 years:
  - Widespread acceptance of diverse semantics (models of computation) in modeling and design.
  - Acceptance of formal, heterogeneous, visual system descriptions.

Actual Deliverables

- Reports
  - monthly reports
  - annual reports
- Software
  - Tycho 0.2 released (May, 1997)
  - PtPlot 0.1 released (October, 1997)
  - Java Ptolemy Modules (June 1998 - December 1999)
  - Annual updates of Tycho (est. June, 1998, 1999)
- Papers
  - 13 papers to date (reports, journal, and conference papers.)

More Information



http://ptolemy.eecs.berkeley.edu/ptolemyhmad.html

Publications

- A. Girault, B. Lee, and E. A. Lee, ``A Preliminary Study of Hierarchical Finite State Machines with Multiple Concurrency Models,'' Memorandum UCB/ERL M97/57, Electronics Research Laboratory, University of California, Berkeley, CA 94720, August 1997.
- S. Edwards, L. Lavagno, E. A. Lee, and A. Sangiovanni-Vincentelli, ``Design of Embedded Systems: Formal Models, Validation, and Synthesis,'' *Proceedings of the IEEE*, Vol. 85, No. 3, March 1997.
- S. A. Edwards, ``The Specification and Execution of Heterogeneous Synchronous Reactive Systems,'' Ph.D. thesis, University of California, Berkeley, May 1997. Available as UCB/ERL M97/31 .
- C. Hylands, E. A. Lee, and H. J. Reekie, ``The Tycho User Interface System,'' to be presented at the 5th Annual Tcl/Tk Workshop '97, Boston, Massachusetts, July, 1997.
- S. S. Bhattacharyya, P. K. Murthy, and E. A. Lee, ``Software Synthesis for Synchronous Dataflow,'' International Conference on Application Specific Systems, Architectures, and Processors, July, 1997, invited paper.

Publications (continued)

- W.-T. Chang, S.-H. Ha, and E. A. Lee, ``Heterogeneous Simulation -- Mixing Discrete-Event Models with Dataflow,'' invited paper, Journal on VLSI Signal Processing, Vol. 13, No. 1, January 1997.
- E. A. Lee and A. Sangiovanni-Vincentelli, ``A Denotational Framework for Comparing Models of Computation,'' ERL Memorandum UCB/ERL M97/11, University of California, Berkeley, CA 94720, January 30, 1997.
- P. K. Murthy, E. A. Lee, "Some cycle-related problems for regular dataflow graphs: complexity and heuristics," UCB/ERL Tech. Report, UCB/ERL M97/76, July 1997.
- S. Kim and E. A. Lee, ``An Infrastructure for Numeric Precision Control in the Ptolemy Environment'', Proceedings of the 40th Midwest Symposium on Circuits and Systems, August 3-6, 1997.
- Richard S, Stevens (Naval Research Laboratory), Marlene Wan, Peggy Laramie (UCB), Thomas M. Parks (MIT Lincoln Labs), and Edward A. Lee (UCB), "Implementation of Process Networks in Java," UCB/ERL Tech. Report, number pending, November 1997.

Publications (continued)

Under subcontract to UT Austin (Brian Evans):

- D. Arifler, C. Duong, B. L. Evans, S. K. Marwat, C. M. Moy, and A. Yuan, ``A Configurable, Portable, Extensible Framework for Web-Enabled Interactive Simulation of Software for Embedded Programmable Processors,'' submitted.
- A. K. Kulkarni, A. Dube, and B. L. Evans, ``Benchmarking Code Generation Methodologies for Programmable Digital Signal Processors,'' submitted.
- B. Lu, B. L. Evans, and D. V. Tosic, ``Simulation and Synthesis of Artificial Neural Networks Using Dataflow Models in Ptolemy,'' Invited Paper, Proc. IEEE Conf. on Neural Network Applications in Engineering, Sep. 8-9, 1997.