# Center for Hybrid and Embedded Software and Systems

(Edited and presented by)
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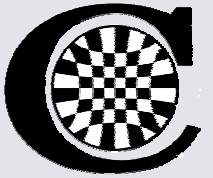
**http://chess.eecs.berkeley.edu**

NSF-EU IST Workshop
July 8th 2005
Paris

Chess

# Chess Investigators



**UC Berkeley**
**Vanderbilt**
**Memphis**

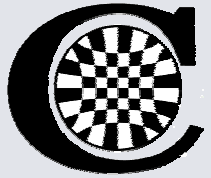
Ruzena Bajcsy, Ras Bodik, Bella Bollobas, Gautam Biswas,Tom Henzinger, Kenneth Frampton, Gabor Karsai, Kurt Keutzer, John Koo, Edward Lee, George Necula, Alberto Sangiovanni Vincentelli, Shankar Sastry, Janos Sztipanovits, Claire Tomlin, Pravin Varaiya.

**Berkeley Chess Board of Directors:** Henzinger, Lee, Sangiovanni Vincentelli, Sastry, Tomlin

**ISIS Director:** Sztipanovits

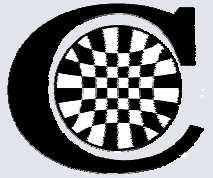
**Memphis Director:** Bollobas

# Center Organization



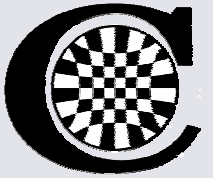
- Funding Sources
  - Large NSF ITR
  - Other federal (NSF, DARPA, NIH, MURIs)
  - Industrial (Participating Member Companies): IT and applications (automotive, aerospace, consumer electronics, systems biology)
- Outreach
  - Curriculum development
  - Community colleges+ San Jose State University (EECS 20)
  - SUPERB-IT program (Sum. Prog. for Engg. Res. In IT @Berkeley)
  - SIPHER program (Sum. Intern. Prog. For Hybrid and Embedded Res @Vanderbilt)

# NSF ITR Organization



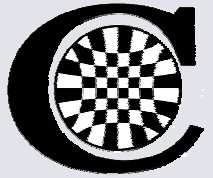
- PI: Shankar Sastry
- coPIs: Tom Henzinger, Edward Lee, Alberto Sangiovanni-Vincentelli, Janos Sztipanovits
- Participating Institutions: UCB, Vanderbilt, Memphis State
- Five Thrusts:
  - Hybrid Systems Theory (Henzinger)
  - Model-Based Design (Sztipanovits)
  - Advanced Tool Architectures (Lee)
  - Applications: automotive (ASV), aerospace (Sastry)
  - Education and Outreach (Karsai, Lee, Varaiya)
- Five year project: kick-off meeting November 14th , 2002. First Review May 8th, 2003, Second Review Dec 3rd, 2003, Third Review May 10th, 2004, Fourth Review Nov 18th, 2004, Fifth Review May 11th, 2005.
  - Weekly seminar series
  - Ptolemy workshop May 9th, 2003, April 27th 2004
  - NEST + CHESS Workshop May 9th, 2003
  - BEARS Open House, February 27th 2004

# Foundational Research



- The science of computation has traditionally abstracted away the physical world; while the science of physical systems has ignored computational limitations. Embedded software systems, however, engage the physical world in a computational manner.
- We believe that it is time to construct an Integrated Systems Science (ISS) that is simultaneously computational and physical. Time, concurrency, robustness, continuums, and resource management must be remarried to computation.

# Mission of Chess



To provide an environment for graduate research on the design issues necessary for supporting next-generation embedded software systems.

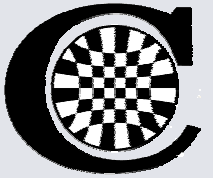
- Model-based design
- Tool-supported methodologies

For

- Real-time
- Fault-tolerant
- Robust
- Secure
- Heterogeneous
- Distributed Software

We are on the line to create a "new systems science" that is at once computational and physical.

# Hybrid and Embedded Software: Problem for Whom?



- *DoD (from avionics to micro-robots)*
  - *Large, complex systems*
- *Automotive (drive-by-wire)*
  - *Key competitive element in the future*
  - *Increasing interest, low risk-taking*
- *Consumer Electronics (from mobile phones to TVs to sensor webs)*
  - *Problem is generally simpler*
  - *US industry is strongly challenged*
- *Plant Automation Systems*
  - *Conservative solutions to date*
  - *Importance of SCADA in Critical Infrastructure Protection*

# Some Applications Addressed


Stanford Testbed of Autonomous Rotorcraft for Multi-Agent Control (STARMAC)

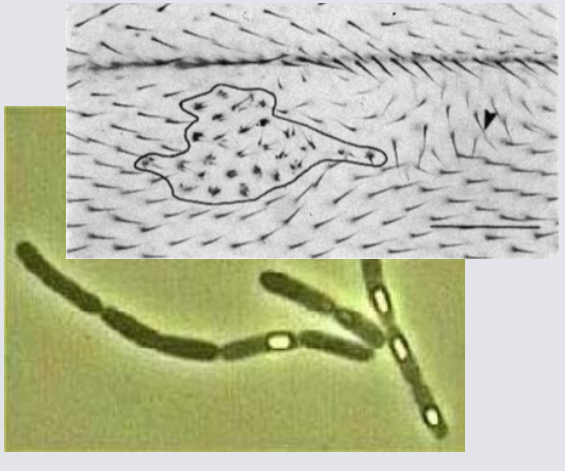
Autonomous Flight Demonstration

Avionics: UAVs

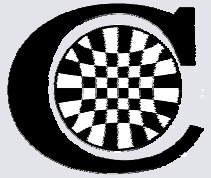
Automotive

Networked Embedded Systems

Systems Biology

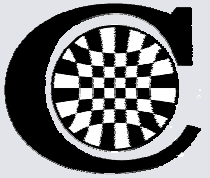


# Key Properties of Hybrid & Embedded Software Systems



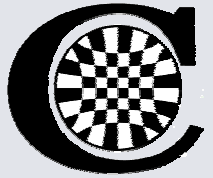
- Computational systems
  - but not first-and-foremost a computer
- Integral with physical processes
  - sensors, actuators
- Reactive
  - at the speed of the environment
- Heterogeneous
  - hardware/software, mixed architectures
- Networked
  - adaptive software, shared data, resource discovery
  - Ubiquitous and pervasive computing devices

# Project Approach



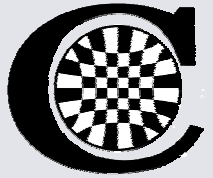
- Model-Based Design (the view from above)
  - principled frameworks for design
  - specification, modeling, and design
  - enabling analysis and verification
  - enabling effective synthesis of implementations
- Platform-Based Design (the view from below)
  - exposing key resource limitations
  - hiding inessential implementation details
- Tools
  - concrete realizations of design methods
  - synthesis, simulation, verification, code generation

# Some Current Research Focus Areas



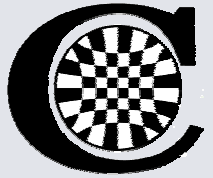
- Software architectures for actor-oriented design
- Interface theories for component-based design
- Virtual machines for embedded software
- Semantic models for time and concurrency
- Design transformation technology (code generation)
- Visual syntaxes for design
- Model checking hybrid systems
- Autonomous helicopters
- Automotive systems design
- Networked Embedded Systems
- Systems Biology

# Thrust I Hybrid Systems



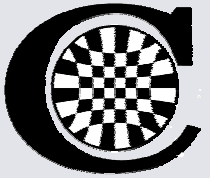
- Deep Compositionality
  - Assume Guarantee Reasoning for Hybrid Systems
  - Practical Hybrid System Modeling Language
  - Interface Theory for hybrid components
- Robust Hybrid Systems
  - Bundle Properties for hybrid systems
  - Topologies for hybrid systems
  - Stochastic hybrid systems
- Computational hybrid systems
  - Approximation techniques for H-J equations
  - Synthesis of safe and live controllers for hybrid systems
- Phase Transitions

# Thrust II: Model Based Design



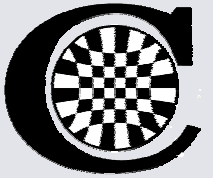
- Composition of Domain Specific Modeling Languages
  - Meta Modeling
  - Components to manipulate meta-models
  - Integration of meta-modeling with hybrid systems
- Model Synthesis Using Design Patterns
  - Pattern Based Modal Synthesis
  - Models of Computation
  - Design Constraints and Patterns for MMOC
- Model Transformation
  - Meta Generators
  - Scalable Models
  - Construction of Embeddable Generators

# Thrust III:Advanced Tool Architectures



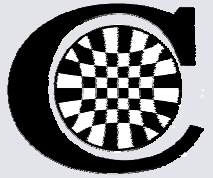
- Syntax and Synthesis
  - Semantic Composition
  - Visual Concrete Syntaxes
  - Modal Models
- Interface Theories
- Virtual Machine Architectures
- Components for Embedded Systems

# Thrust IV: Applications



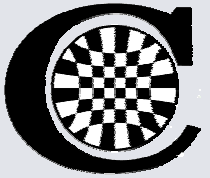
- Embedded Control Systems
  - Avionics
  - Veitronics
  - Wireless Embedded Systems
- Embedded Systems for National/Homeland Security
  - Air Traffic Control
  - UAVs/UGVs
- Networks of Distributed Sensors
- Stochastic Hybrid Systems in Systems Biology
- Hybrid Models in Structural Engineering
  - Active Noise Control
  - Vibration damping of complex structures

# Thrust V: Education and Outreach



- Curriculum Development for MSS
  - Lower Division
  - Upper Division
  - Graduate Courses
- Undergrad Course Insertion and Transfer
  - Goals and ABET requirement
  - New courses for partner institutions (workshop held March 1st 2003, Summer 2004)
  - Introduction of new courses (will be replacing control course at upper division level by embedded control course joint with San Jose State)
  - CHESS-SUPERB/ Summer Program in Embedded Software Research SIPHER program (6 + 4 students in Summer 03, 3 + 5 in Summer 04)
- Graduate Courses
  - EECS 249 Design of Embedded Systems: Models, Validation, and Synthesis
  - EECS 290N Concurrent Models of Computation for Embedded Software
  - EECS 291E/ME 290S Hybrid Systems

# EU-US collaborations



- Interaction with EU-IST programs
  - RUNES, EU-IST program in network embedded systems (Ericsson, KTH, Aachen, Brescia, Pisa, Patras, …)
  - Columbus (with Cambridge, l'Aquila, Rome, Patras, INRIA)
  - Hybridge, Hycon (with Cambridge, Patras, NLR, Eurocontrol, Brescia, KTH)
  - ARTIST, ARTIST-2 (Grenoble, INRIA, ETH-Zurich)
- Foundation of non-profit ESCHER
  - Interaction with F-22/JSF design review teams
  - Secure Networked Embedded Systems: SCADA systems

# *Adaptive Networked Infrastructure*

**Core partners: Berkeley (lead), Cornell, Vanderbilt**

**Outreach partners: San Jose State, Smith, Tennessee Tech, UC Davis, UC Merced.**

*Principal investigator: Edward A. Lee, Professor, EECS, UC Berkeley, eal@eecs.berkeley.edu*

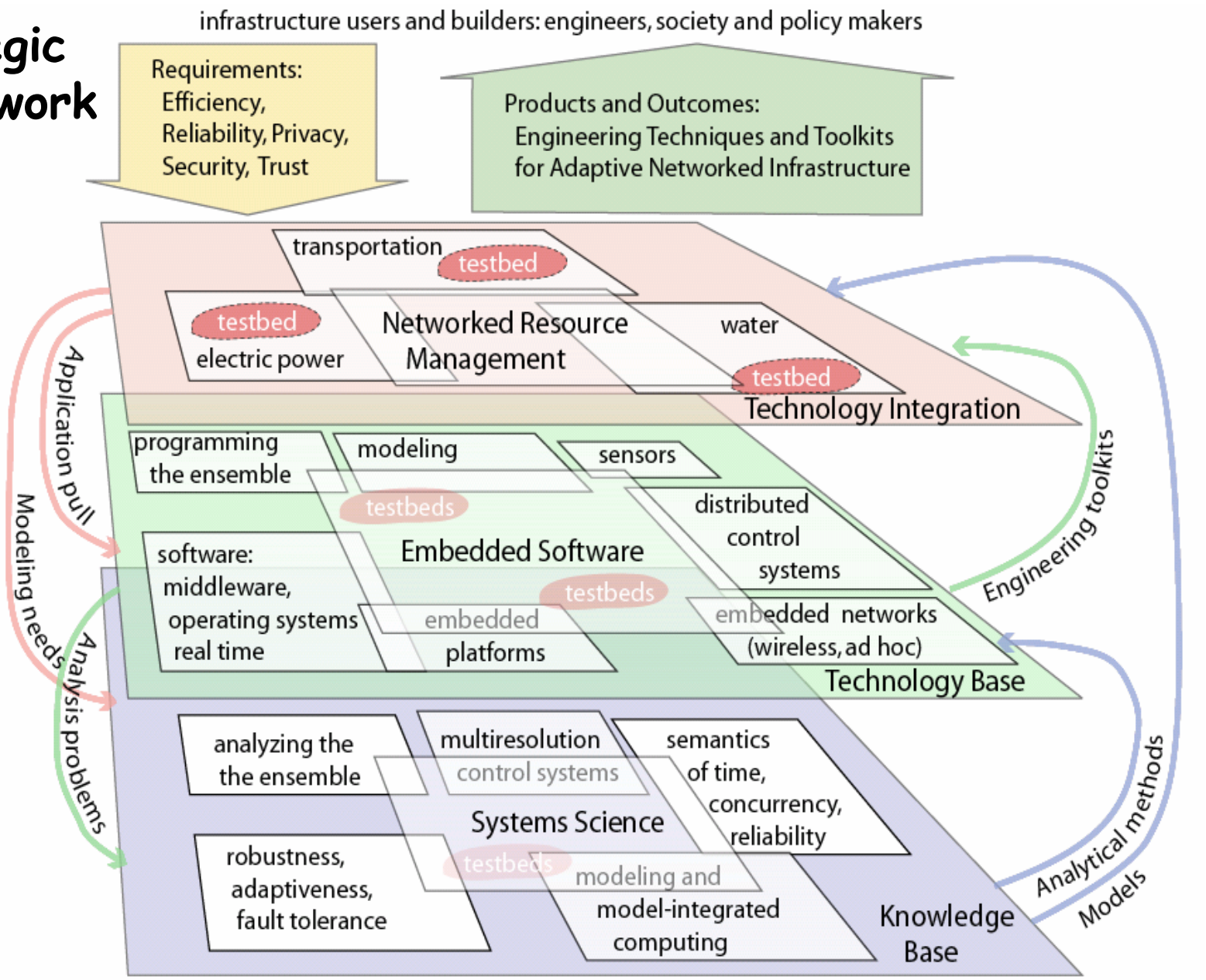

• *Enabling technologies*: wireless networked embedded systems with sensors and actuators

• *Approach*: Engineering methods for integrating computer-controlled, networked sensors and actuators in societal-scale infrastructure systems.

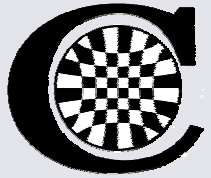
• *Resource management test beds*:
- electric power
- transportation
- water


- *Deliverables*: Engineering Methods, Models, and Toolkits for:
- design and analysis of systems with embedded computing
- computation integrated with the physical world
- analysis of control dynamics with software and network behavior
- programming the ensemble, not the computer
- computer-integrated systems oriented engineering curricula

# Strategic Framework



# Caltech ITR



**Information Dynamics for Networked Feedback Systems**
Murray, Hassibi, Effros, Schulman, Low, Doyle

- investigating the dynamics of information in complex, interconnected systems
- key technical thrusts of the project:
  (1) real-time information theory
  (2) robust control of networks
  (3) packet-based control theory
  (4) computational complexity of network systems
- explores aspects of information systems that must interact with the real-world in a manner that requires careful control of the timing of the computation and the evolution of the information state of the system

- with Karl-Erik Arzen (Lund) (Yasi Mostofi and Anders Rantzer)