

# Developing the Personal Robotics Market: Enabling New Applications Through Novel Sensors and Shared Autonomy

A Proposal for Willow Garage's PR2 Beta Program

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Research and Technology Center North America



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## Bosch Proposal for PR2 Beta Program

# Bosch

### **Bosch Group**

- Founded 1886, privately held (Robert Bosch Foundation and Bosch Family)
- 270.000 employees, 45b Euro revenue (2008)
- Divisions: Automotive, Industrial Technology, Consumer Goods, Building Technologies, Solar Technologies
- Largest Automotive Supplier worldwide

### **Bosch Corporate Research**

- 1300 employees
- Offices in Germany, USA, Japan, China, Singapore, Russia



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# Bosch Research and Technology Center NA

- Offices in Palo Alto, CA; Pittsburgh, PA; Cambridge, MA.
- Topics: MEMS, sensors, circuit design, wireless solutions, energy materials and technologies, complex simulations, software engineering, HMI design, car infotainment, web technologies, autonomous systems, robotics.



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# Developing the Personal Robotics Market: Enabling New Applications Through Novel Sensors and Shared Autonomy

### Motivation

- **Safe** through a robotic sensor skin
- **Affordable** through low-cost performance sensors and remote access
- **Capable** through shared autonomy and 3D mapping/exploration

### Projects

- Affordable Sensing for the PR2
- Robot Skin
- Shared Autonomy
- PR2 Remote Laboratory
- 3D Mapping

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# Affordable Sensing for the PR2

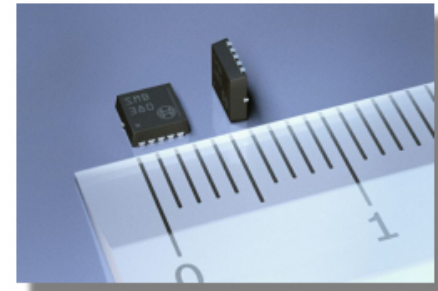
**Lead:** Lukas Marti

### Goal

- To enable new robot applications through the use of affordable sensing technologies

### Motivation

- Low-cost performance MEMS sensors available
  - enable massive deployment on robots
- Enabler for new and/or lower cost robotic applications, e.g.
  - Replace expensive encoder by inexpensive MEMS sensors for manipulator state estimation
  - Manipulator health monitoring through e.g. spectrum analysis of vibrations
  - Collision and arm stiffness detection
  - User input detection by sensing external forces exerted onto the robot



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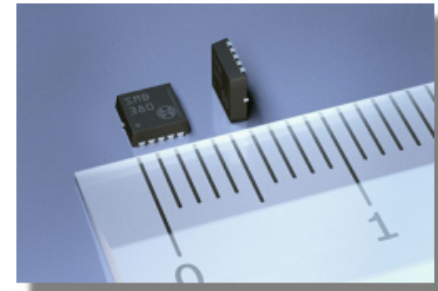


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# Affordable Sensing for the PR2

### Tasks

- Integration of sensors into ROS
- Autonomous sensor self-calibration algorithms
- Multi-cluster sensor integration and state tracking
- Manipulator state estimation using low cost accelerometers
- PR2 arm calibration using accelerometers
  
- Provide sensors to PR2 community
  - 3-axis accelerometers (3mmx3mm, PCB 8mmx10mm)
  - Gyros (combination of 2-axis accelerometer (x,y) and gyro (z) )
  - Pressure sensors, force sensors, magnetic sensors, torque sensors (anticipated, if community interest)
    - enable new applications



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# Robot Skin

**Lead:** Lukas Marti

### Goal

- Leverage the Bosch robotic skin for touch-less human robot interaction for the PR2



### Motivation

- New interaction technologies: touch-less teaching of PR2
- Safety: Collision-free manipulation with PR2
- Obstacle detection and collision free manipulation

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# Robot Skin

### Tasks

- Customize skin for the PR2
  - ROS drivers for the skin
  - Collision avoidance with humans
  - Touch-less guidance of the PR2 base
  - Touch-less guidance of the PR2 arms
- 
- Distribute three sets of PR2 skins to the community



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# Shared Autonomy

**Lead:** Charles DuHadway

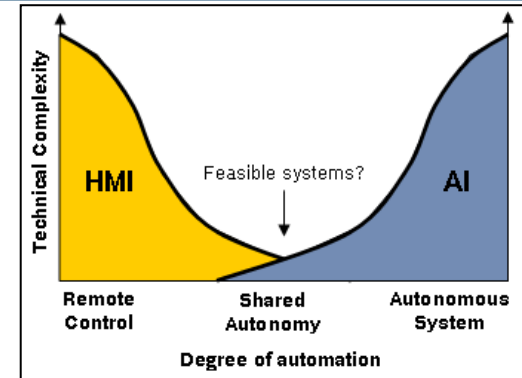
## Goal

- Develop a robotic system that coordinates with a human operator to increase its effectiveness

## Motivation

Adding human in the loop to

- increase effectiveness: Explore how a human-PR2 team can work together effectively
- increase robustness: Human can step in to help robot recover from failure
- decrease cost: reduce time, reduce computational needs
- “Let robots do what they are good at, let humans do what they are good at”



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### Shared Autonomy (Video)



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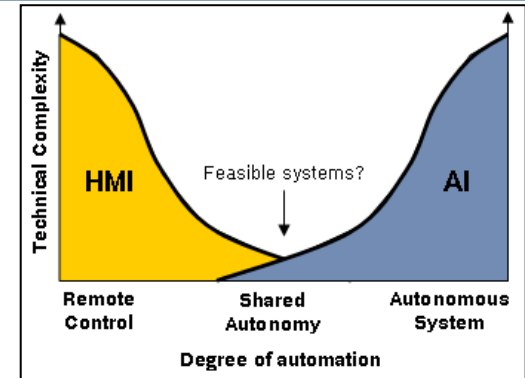
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# Shared Autonomy

### Tasks

- "smart" tele-operation package for PR2 base and arms with automated collision avoidance.
- Collaborative control interface for perception and manipulation queries:
  - Demonstrate a human operator coordinating with the PR2 to pick and fetch unknown items.
  - Demonstrate single human operator coordinating with multiple PR2's



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# PR2 Remote Laboratory

**Lead:** Charles DuHadway and Ben Pitzer

### Goal

- Develop a remote laboratory to share a PR2 between research groups

### Motivation

- Most research robots spend most of their time idle
- Provide PR2 access to a wider community
- Design repeatable tasks that allow direct comparison of competing solutions



# PR2 Remote Laboratory

### Tasks

- Build, deploy, and maintain a system for allowing remote use of the PR2 by other institutions for research
  
- Phase 1: Make PR2 lab available to ROS institution
  - Build an instrumented prototype remote laboratory environment
  - Release package for remote controlling the laboratory
  - Release package to detect hardware failures and remote shutdown
  - Demonstrate an external institution using the PR2 remote lab
  
- Phase 2: Make PR2 lab available to the public
  - Release webui package for tele-operation of the PR2 lab
  - Extend webui to upload a file implementing a task



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# 3D Mapping and Exploration

**Lead:** Ben Pitzer

### Goal

- Establish an autonomous 3D exploration and mapping stack in ROS

### Tasks

- Transfer developed algorithms to ROS
  - exploration, 3D slam, geometry reconstruction, and texture reconstruction
- PR2 application for 3D mapping and reconstruction
- Release ROS stack for 3D mapping and reconstruction
- Demonstrate mapping system by using PR2 to explore and reconstruct several large buildings



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# 3D Mapping and Exploration (Video)



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# Thank You!

The Bosch RTC team is looking forward to continue to work with Willow Garage, the PR2 community and the ROS community.

We would like to thank Willow Garage and its sponsors and contributors for making the PR2 and ROS happen.

<http://www.boschresearch.com>

<http://www.ros.org/wiki/bosch-ros-pkg>

<http://bosch-ros-pkg.sourceforge.net>

