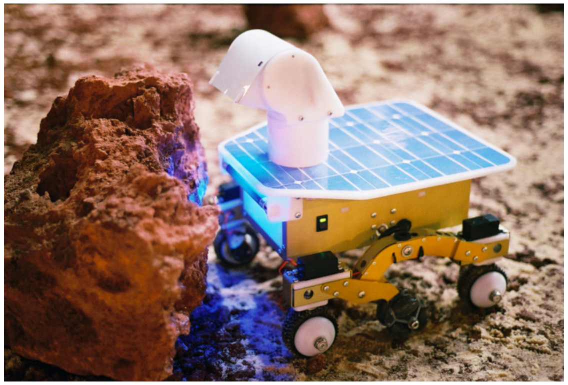
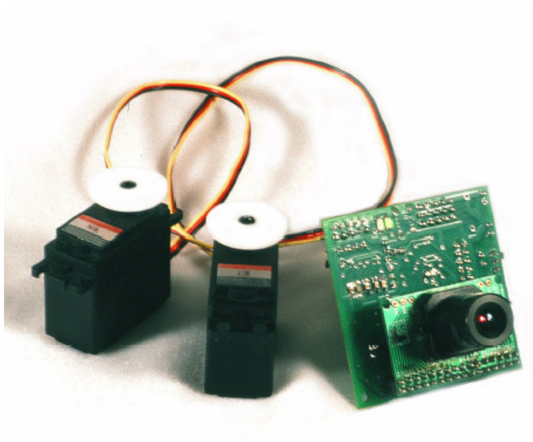
Personal Rover Project





Illah Nourbakhsh | Boeing | January 2005

The Toy Robots Initiative

Research Agenda

Human-robot interaction

Low-overhead perception

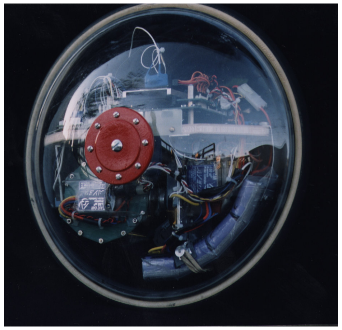
Embedded robotic computation

Human-scale locomotion

Educational Robotics

Commercialization Plan

Open source licensing..



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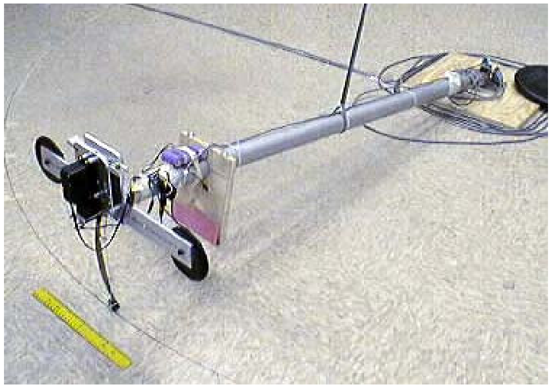

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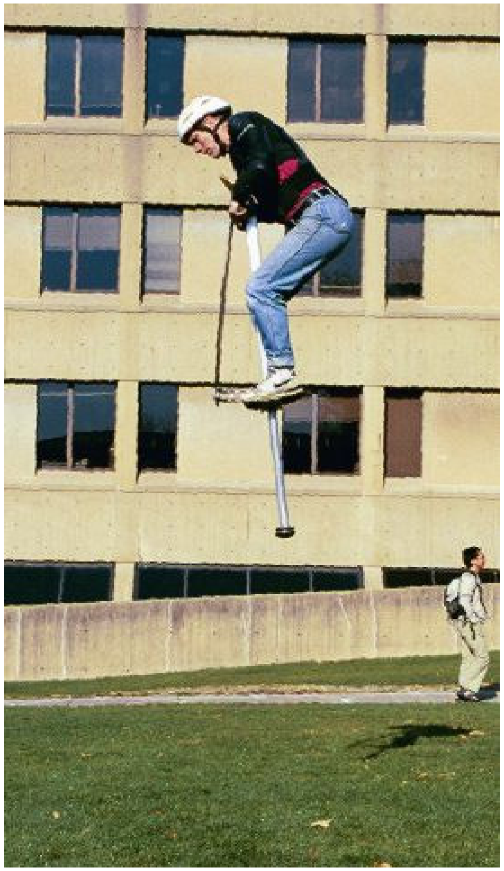


Personal Rover Project Goals

- Inspire children to explore the boundaries of knowledge and creativity; science and technology
- Stimulate the public's appreciation of the technologies that enable NASA missions and mobile robotics to succeed - the role of advanced autonomy
- Provide an Apple II trajectory for robotics

  curriculum >> community >> invention

A Personal Rover

The rover is a a *tool* for science & exploration:

- Remote eyes for inaccessible places & times
- Patient observer
- Consistent documentarian
- Creative outlet
- Proactive team member

Research Questions

Long-term mixed autonomy: planning, control and diagnostic reasoning

Human-robot interaction design: inquiry, formative analysis

Enabling competencies:

- Low-cost robust motor control and locomotion
- Low-overhead perception for tracking and avoidance
- On-board embedded architecture, with wireless

Human-Robot Experience

How would the user remain engaged with the personal rover over the course of weeks and months?

-Emergent Design

Study conclusions

1 Develop a rich user community

2 Draw the user into the robot's sophistication

3 Provide sufficient perception for real results

https://postdoc.arc.nasa.gov/postdoc/t/folder/main.ehtml?url_id=77529

The Plan

1. Perception and locomotion technology
2. Conduct “pilot” study with formal assessment
3. Refine then expand the educational footprint

Embedded Perception Goals

Lower the barrier to using vision as a sensor

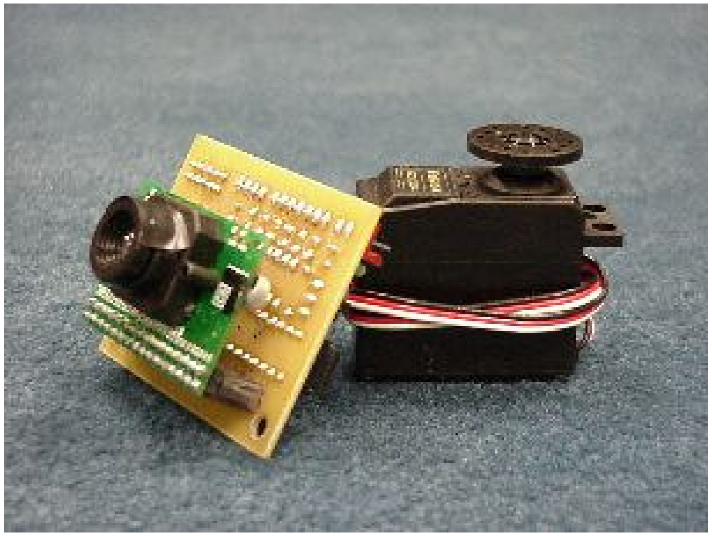
- Simple interface provides high level meta-data
- Low-overhead: cost, construction, power
- Complete package

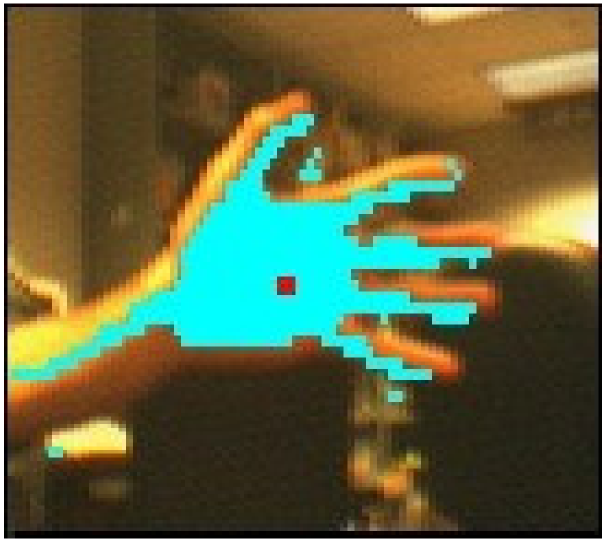
Pack as much functionality as possible into the simplest system possible.

- Speed & robustness over precision

CMUcam: Low-overhead Perception

Anthony Rowe, Chuck Rosenberg

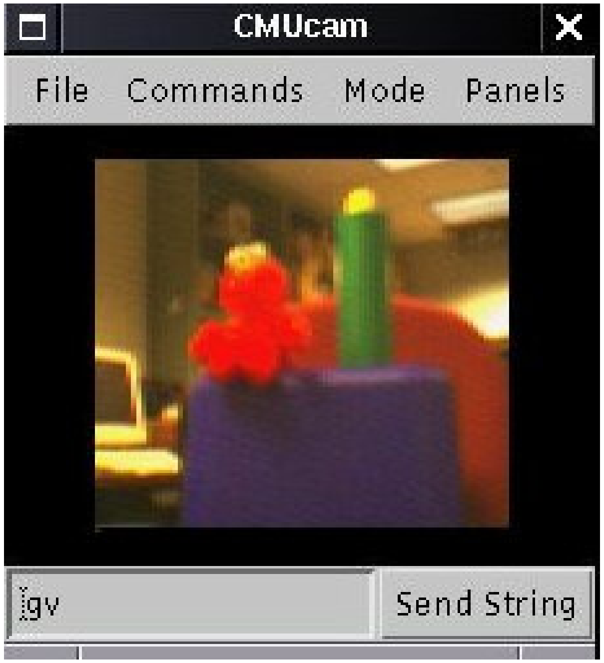


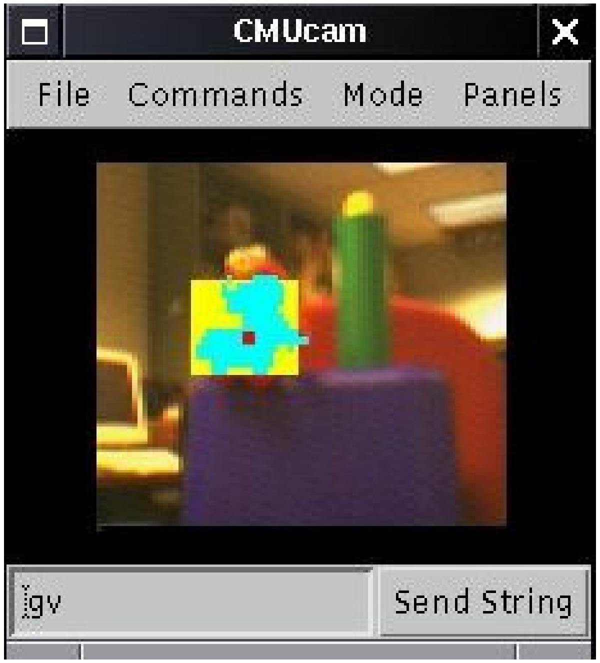


-User community exceeds 1,000 individuals

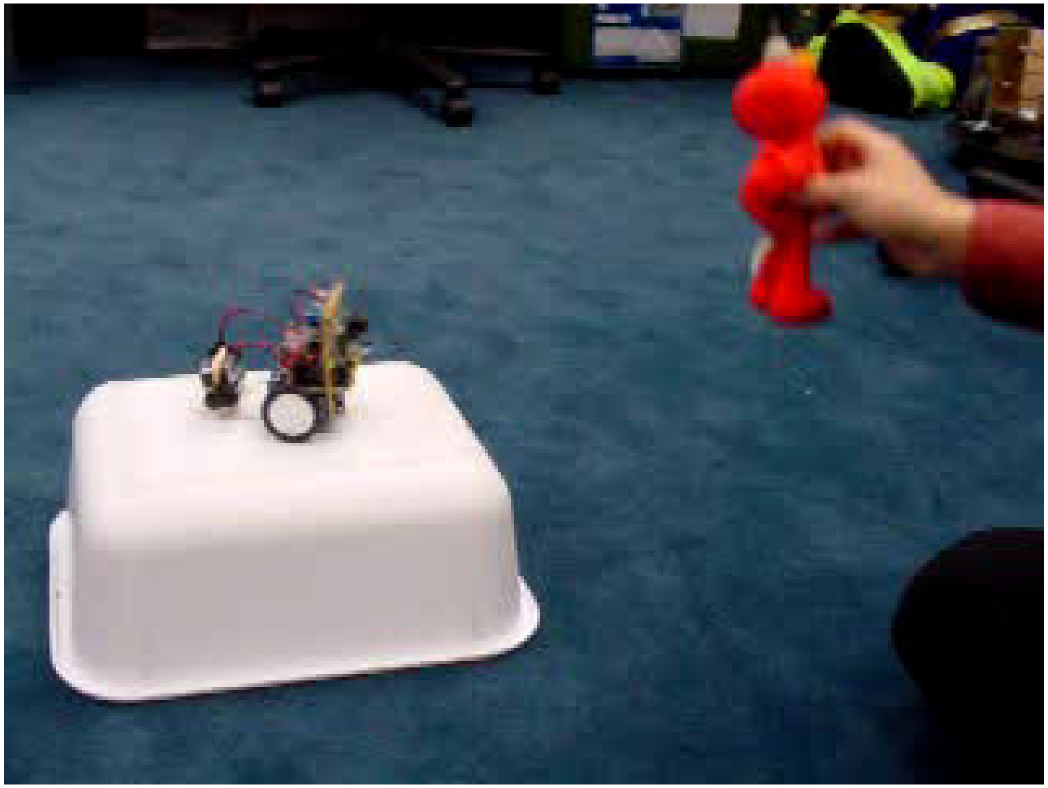
-Color tracking + image statistics at 17 fps

Functionality:
blob bitmap

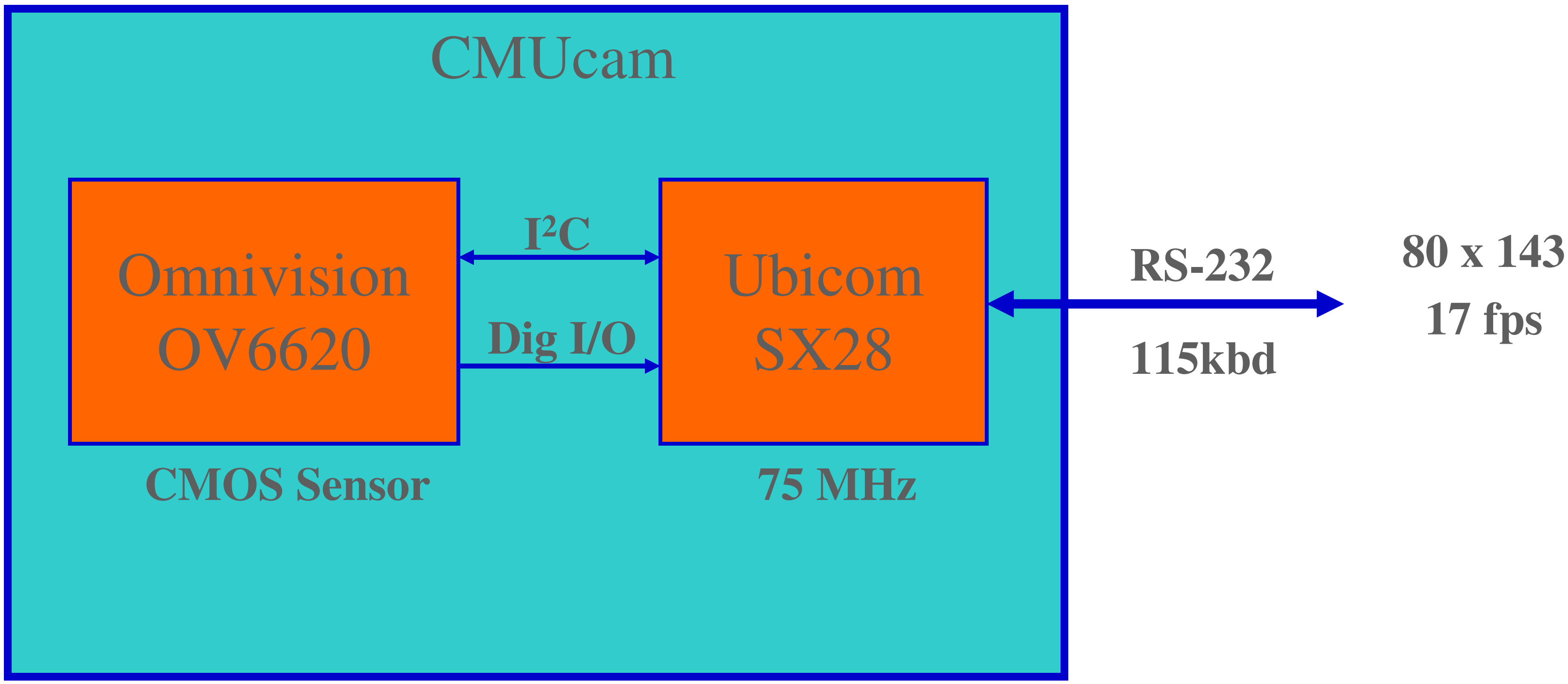




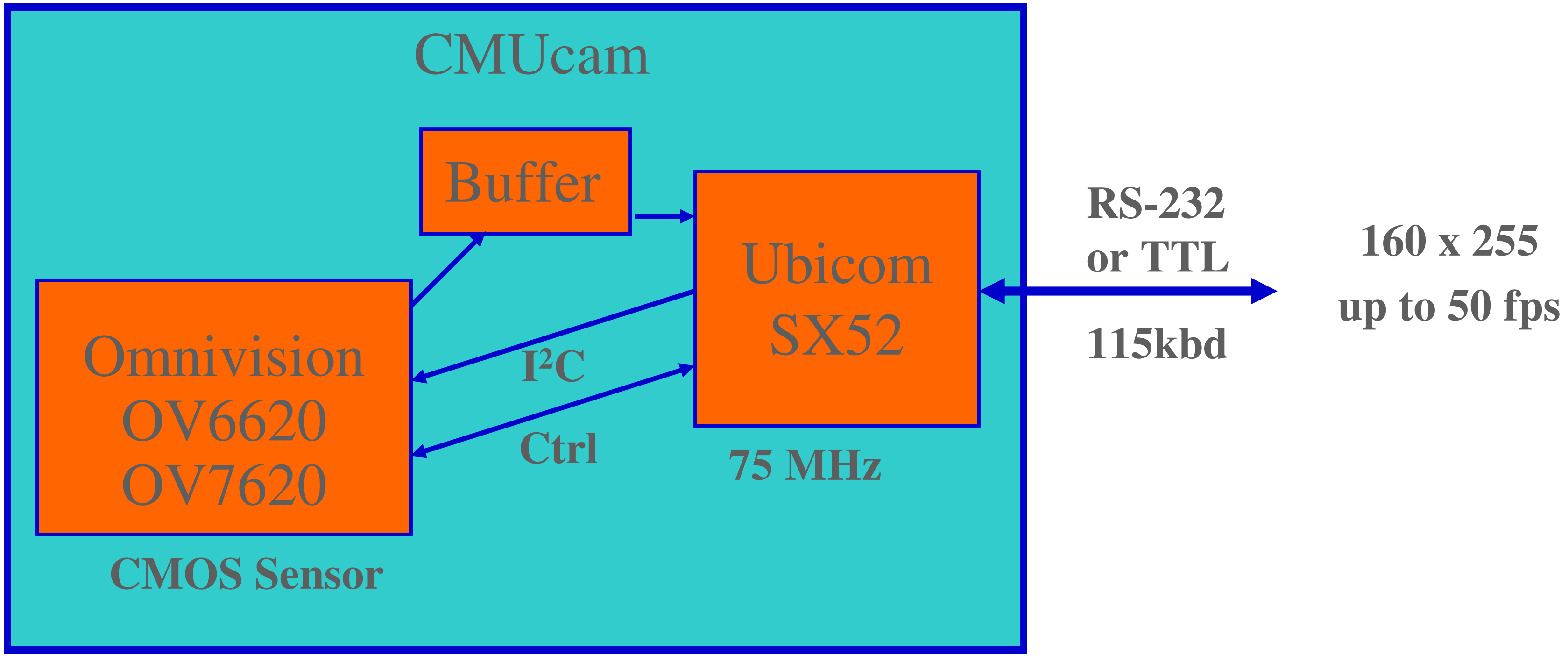
Tracking video



CMUcam Architecture:



CMUcam2 Architecture:



Version Comparison

Chuck Rosenberg, Anthony Rowe

CMUcam	CMUcam2
80 x 143 resolution	160 x 255 resolution
color tracking, 17fps	color tracking, 50fps
color stats, 17fps	color histograms, 26fps
multi-frame capture	motion differencing, 26fps
camera parameters	pixel differencing
1 controlled servo	single frame capture
	multi-pass single frame
	5 servo outputs, pan+tilt
	analog video output

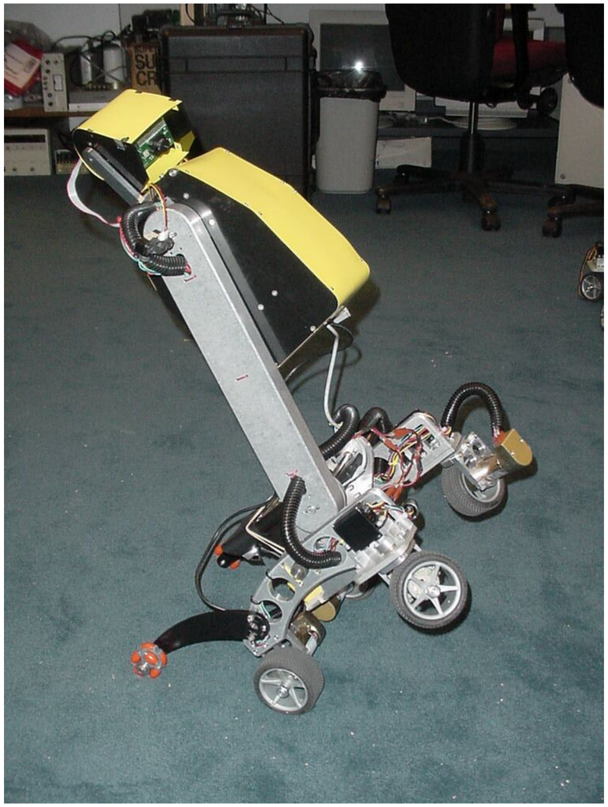
CMUcam2 Demonstration...

Locomotion Goals

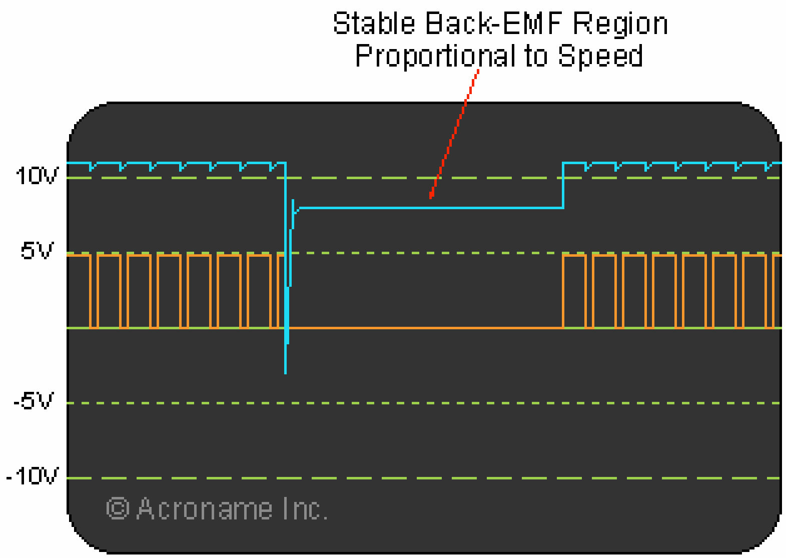
- Mechanical expressiveness
- Low static power consumption
- Terrainability in indoor and backyard settings
- 6 -7 inch ledge traversal
- Vision-centered sensing mechanism
- Unmodified off-the-shelf motors and servoes
- No joint zeroing / calibration
- Designed for manufacturability

Personal Rover1

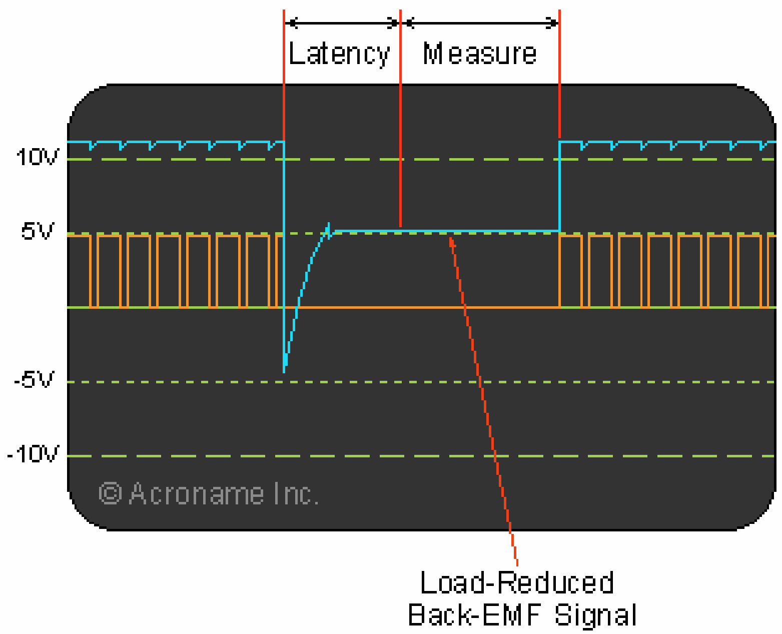
- COM-moving Rover1 mechanism
- Back-EMF speed control
- Duty-based terrain inference
- Mechanical expressiveness
- CMUcam-based perception
- Distributed motor network model



Back-EMF Speed Control
EPFL, Randy Sargent, Steve Richards



75% Duty Cycle Simulated Scope



75% Duty Cycle with High Load Simulated Scope

Terrain-sensed ledge climbing

Mechanical awareness

Robotic Autonomy: *RI 16-162U*

Course Overview

July 1 – August 16, 2002

30 students: 20 Latino; 9 women; 2 NHU teachers

3-person teams

Challenge-based curricula

CMU University credit

Web “open-source”

Goals

Empower students toward all robot hardware, electronics and software

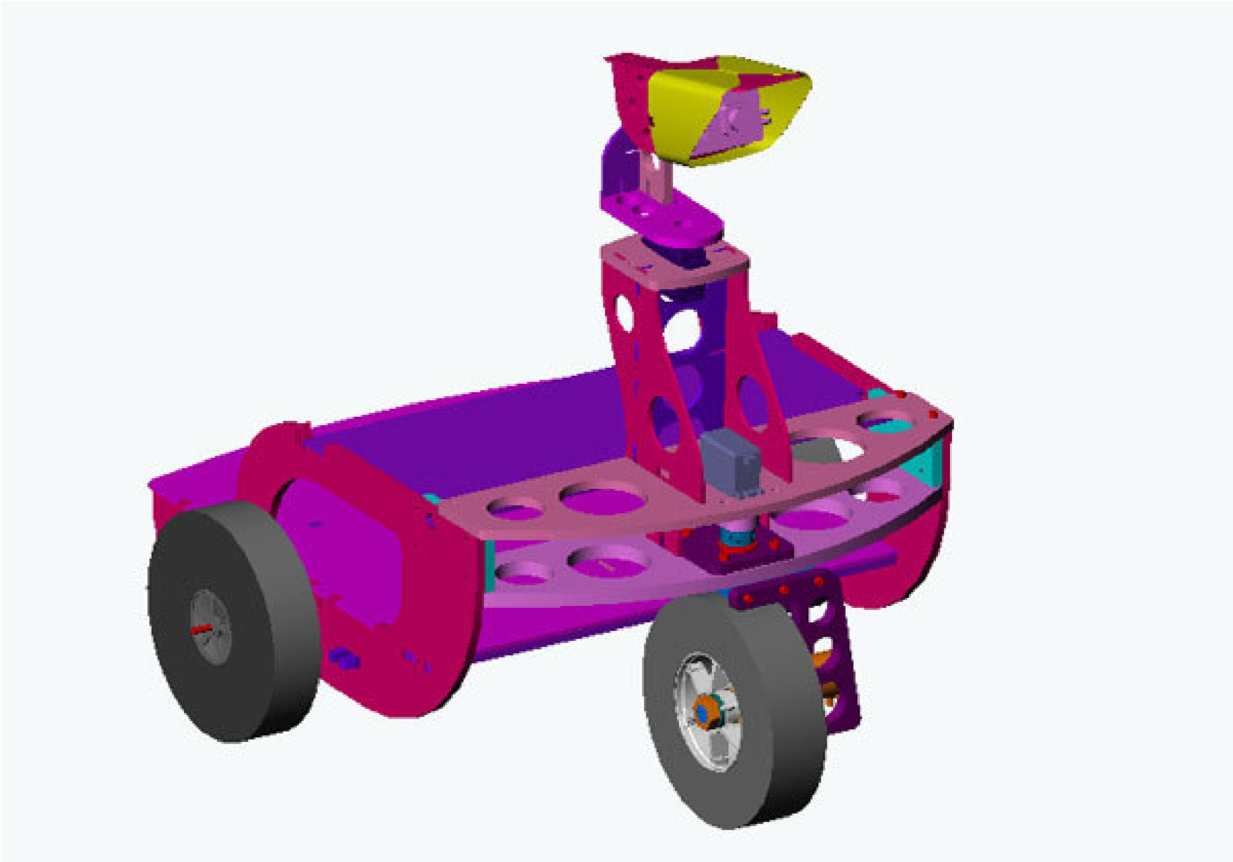
Encourage internalized student goals, both creative and technical

Collect comprehensive weekly information for off-line evaluation

Make the course a starting point for learning

- create a rover community
- give a complete robot to every graduate

Rover2: Trikebot design

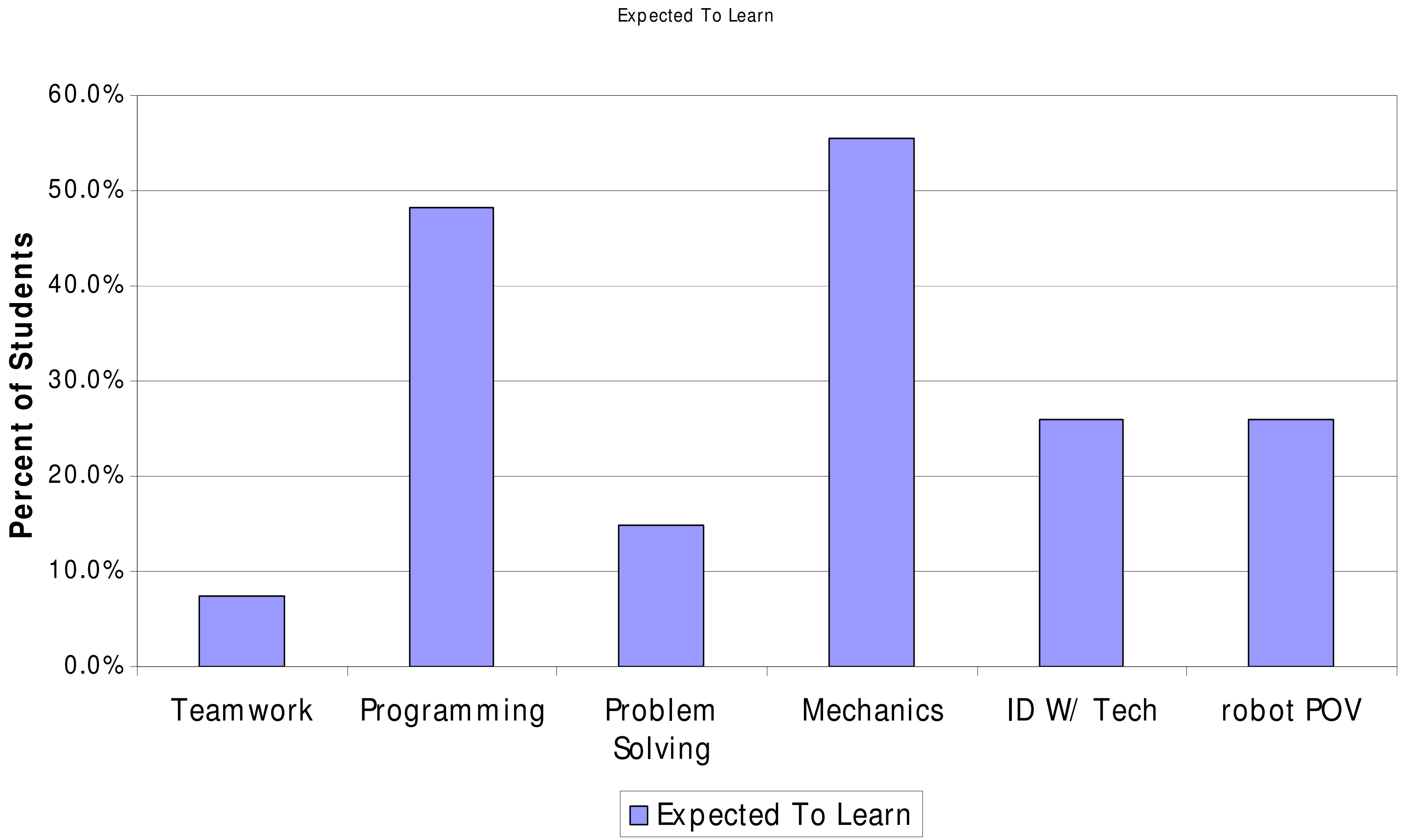


Production

Educational Evaluation Team

- Prof. Kevin Crowley, University of Pittsburgh
  - Assoc. Prof. of Education and Cognitive Psychology, U. Pitt.
  - Learning Research and Development Center, U. Pitt.
  - Director, Research & Evaluation, Pgh Children's Museum
  - "Informal science experiences preparing students for classroom-based science and math education"
- Katie Wilkinson, Psychology at LRDC
- Emily Hamner, Psychology and C.S.
- John D'Ignazio, M.Des and journalist

What Students Expected to Learn and What They Reported Learning



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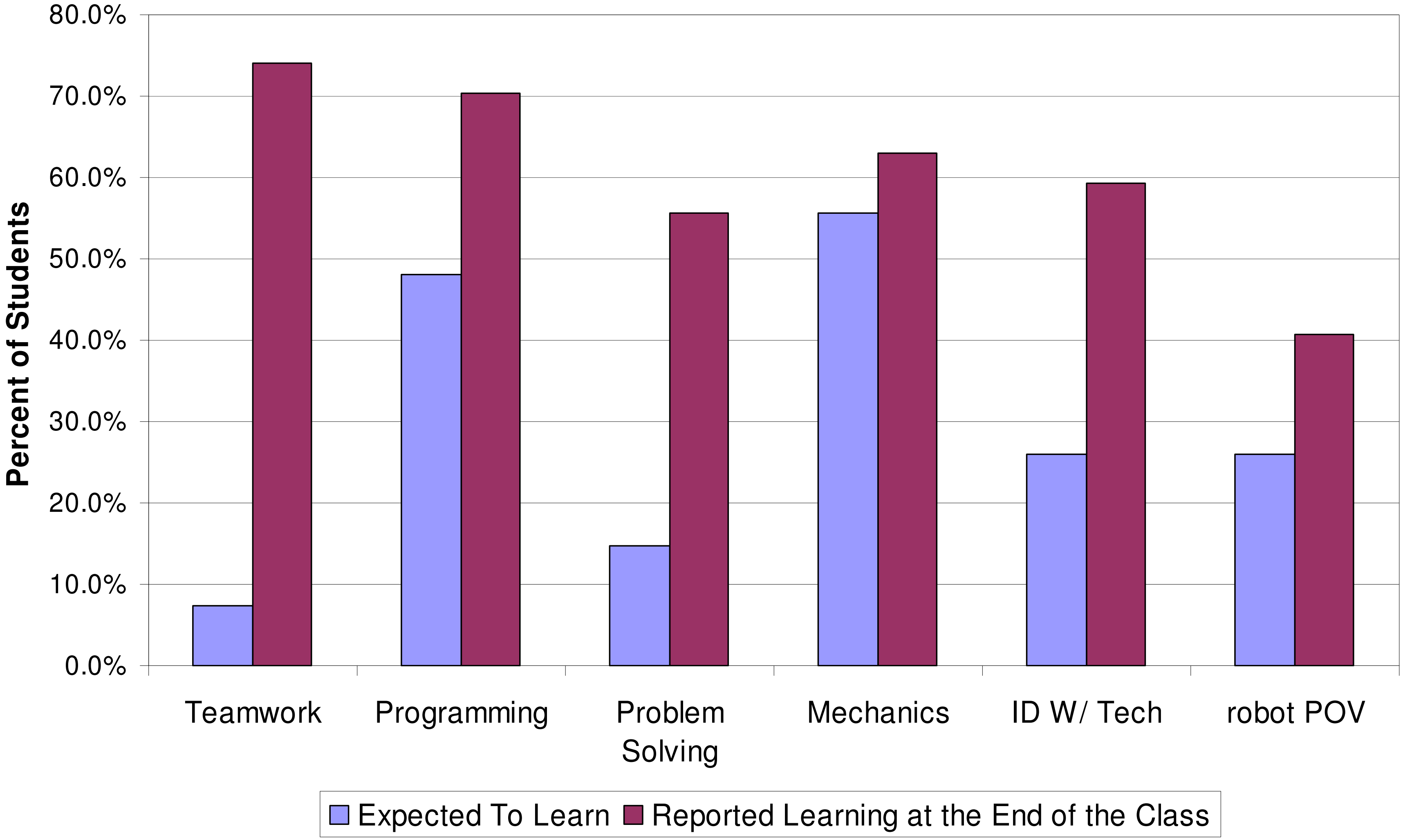


Reported Learning

Quotes from Final Survey

"To have patience."

"To open source ones code for the better of robotics."

"Document what one does so someone else can repeat the experiment [and] be just or even more successful."

"Developed better skills in working in groups"

"That no matter what the obstacle we have, we can still overcome it and solve it."

"Have more confidence with myself."

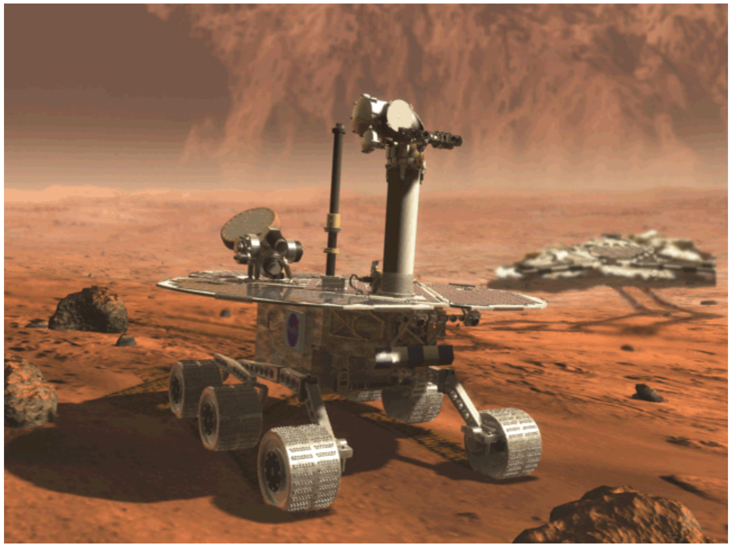
"Teamwork takes a lot of communication."

"I learned that doing something slow is better than doing it twice."

MER Landings, January 2004

Educational goals:

- Rover as tool for performing science exploration
- The role of rover autonomy during science missions



Technical Constraints

System safety & reliability
Power efficiency
Unmediated usability
Time on Task
Throughput
Mechanical expressiveness
Evaluation accessibility

The Team

Carnegie Mellon University Robotics Institute
- *Hamner, Porter, Zhang, Blain, and many others*

Funding & sponsorship
- *NASA/Ames*
- *Intel Corp.*

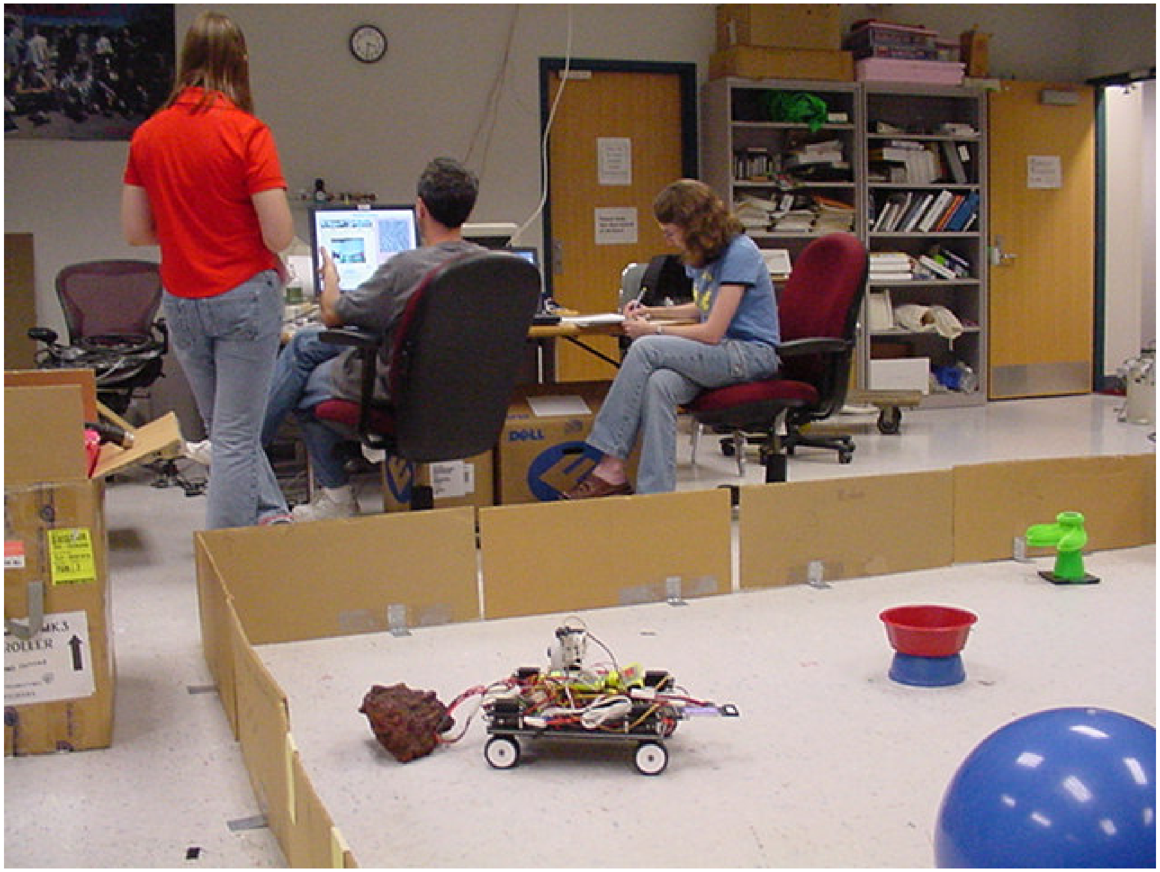
Mechanical design and shepherding
- *Gogoco, LLC*

Electronics production
- *Botrics, Inc., Intel Corp.*

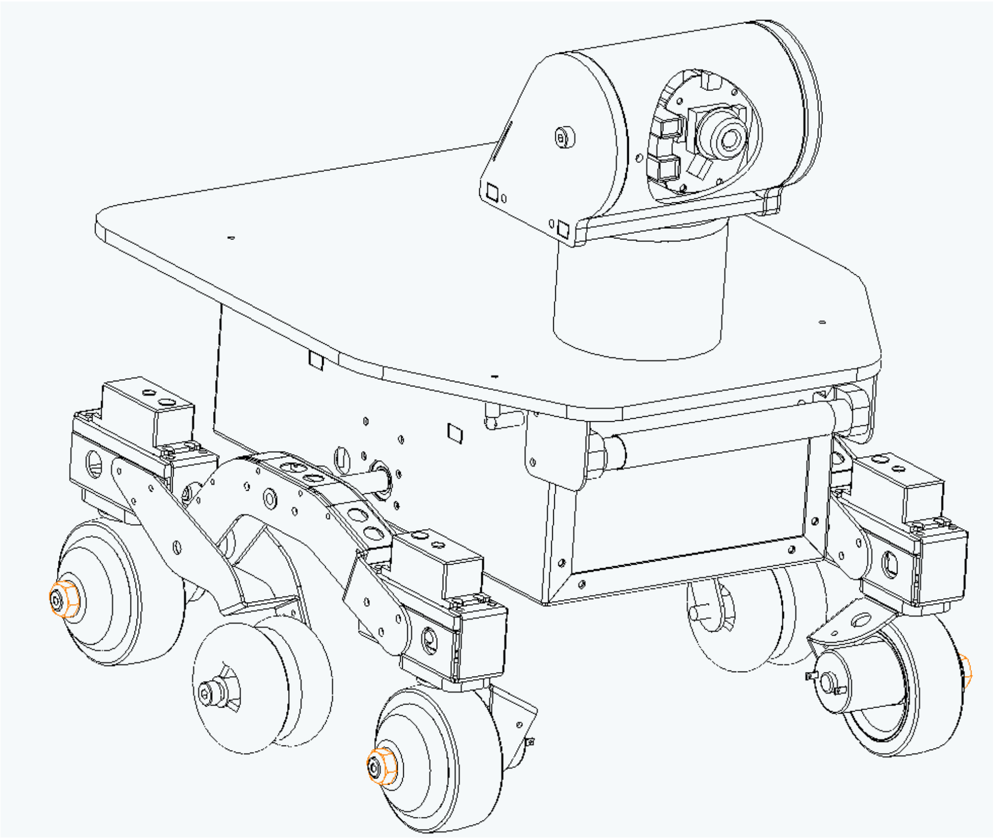
Professional graphic design
- *LotterShelly, Inc*.

Third party educational assessment
- *Learning Research & Development Center (UPITT)*
- *Institute for Learning Innovation (UMD)*

User Studies



Rover Design



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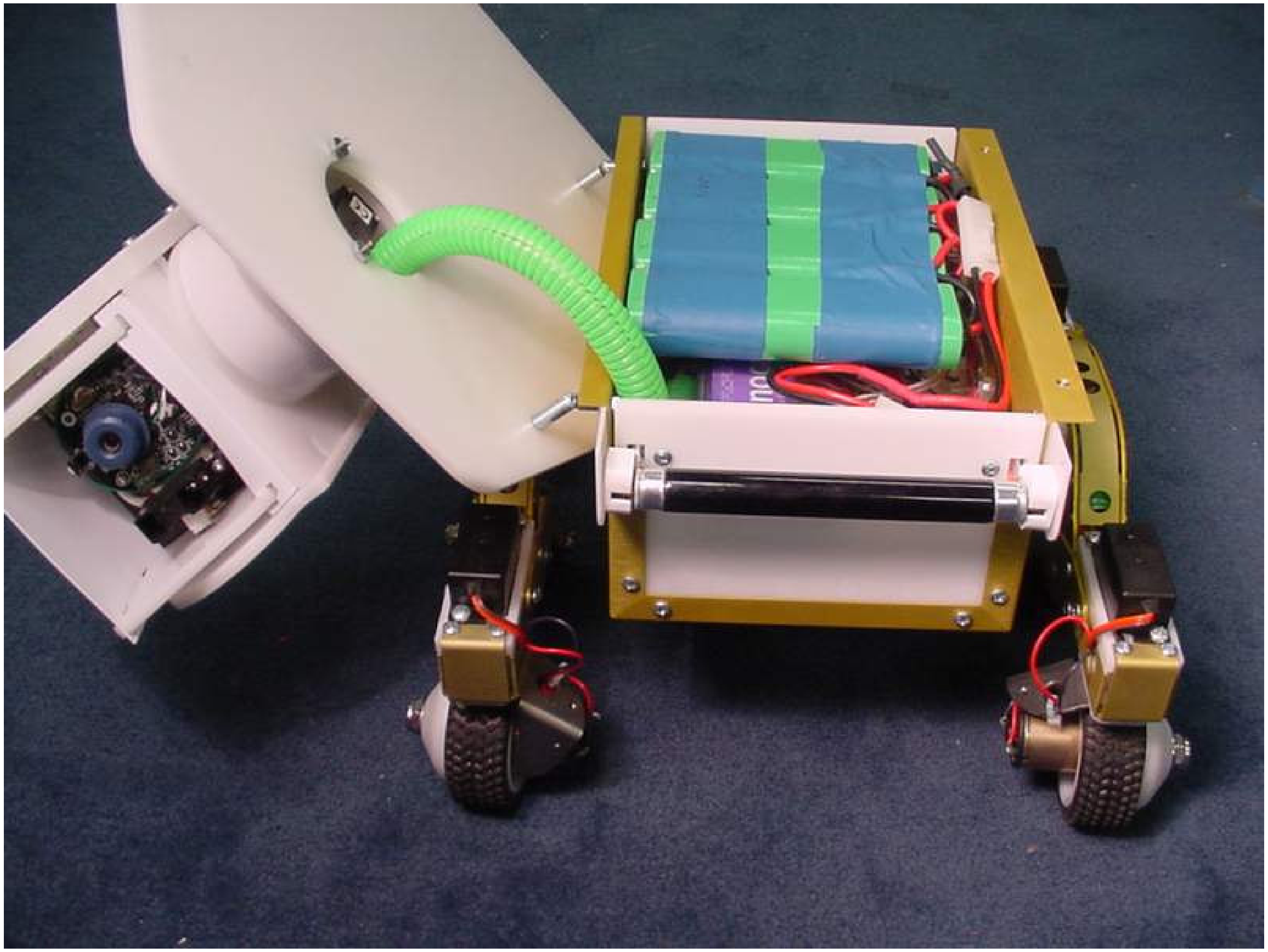

Rover Design

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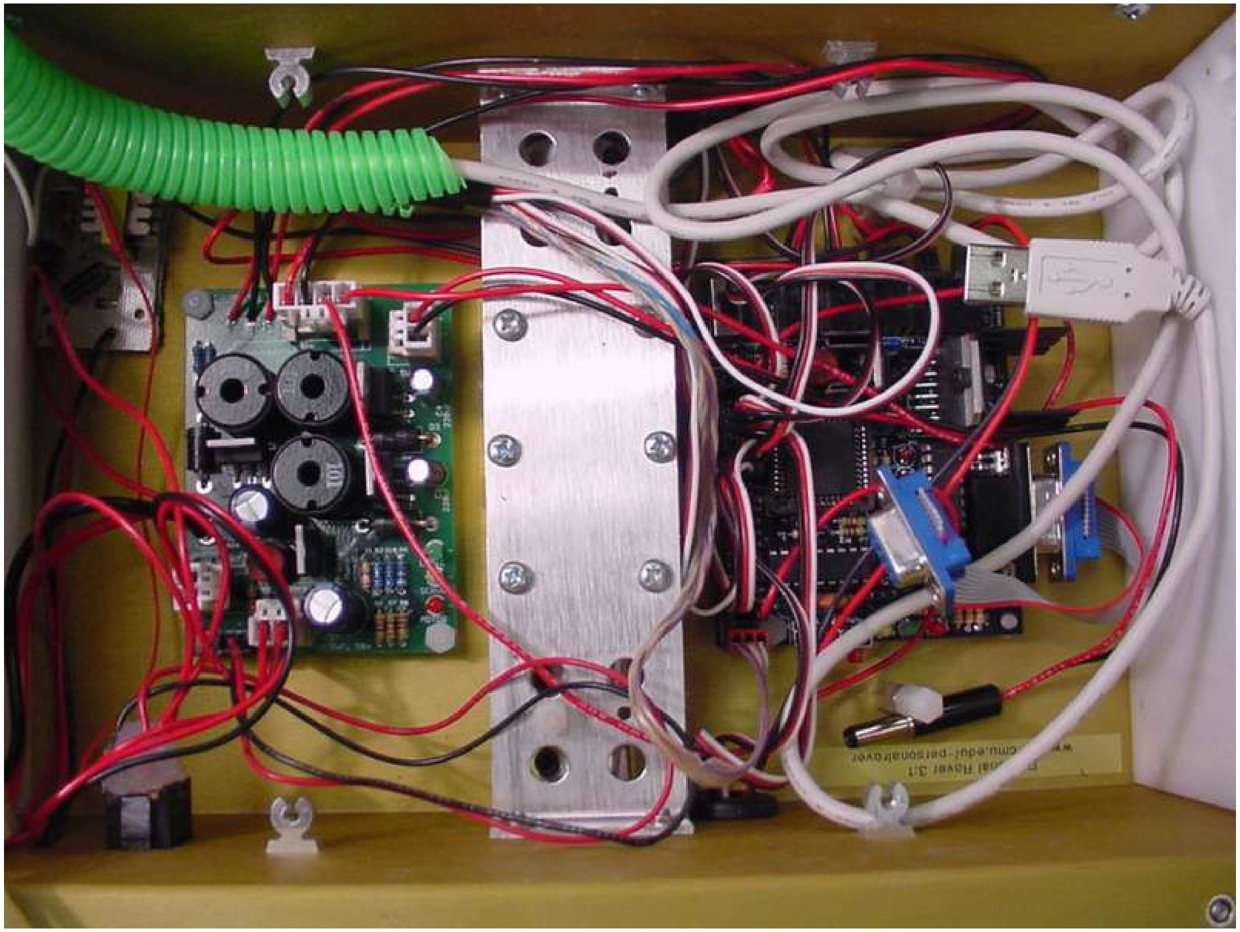


Rover Fabrication

Rover Innovation

Omnidirectional chassis design
Our own production wheel hub
Speed control solution: extreme ratio
Electromechanical sourcing: Taiwan!
Extreme power efficiency
Panorama acquisition
Obstacle and target rangemapping
On-board Arm core Linux
Twin processor control architecture
Production quantity and QA process

San Francisco Exploratorium

The Museum PER Package

- 1 PER per Mars yard
- 1 Kiosk computer per yard (Intel Corp.)
- Spare PER for immediate swap
- Design guidelines for yard, kiosk, signage, flow
- Curriculum package for outreach
  - MER / PER comparison and analysis
  - PER dissection and description
  - Rover scientist interview footage
  - MER link organization
- 6 months equipment and support

Museum Summary

- Smithsonian Air & Space Museum
- San Francisco Exploratorium
- Smithsonian Udvar-Hazy Center
- National Science Center
- NASA/Ames Mars Center

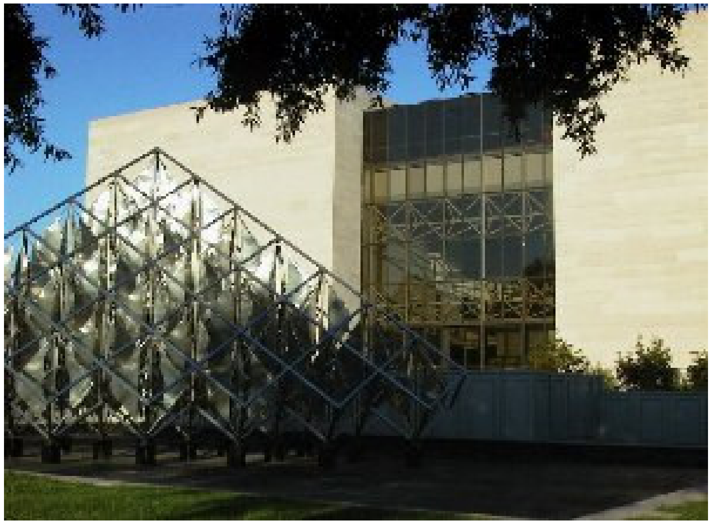
National Air & Space Museum

15 million visitors per year

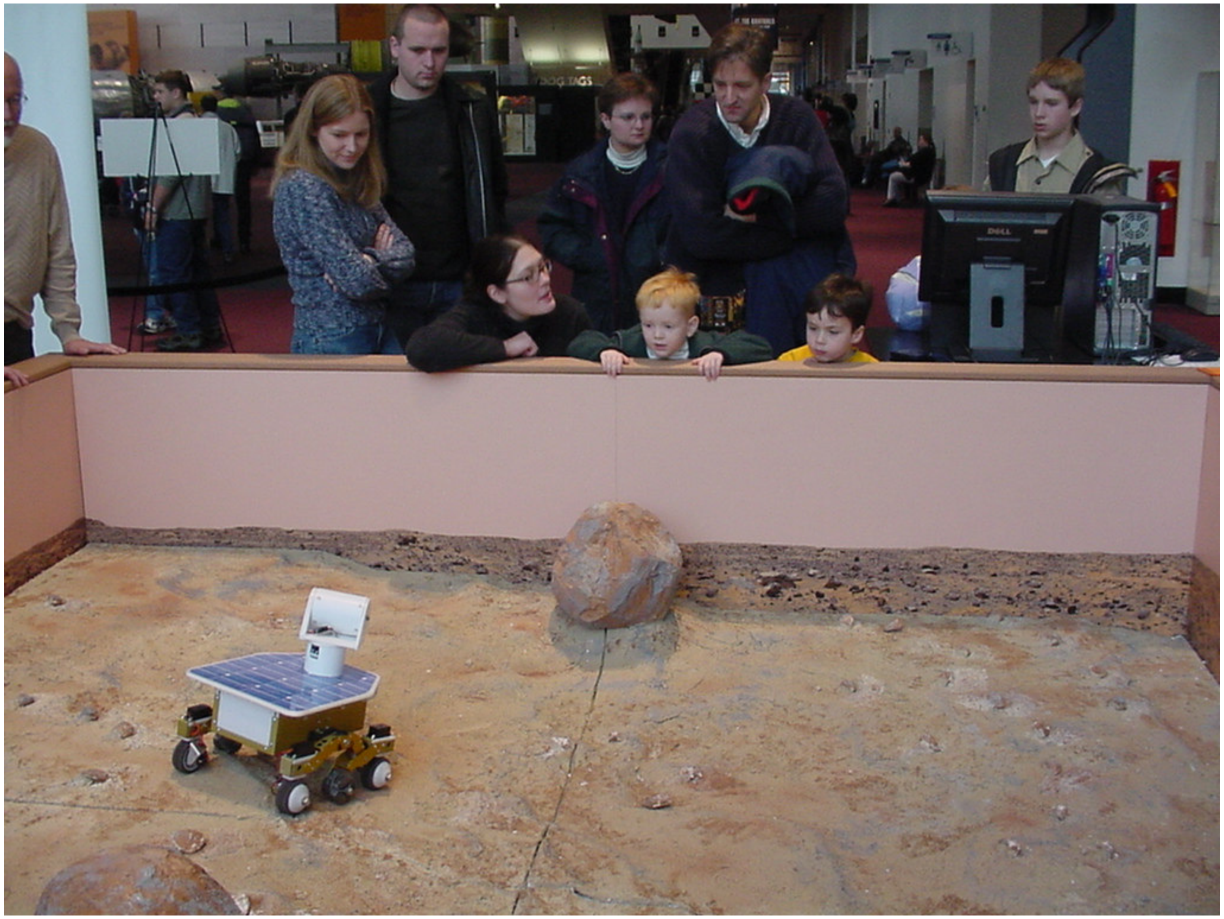
Mars yards built as middle school outreach project

Topography based on Pathfinder landing site

Strong collaboration with educational evaluators



National Air & Space Museum



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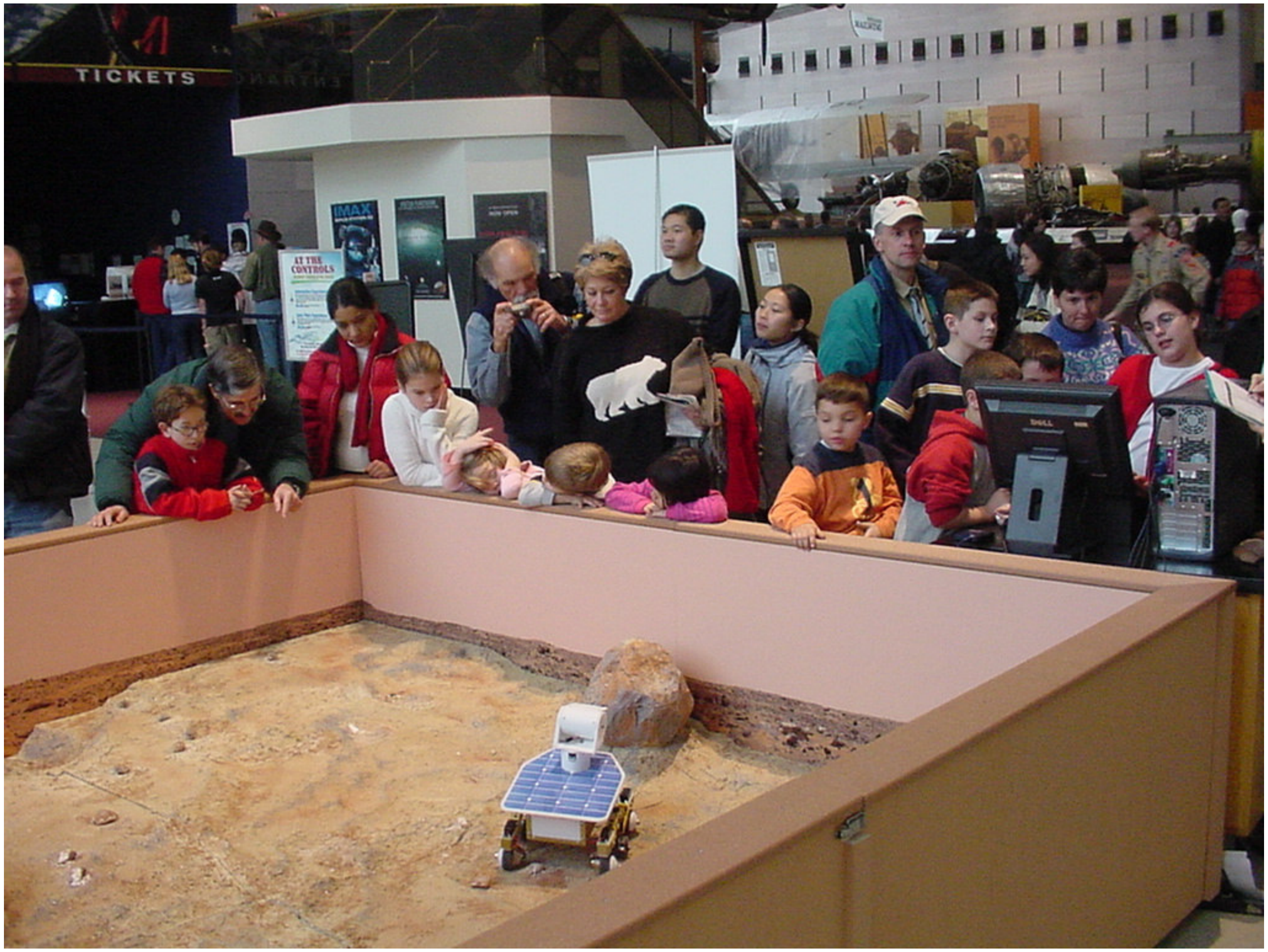

San Francisco Exploratorium

- Together with NASM, the Big Two
- Joint exhibit, NASM and Explo, is unprecedented
- Twin PER yards separated by full-scale MER model
- Special January “open house” for us

San Francisco Exploratorium

San Francisco Exploratorium

Preliminary Quantitative Results

Rover Performance Findings (Jan 29, 2004):

- 5 operational exhibits for 4 weeks; 7 rovers
- 670 rover-hrs; 13 rover-miles; 12,000 approaches
- Failures: 5 tilt servo, 2 drive motor, 2 steering servo,
- Wireless flakiness at NASM (disappeared)
- Cerebellum, Stayton, camera, ranger perfect record
- 1 overturn accident
- Full-day battery endurance (Explo and NASM)

Preliminary Quantitative Results

- Bimodal child/parent age distribution
  - Average child's age: 6.75 ; adult: 35.4
- Girls will actuate the interface significantly
  - Child driver penetration: 61% boys; 71% girls
  - Adult: 26% male; 14% female
- All visitors complete a full cycle of interaction
  - Interface penetration is ~ 100%
  - Mission length: 2.87 minutes (sigma 1.05)
- Interface countdown is effectively triggering turn-taking
  - Number of missions: 1.6 (sigma 0.94)
- Primary use pattern is team-based collaboration
  - Mean group size: 3.06 (1.22)
  - Gestural and verbal communication frequent

Next Steps

- Ensure rover success at all installations
- Deploy all evaluation instruments (LRDC; ILI)
- Find sponsorship for a national traveling exhibit
- Extend curriculum to secondary school outreach and informal learning settings
- Potential development as research platform

Thank you