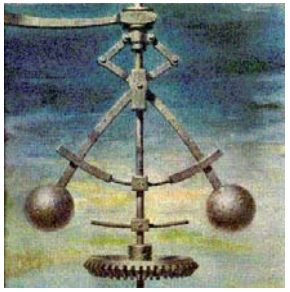
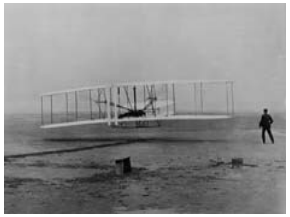


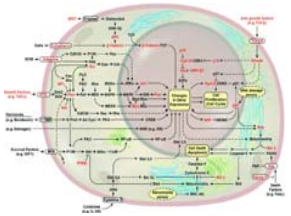


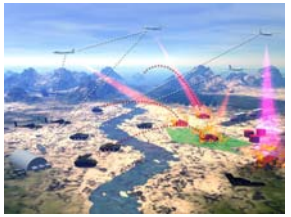
Cross Disciplinary Research and the Role of Industry

Richard Murray

John Baras **Bob Barmish**

Mike Grimble **Lennart Lung**

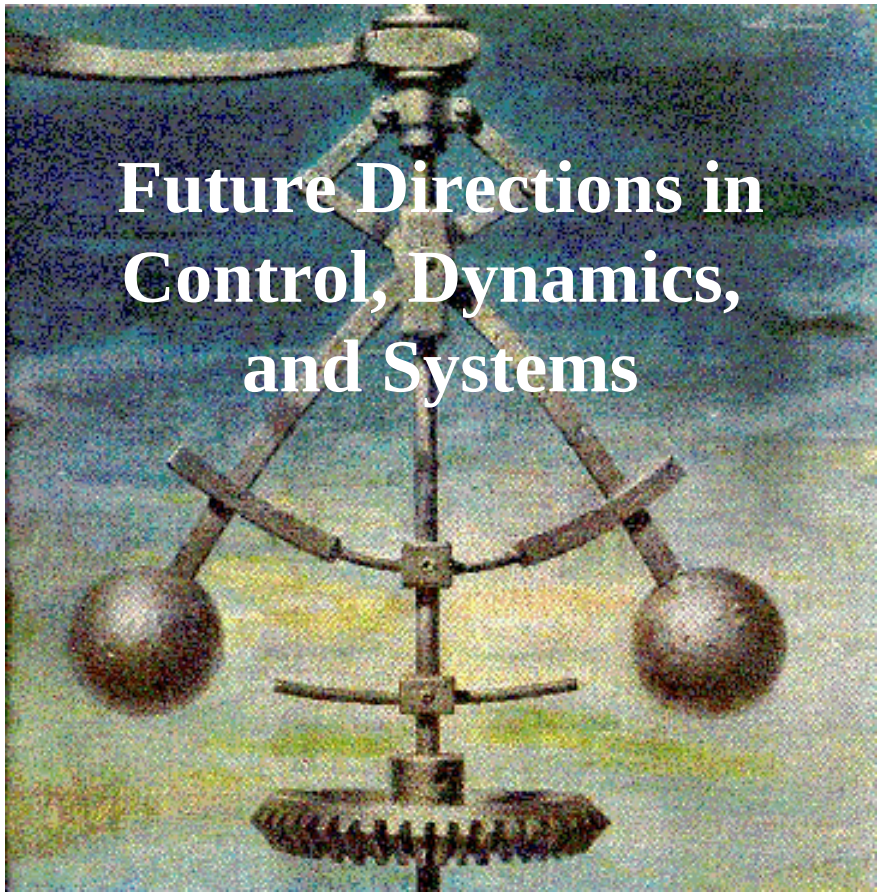




Outline

I. CDS Panel Overview
II. Findings and Recommendations
III. Workshop Agenda and Goals

http://www.cds.caltech.edu/~murray/cdspanel



Panel on Future Directions in Control, Dynamics, and Systems

Goals

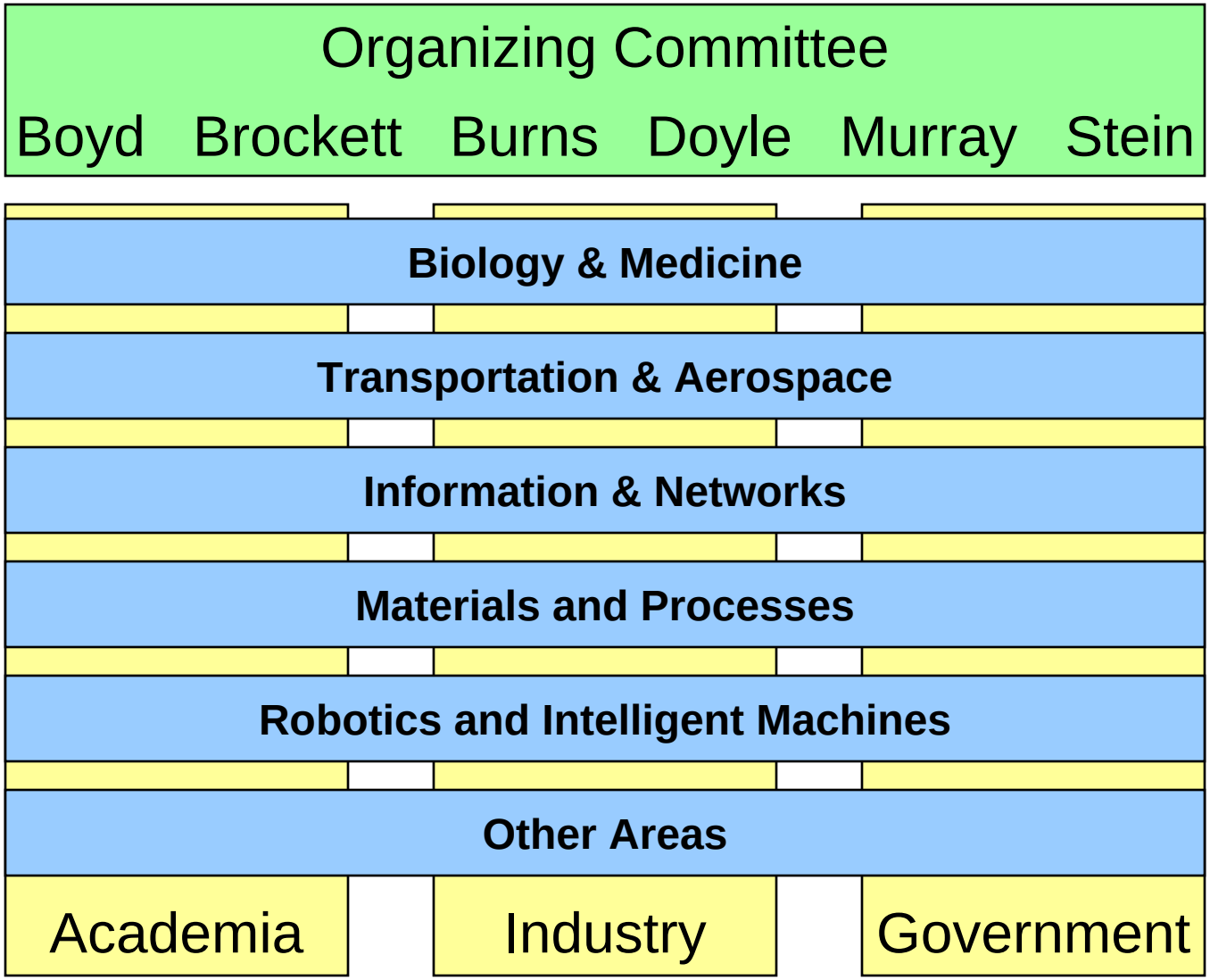
- Articulate the challenges and opportunities for the field
- Respond to the changing nature of control, dynamics, and systems research

Approach

- Workshops and discussions
- SIAM report

Karl Åström	Siva Banda	Stephen Boyd	Roger Brockett	John Burns
Munther Dahleh	John Doyle	J. Guckenheimer	Charles Holland	P. Khargonekar
P. S. Krishnaprasad	P. R. Kumar	Jerrold Marsden	Greg McRae	George Meyer
Richard Murray	William Powers	Gunter Stein	Pravin Varaiya	

Panel Organization and Timeline



Apr ’00	Formation
Jun ’00	Workshop
Jan ’01	Draft 1.0
Oct ’01	Draft 2.0
Jan ’02	Draft 3.0
Apr ’02	Release + Workshop
Jul ’03	Published
Dec ’03	CDC 2003 workshop

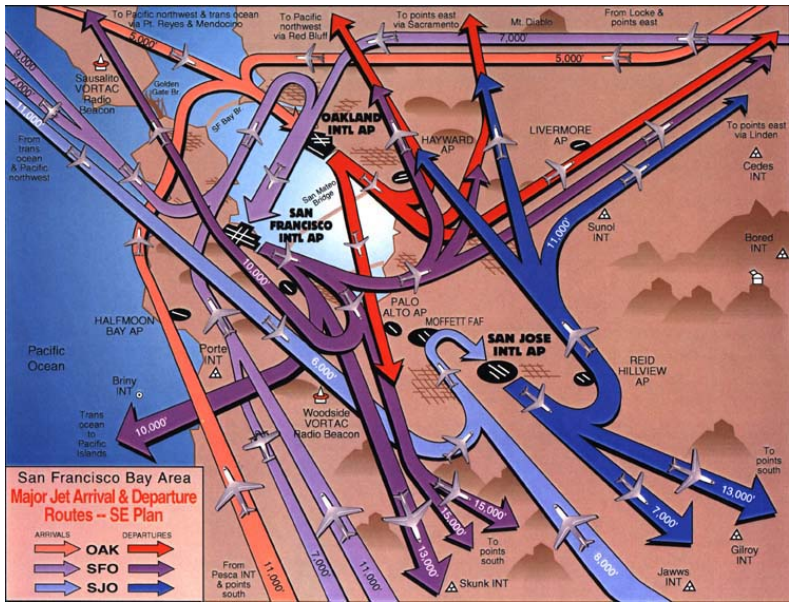
Transportation and Aerospace

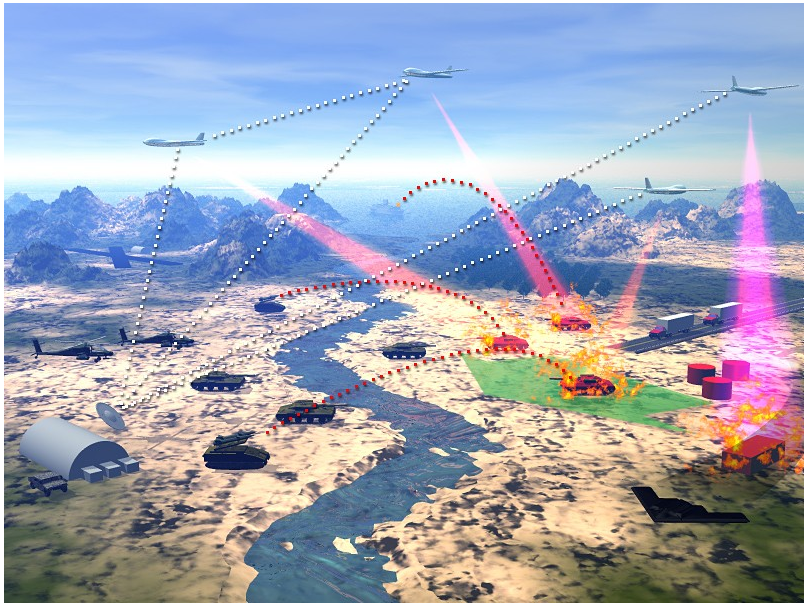
Themes

- Autonomy
- Real-time, global, dynamic networks
- Ultra-reliable embedded systems
- Multi-disciplinary teams
- Modeling for control
  - more than just $\dot{x} = f(x, u, p, w)$
  - analyzable accurate hybrid models

Technology Areas

- Air traffic control, vehicle management
- Mission/multi-vehicle management
- Command & control, human in the loop
- Ground traffic control (air & ground)
- Automotive vehicle & engine control
- Space vehicle clusters
- Autonomous control for deep space





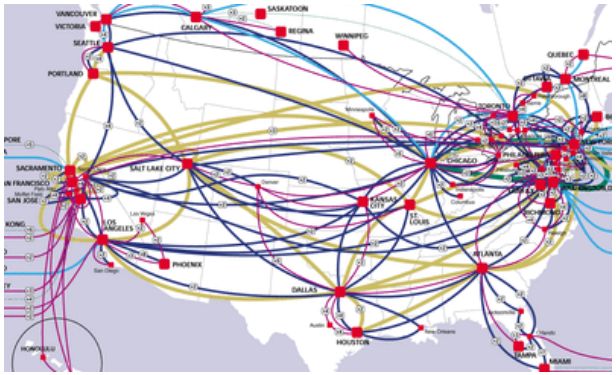
Information and Networks

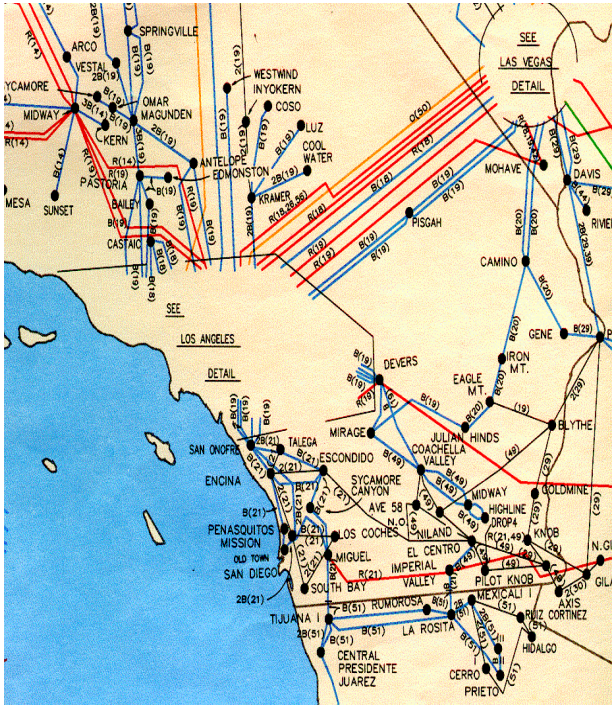
Pervasive, ubiquitous, convergent networking

- Heterogeneous networks merging communications, computing, transportation, finance, utilities, manufacturing, health, entertainment, ...
- Robustness/reliability are dominant challenges
- Need "unified field theory" of communications, computing, and control

Many applications

- Congestion control on the internet
- Power and transportation systems
- Financial and economic systems
- Quantum networks and computation
- Biological regulatory networks and evolution
- Ecosystems and global change





Control <u>of</u> the network

Control <u>over</u> the network

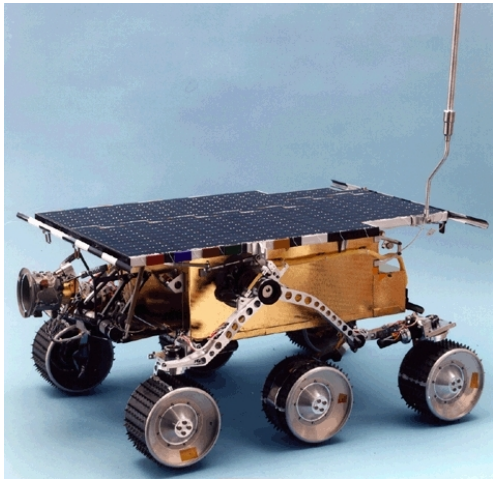
Robotics and Intelligent Machines

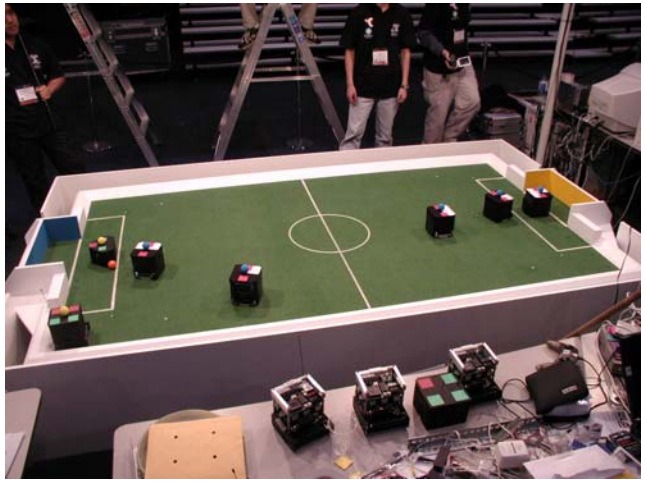
Wiener, 1948: Cybernetics

- Goal: implement systems capable of exhibiting highly flexible or ``intelligent'' responses to changing circumstances

DARPA, 2003: Grand Challenge

- LA to Las Vegas (400 km) in 10 hours or less
- Goal: implement systems capable of exhibiting highly flexible or ``intelligent'' responses to changing circumstances





Biology and Medicine

"Systems Biology"

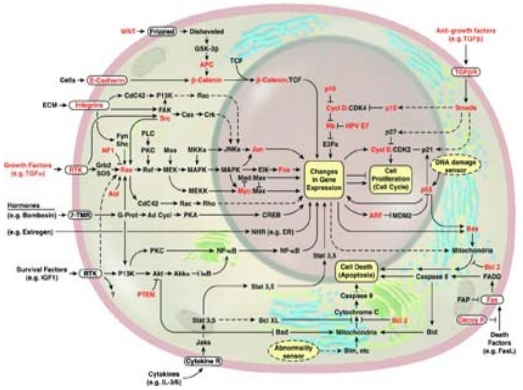
- Many molecular mechanisms for biological organisms are characterized
- Missing piece: understanding of how network interconnection creates robust behavior from uncertain components in an uncertain environment
- Transition from organisms as genes, to organisms as networks of integrated chemical, electrical, fluid, and structural elements

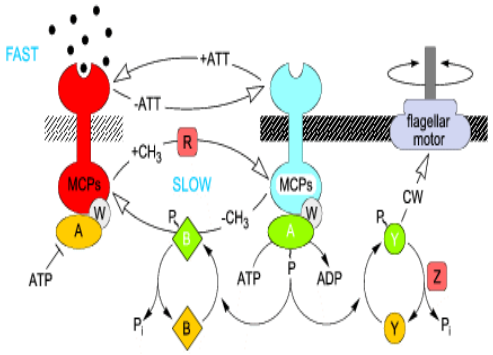
Key features of biological systems

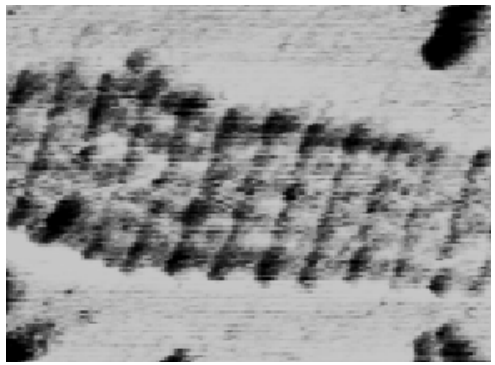
- Integrated control, communications, computing
- Reconfigurable, distributed control, at *molecular* level

Design and analysis of biological systems

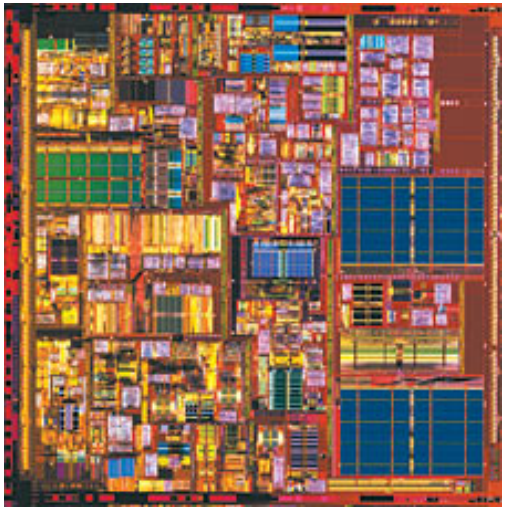
- Apply engineering principles to biological systems
- Systems level analysis is required
- Processing and flow of information is key







Materials and Processing

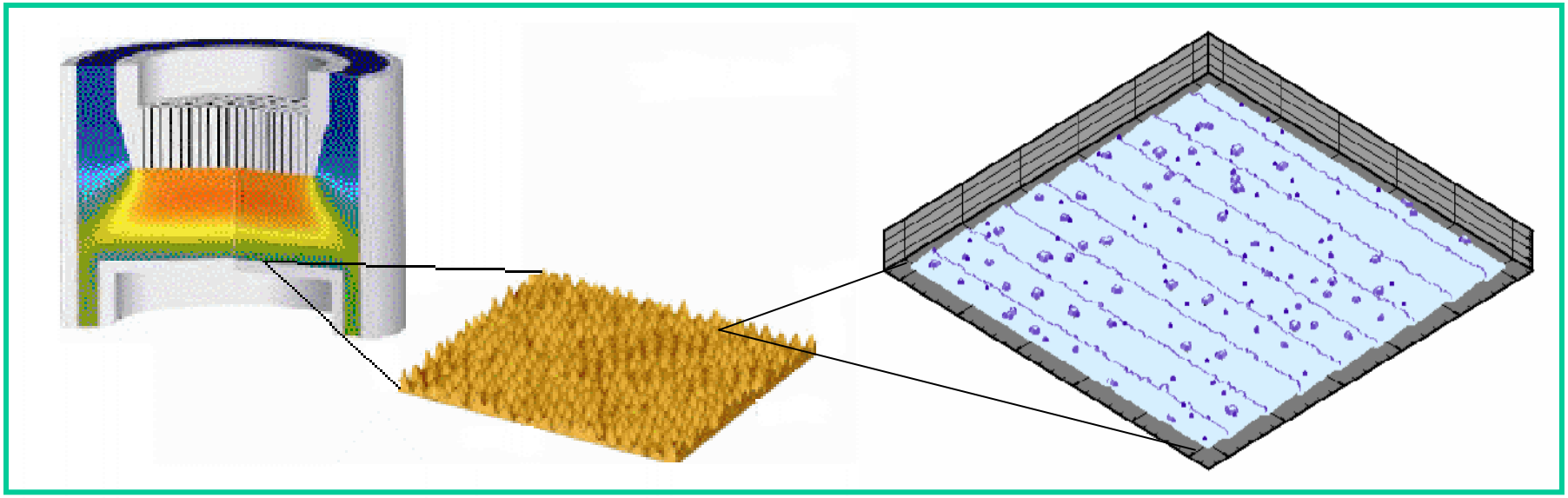


Multi-scale, multi-disciplinary modeling and simulation

- Coupling between macro-scale actuation and micro-scale physics
- Models suitable for control analysis and design

Increased use of in situ measurements

- Many new sensors available that generate real-time data about microstructural properties



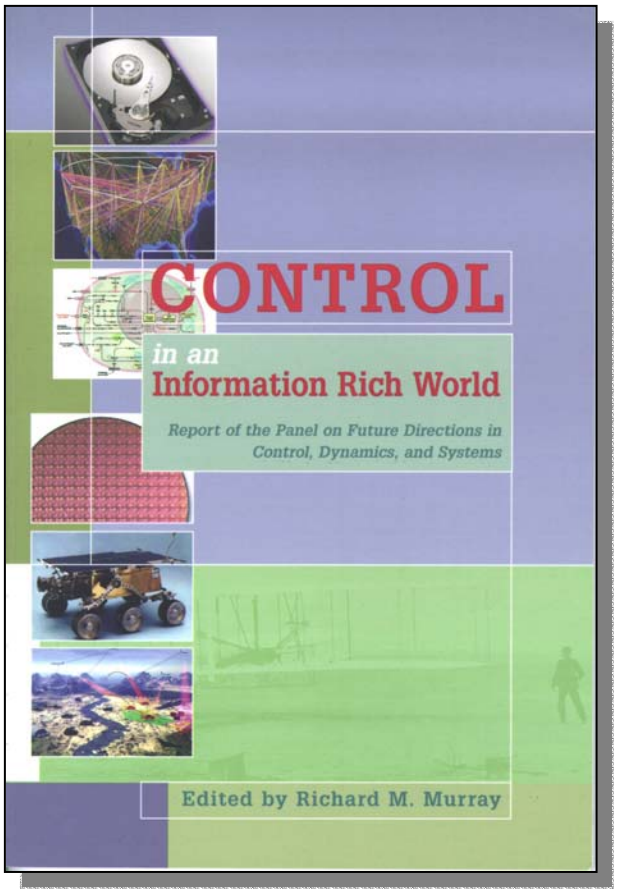
Control in an Information Rich World

Control remains an exciting area, with *many* new applications

- Community needs to get involved in new applications (already happening!)
- Need to maintain support for control research by government, industry

Panel Recommendations

1. Increase research aimed at the integration of control, computer science, & communications
2. Increase research in control at higher levels of decision making, moving toward enterprise level systems
3. Explore high-risk, long-range applications of control in nanotechnology, quantum mechanics, electro-magnetics, biology, environmental science, etc
4. Maintain support for theory and interaction with mathematics
5. New approaches to education to disseminate control concepts and tools to non-traditional audiences



Education and Outreach (Ch 4 of report)

Expanding applications placing new demands on education

- Must continue to unify and compact the knowledge base
- Material needs to be more accessible to broad range of potential user
- Eg, computer scientists, biologists, physicists, medical researchers

Increased interaction with industry

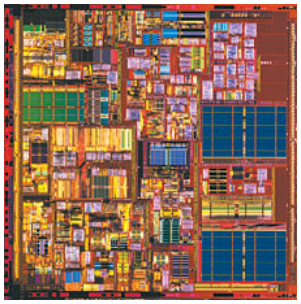
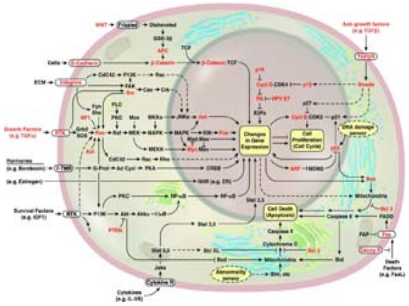
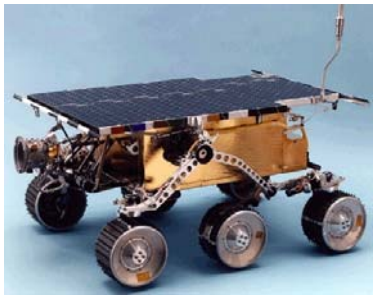
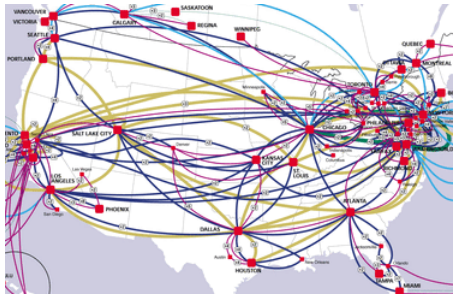
- Cooperative Ph.D. programs: industrial researchers by companies and universities to pursue Ph.D.'s (full-time)
- Industry leaders from the control community should continue to interact and help communicate needs of their constituencies

Additional steps

- New textbooks, teaching materials, pedagogy
- Better education of the public about relevant technical areas

Cross-Disciplinary Research

Need for increased cross-disciplineary research and eduction

Challenges of cross-disciplinary research

- Educational programs often defined by traditional disciplines (esp in US)
- Control is small part of discussions on curriculum in these disciplines
- Additionally, many new applications are outside the current boundaries

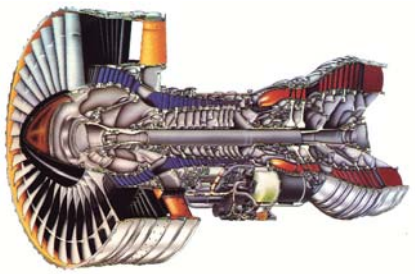
Education and research programs may need to be restructured

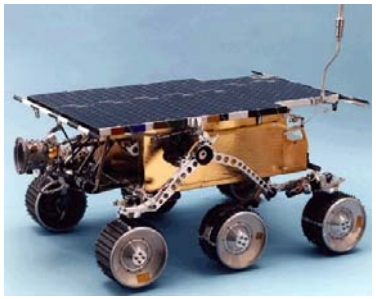
- Step 1: cross-disciplinary research centers (eg, ISR, CSL, CCEC)
- Step 2: cross-departmental graduate courses, seminars, projects
- Step 3: undergraduate minors and MS/PhD programs in systems and control
- Additional possibilities: regional alliances - DISC, SoCal NLC, etc

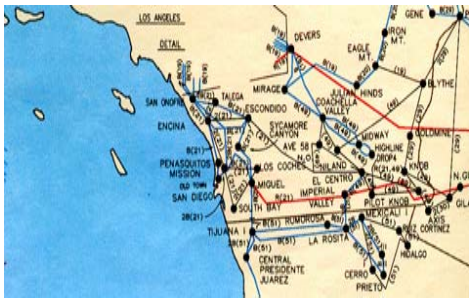
The Role of Industry

Role of control in industry

- Industry has substantial experience in cross-disciplinary projects (eg IPTs)
- Increasingly, control engineers are serving as *systems* engineers
- Requires strong interdisciplinary skills and interpersonal (team) skills







Increased need for *interaction* with industry

- Best practices in team-oriented, systems engineering integrated into courses
- Transition of new ideas and tools to industry; new problems to universities

Obstacles

- Intellectual property, publishing restrictions, ITAR, competition
- Low priority on funding universities for long range, fundamental research
- Industry researchers often too busy to attend workshops (like this one!)

Workshop Goals

Explore mechanisms for cross-disciplinary research, particularly through interaction with industry

- Discussion of obstacles and issues that must be overcome
- Examples of success stories and models from around the world
- Information on programs that can be used to support interaction

Short term goal: provide ideas for things to try when you go home

- Copies of presentations will be placed on CDS Panel web site
- Summary report for NSF will be generated and distributed to praticipants

Long term goal: increase role of control in cross-disciplinary research

- Get students excited about control courses and research opportunities
- Provide students with training that makes them in high demand by industry
- Increase the support for control research by industry and within industry

http://www.cds.caltech.edu/~murray/cdspanel

Workshop Agenda

8:30 am	Richard Murray	Welcome and Introduction
9:00 am	P. Khargonekar	Issues and Perspectives on Cross Disciplinary Research
9:30 am	Bob Barmish	Cross-Disciplinary Research and Industrial Collaboration: A Two-Edged Sword
10:00 am		Discussion and break
10:30 am	Richard Murray	Three Views on Industry/University Collaboration
11:00 am	Mike Grimble	Integrated International Services for Industry
11:30 am	Lennart Ljung	ISIS -- A center for industry-university cooperation at Linkoping University
12:00 pm		Lunch
1:30 pm	Kishan Baheti	NSF Grants Opportunity for Academic Liason with Industry (GOALI)
2:00 pm	Panel discussion	Recommendations for future activities