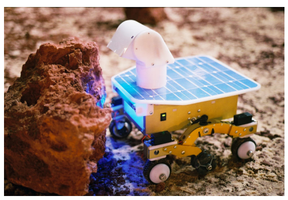
Illah's CREATE examples

Illah Nourbakhsh
AI



Motivation

Rich, effective, satisfying interactions

Research Focus

Human-Robot Interaction (HRI)

↓

Human-Robot Collaboration for Learning (HRC)

- HRC as a special case
  - Shared goal amongst all agents
  - Peer-to-peer relationships
- Learning through exploration & discovery
- Leverage education-based evaluation models
- Facilitates *rich, effective, satisfying* interaction

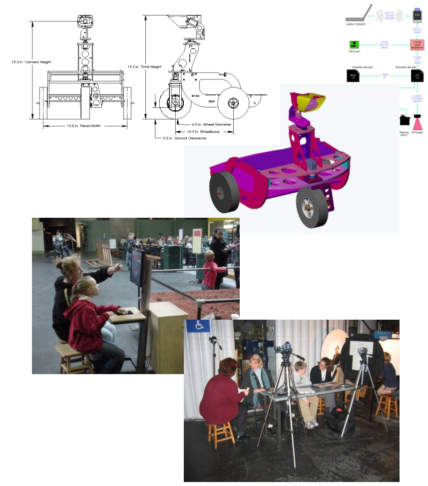
Tools for HRC

1. The Science & Technology of Interaction
   modeling, reasoning, execution
   perception, actuation
2. Physical and Interaction Design
   morphology, behavior
3. Evaluation: HCI, Human Factors, Education
   formative & summative techniques

Complete Design Cycle Approach

Cycle of Innovation

Robot morphology
Control and behavior
Social perception
Cognitive models
Interaction design
Evaluation



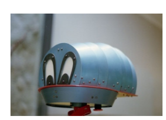
Four Applications of HRC for Learning

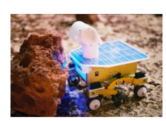
Insect telepresence

Chips museum educator

Robotic Autonomy course

Personal Exploration Rover





Insect Telepresence Robot

Problem

Increase visitors' engagement with and appreciation of insects in a museum terrarium at CMNH.

Approach

Provide a scalar telepresence experience with insect-safe visual browsing

Apply HCI techniques to design and evaluate the input device and system

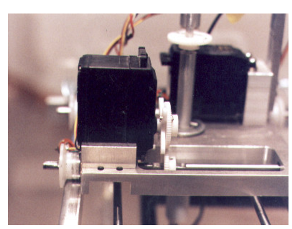
Measure engagement indirectly by 'time on task'

Partner with HCII, CMNH

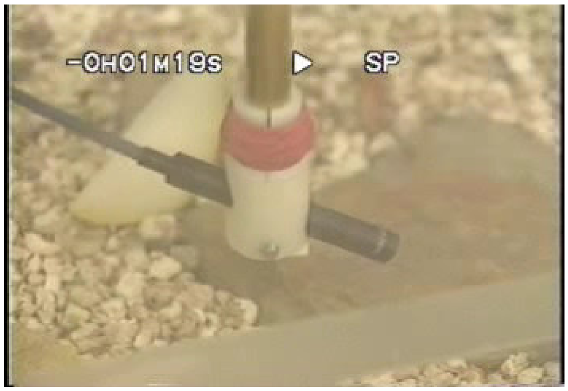
Insect Telepresence Robot

Innovations

- Asymmetric exhibit layout
- Mechanical transparency
- Clutched gantry lever arm
- FOV-relative 3 DOF joystick



Insect Telepresence Robot



Insect Telepresence Robot

Evaluation Results:

- Average group size: 3
- Average age of users: 19.5 years
- Three age modes: 8 years, 10 years, and 35 years
- Average time on task of all users: **60 seconds**
- Average time on task of a single user: 27 seconds
- Average time on task for user groups: 93 seconds

A Human-Scale Museum Edubot

Problem
Increase visitors' engagement and learning at secondary exhibits in Dinosaur Hall.

Approach
Lead visitors to secondary exhibits and new facts
Design a robot to share the human social space
Establish long-term iterative testing over years, not days
Time on task, observation and learning evaluations
Partner with Magic Lantern, Maya, CMNH

Museum Edubot: Technical Contributions

Required Robot Competencies:
Safety, navigation, longevity

Approaches

- Property-based control programming
- Visual landmark-based SUF (Latombe)
- Visual self-docking
- h/w and s/w restart diagnostics
- Fault detection & communication

Museum Edubot: Technical Contributions

Required Robot Competencies:
Safety, navigation, longevity

Outcome

- Zero human injuries
- 4 years deployment, over 500 km traversed
- MTBF converging beyond 1 week
- Uptime: 98%
- Active diagnosis approaching 100%

Museum Edubot: Iterative Design Cycle

Design Refinements

- Physical Design
  - Morphological Transparency: designing informative form
- Interaction Design
  - Behavioral Transparency: affective interaction model
  - Shortened length of media segments
  - Two-way interaction, goal-based learning

Museum Edubot - *Chips*

Museum Edubot: Evaluation Results

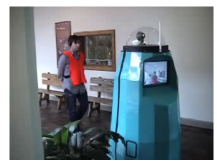
- Increased engagement time:
  74% visitors 5 – 15 min.
- Peak ages engaged: 5-12, 25-34
- 20% overrepresentation of females
- 22% overrepresentation of minorities
- Directed test scores: 46% to 75% correct

HRC Insights

- Reliable public deployments are possible
- Iterative design cycle is essential
- Diagnostic, interaction transparency
- Two-way interaction is preferable

Human learning in human-robot collaborations can be quantified.

Rich robotic interaction can trigger human behavioral change.



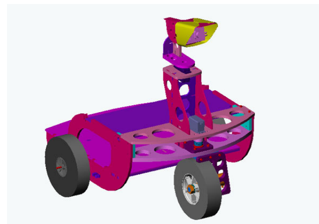
HRC in a Formal Learning Venue

Problem
Create a robot and learning environment for robotics education.

Approach
Use a highly diverse high-school student population
Ground-up platform and curriculum design
Empower students with s/w and h/w; Internalize goals
Short-circuit robot competency delay with *education*
Give away the entire *software* and *hardware* environment
Expert-led formal educational analysis, model development

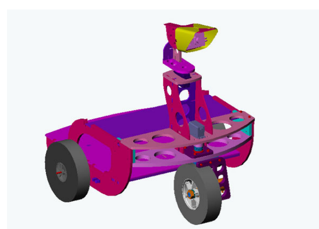
Trikebot Platform Contributions

- Bicycle complexity goal
- Mechanical transparency
- Hybrid design concept
- Camera gaze design
- CMUcam vision system
- Tricycle configuration
  - Torsional stress limited
  - Back-EMF speed control
  - Minimize servo torque



Trikebot Platform Contributions

- Bicycle complexity goal
- Mechanical transparency
- Hybrid design concept
- Camera gaze design
- CMUcam vision system
- Tricycle configuration
  - Torsional stress limited
  - Back-EMF speed control
  - Minimize servo torque



Trikebot Platform Contributions

- Bicycle complexity goal
- Mechanical transparency
- Hybrid design concept
- Camera gaze design
- CMUcam vision system
- Tricycle configuration
  - Torsional stress limited
  - Back-EMF speed control
  - Minimize servo torque

Trikebot: *Snagglepuss*

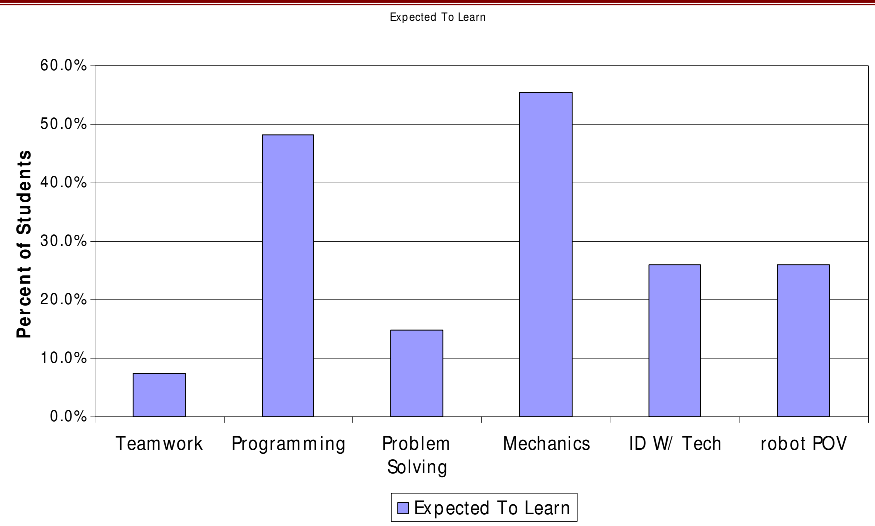
Trikebot: Footage

Trikebot: Educational Evaluation

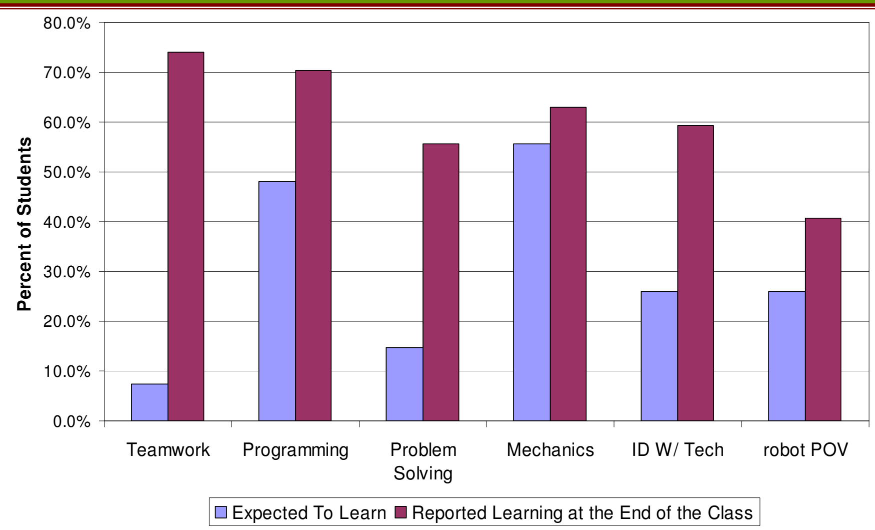
Evaluation Instruments Developed with Prof. Kevin Crowley, Learning Research & Development Center, University of Pittsburgh

- Initial and Final Individual Surveys
- Weekly Individual Surveys
- Online Documentation of Code
- Weekly Interviews and Footage by Onsite
- Ethnographer
- One Week Formal Ethnography (mid-program)
- Follow-up Web-based Monthly Surveys

What Students Expected to Learn and What They Reported Learning



What Students Expected to Learn and What They Reported Learning



Trikebot: Self-Reported Learning

Quotes from students

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

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

"Teamwork is hard especially with varying levels of skill and different personalities…can be rewarding only through compromise."

"Start with the basics, then make things fancier if you want…simple is absolutely fine if it works well."

"Make active decisions. Have the attitude that if I don't do it, no one will and remember that if you choose something, you are also choosing not to do other things because you have limited time, energy, etc. Choose what to do with your talents wisely and don't waste them!"

Trikebot: Evaluation Findings

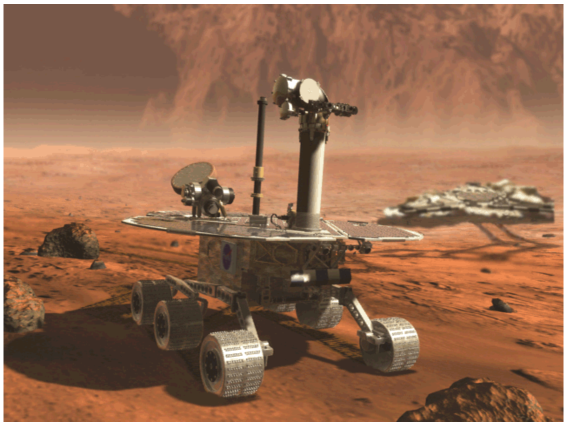
Gender Retention

No significant differences in what girls reported learning in the class as compared to boys.

Girls entered reporting less confidence with technology than boys but reported greater increases in confidence than boys by the end of the class.

Girls reported struggling more with programming than boys.

MER Landings, January 2004



Inspire the next generation of explorers…

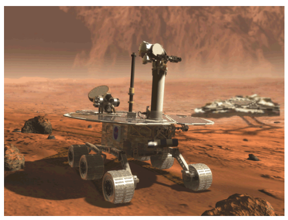
Personal Exploration Rover (PER)

Problem

Connect visitors to the MER mission with an exhibit that demonstrates:

1 Rovers are tools for conducting science

2 Autonomy is essential for collaboration



Approach

Ground-up design of high-reliability museum exhibit

Surmount technology limitations with Intel partnership

Allow for full design and evaluation cycle

Collect data on visitor and docent collaborations with robot

Our Robot Design Approach

- Establish explicit, quantitative goals
- Recruit a multi-disciplinary team
- Create parallel feedback cycles

Our Robot Design Approach

- Establish explicit, quantitative goals
  - Front-end user research to establish needs
  - Clearly defined criteria [+ feed forward ; - feature creep]
  - *Caveat*: Allow for opportunistic changes to goals
- Recruit a multi-disciplinary team
- Create parallel feedback cycles

Our Robot Design Approach

- Establish explicit, quantitative goals
- Recruit a multi-disciplinary team
  - Robotic interaction deserves a systems science approach
  - Expertise beyond robotics: HCI, design, education
- Create parallel feedback cycles

Our Robot Design Approach

- Establish explicit, quantitative goals
- Recruit a multi-disciplinary team
- Create parallel feedback cycles
  - Multiple {design; implement; evaluate; refine} cycles
  - Feed forward results *across* design, EE, HW and firmware efforts

Establish Explicit, Quantitative Goals

- Design for robustness
  - 10 hours battery endurance under constant use
  - Unmediated usability by novice users
  - Constant naïve use without degradation
  - In-museum repairability, MTBF > 1 week, MTTR < 1 hour
- Interaction design for museum setting
  - Less than 3 minutes *Time on Task*
  - Completed immersion in narrative (subject to 3 min. constraint)
  - Panoramic image-centered science mission
- Measurable education outcomes:
  - Role of Autonomy; Role of Rovers in Mission Science
  - (Level of comprehension ; comparison of mediated and unmediated exhibits)

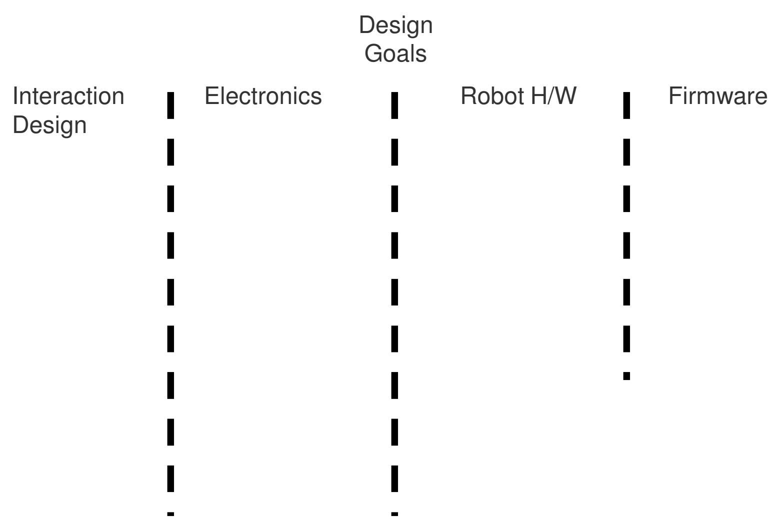
Multidisciplinary Team

- Robotics firmware and software
  - Carnegie Mellon Robotics
- Interaction design and testing
  - Carnegie Mellon Robotics
- Embedded electronics
  - Intel Corporation, Botrics Inc.
- Robot hardware realization
  - Gogoco LLC
- Screen and exhibit graphic design
  - LotterShelly LLC
- Educational evaluation
  - Univ. of Pittsburgh Learning Research & Development Center

Project Timeline (8 months)

- May 2003: PER project kickoff
- June: Establish design goals and parameters
- July: Prototype firmware development
- August: Prototype interaction design & test
- September: Interface, firmware programming
- October: Kickoff museum deployments
- November: Software QA
- December: Rover hardware QA
- Jan 04, 2004: MER *Spirit* lands, exhibits launch!

Parallel Design Efforts



Parallel Design Efforts

Design Goals

Interaction Design | Electronics | Robot H/W | Firmware

Personal Exploration Rover (PER)

Deploy PER's in major national museums
- Visitors and outreach engagement

The search for life using *organofluorescence*
- Panoramic image acquisition
- Science target selection
- Map correspondence, orientation
- Plan synthesis
- Plan sequencing and monitoring
- Autonomous target approach and measurement
- Report generation

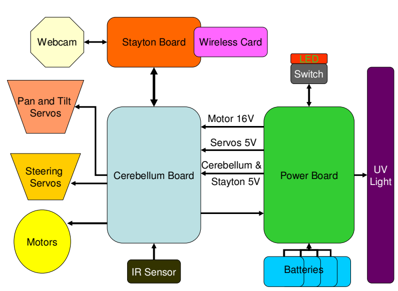
Parallel Design Efforts

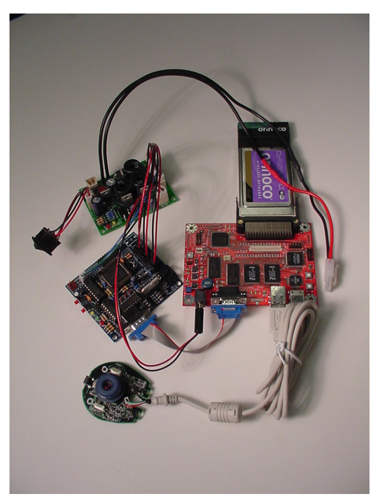
Design Goals

Interaction Design | Electronics | Robot H/W | Firmware

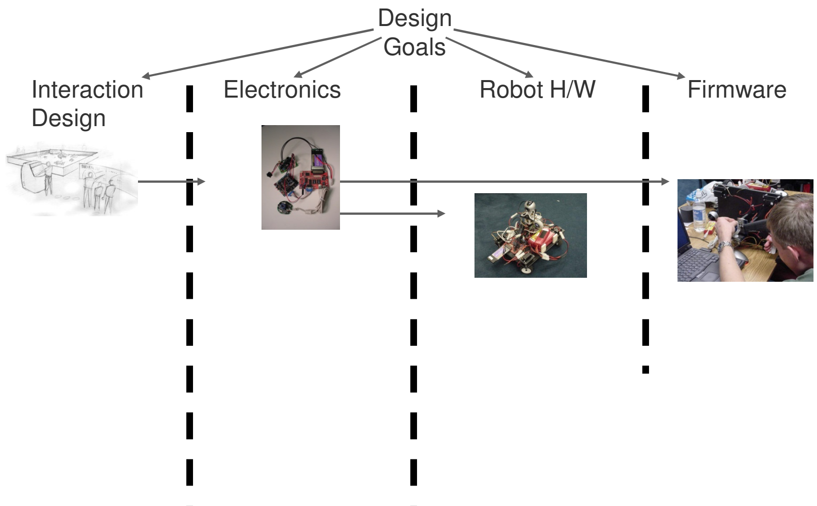
Electronics Overview

- Intel Stargate
- Cerebellum PIC board
- Sharp 2Y0A2 rangefinder
- Single switching regulator buses
- 30V unified NiMH power pack



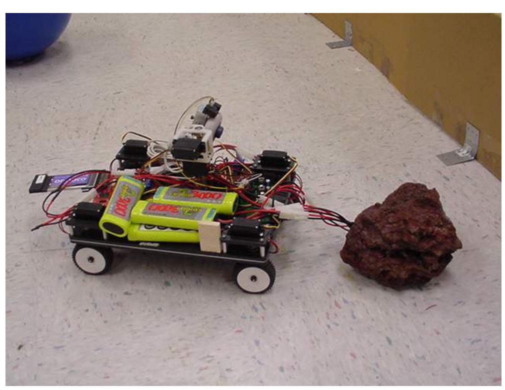


Parallel Design Efforts

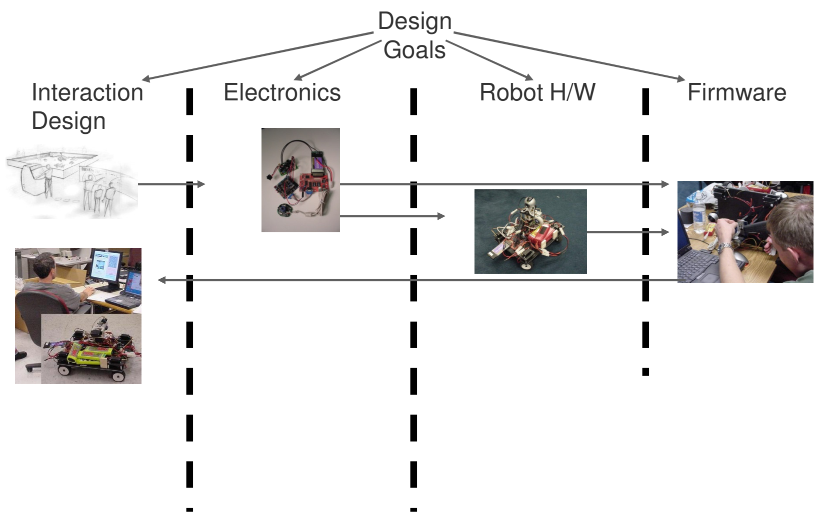


Hardware and Firmware

- Kinematically correct 4-steer simplified chassis for flat-floor evaluation

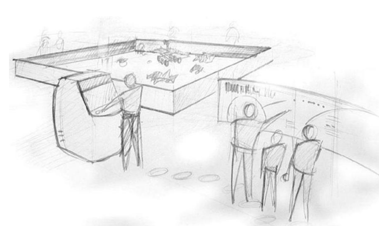


Parallel Design Efforts



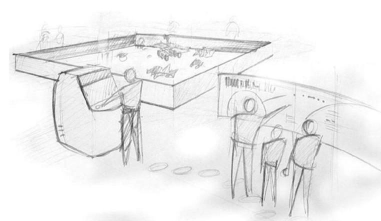
Interaction Design Iterations

- User evaluation using kinematically similar prototype
- Iterative refinement of interface
- 3 minute time on task is hard: key map focus

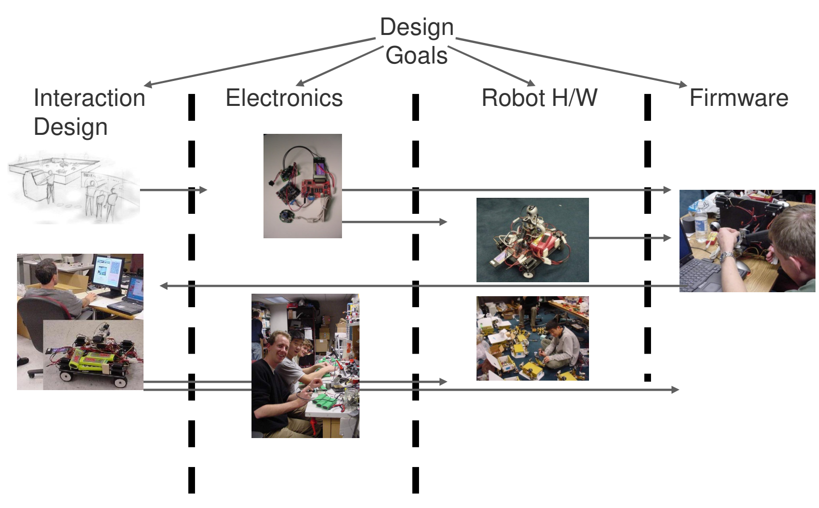


Interaction Design Iterations

- Exploit mechanical error to demonstrate autonomy
- Compensate for robot/human limitation with human/robot guidance
- Establish translation between panoramic, orthographic and physical yard imagery

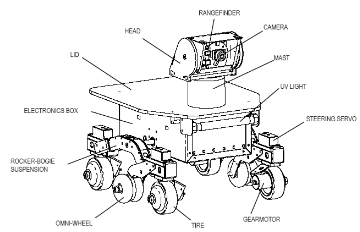


Parallel Design Efforts



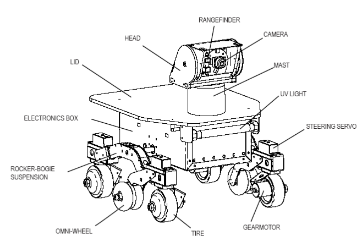
Mechanical Summary

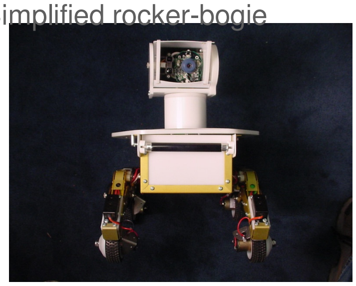
- MER reminiscent look
- Camera-centered morphology
- Directional gaze design
- UV light, IR sensors
- COTS life-limited parts
- Simplified rocker-bogie

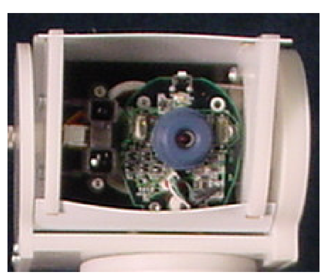


Mechanical Summary

- MER reminiscent look
- Camera-centered morphology
- Directional gaze design
- UV light, IR sensors
- COTS life-limited parts
- Simplified rocker-bogie

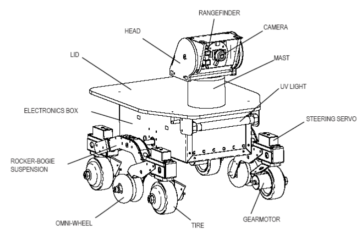


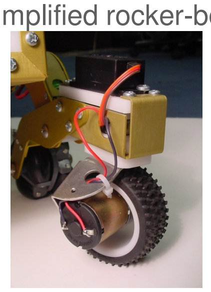




Mechanical Summary

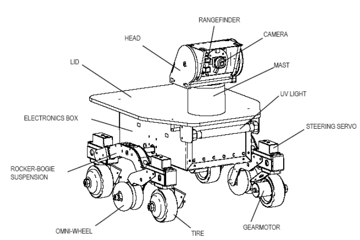
- MER reminiscent look
- Camera-centered morphology
- Directional gaze design
- UV light, IR sensors
- COTS life-limited parts
- Simplified rocker-bogie



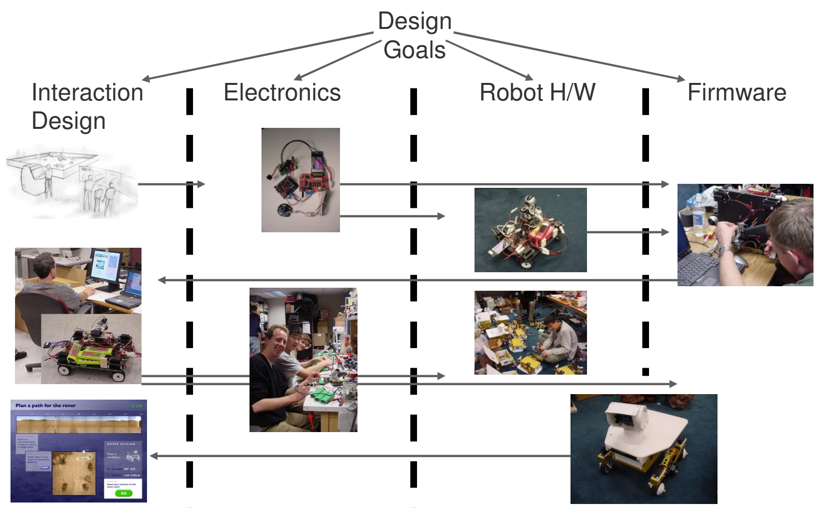


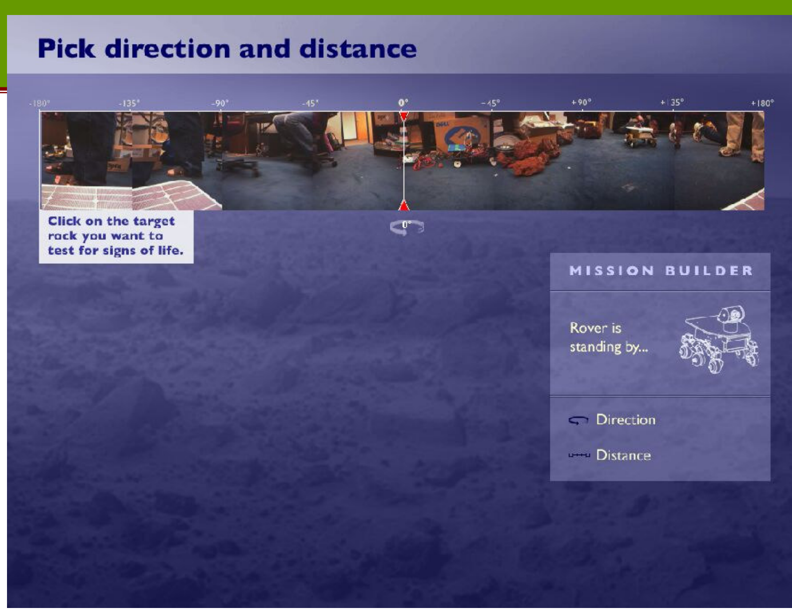
Mechanical Summary

- MER reminiscent look
- Camera-centered morphology
- Directional gaze design
- UV light, IR sensors
- COTS life-limited parts
- Simplified rocker-bogie



Parallel Design Efforts






Pick direction and distance
Click on the target rock you want to test for signs of life.
SUN
79-89cm
Now, click on the target rock in the map to calculate distance.
MISSION BUILDER
Rover is standing by...
Direction 61° right
Distance 79-89 cm


Pick direction and distance
Click on the target rock you want to test for signs of life.
SUN
Click 'clear' if you want to recalculate distance.
CLEAR
MISSION BUILDER
Rover is standing by...
Direction 61° right
Distance 79-89 cm
Send your mission to the rover now.
GO

In-situ Rover Behavior

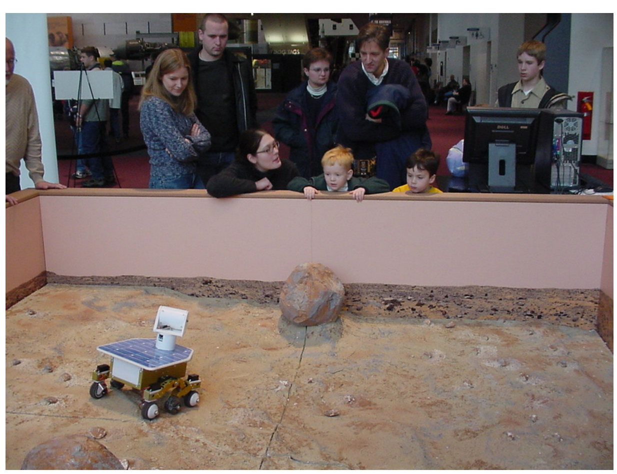
PER: Initial Installations

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

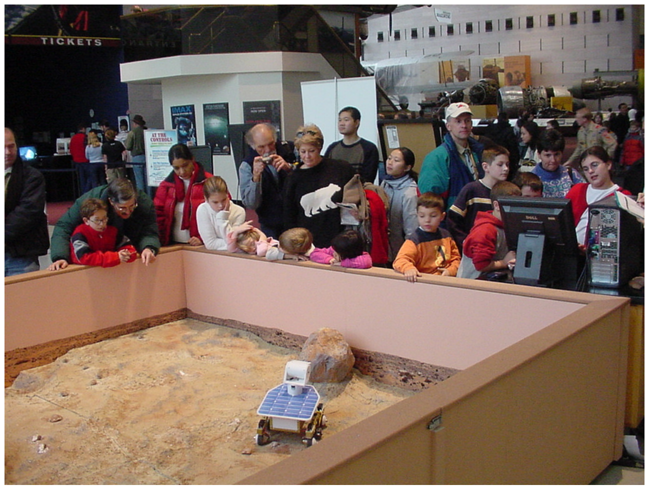
National Air & Space Museum

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



National Air & Space Museum



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

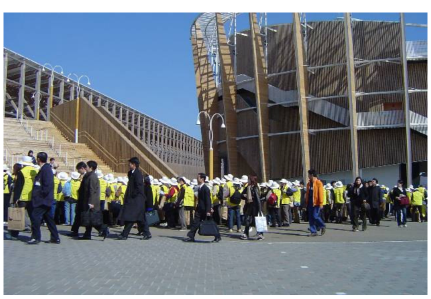
San Francisco Exploratorium

San Francisco Exploratorium

San Francisco Exploratorium

NASA/Ames Mars Center

Japan World Expo 2005 (Aichi)



PER Performance Results

Month 1: 670 rover-hrs; 13 rover-miles; 12,000 approaches

Full-day power endurance in all locations

As of 20 April 2004: 50,000+ approaches complete

Cerebellum, Stargate, camera, ranger perfect record

Failures: exclusively replaceable servos

Museum ownership and repair

PER: Exhibit Use Statistics

- 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
  - Mission command proportion: 98%
  - Mission failure retry proportion: 98.1%
  - Mission length: 2.87 minutes unimodal (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

PER: Comparing Learning across Museums

45 families analyzed
Process: socio-cognitive activity during exhibit use
Outcome: individual visitor understanding after use

Themes	Exploratorium	NASM
About the Mars Mission*	55%	93%
Comparisons between MER and PER*	24%	79%
Communicating with Robots	45%	72%
Collaborating with Robots	86%	93%

Themes	Exploratorium	NASM
Rover Design*	34%	93%
Rover Activities*	45%	100%
Rover Autonomy*	52%	93%