



WPI

Design and Development of AERO

Autonomous Exploration Rover



2013 Sample Return Robot Centennial Challenge

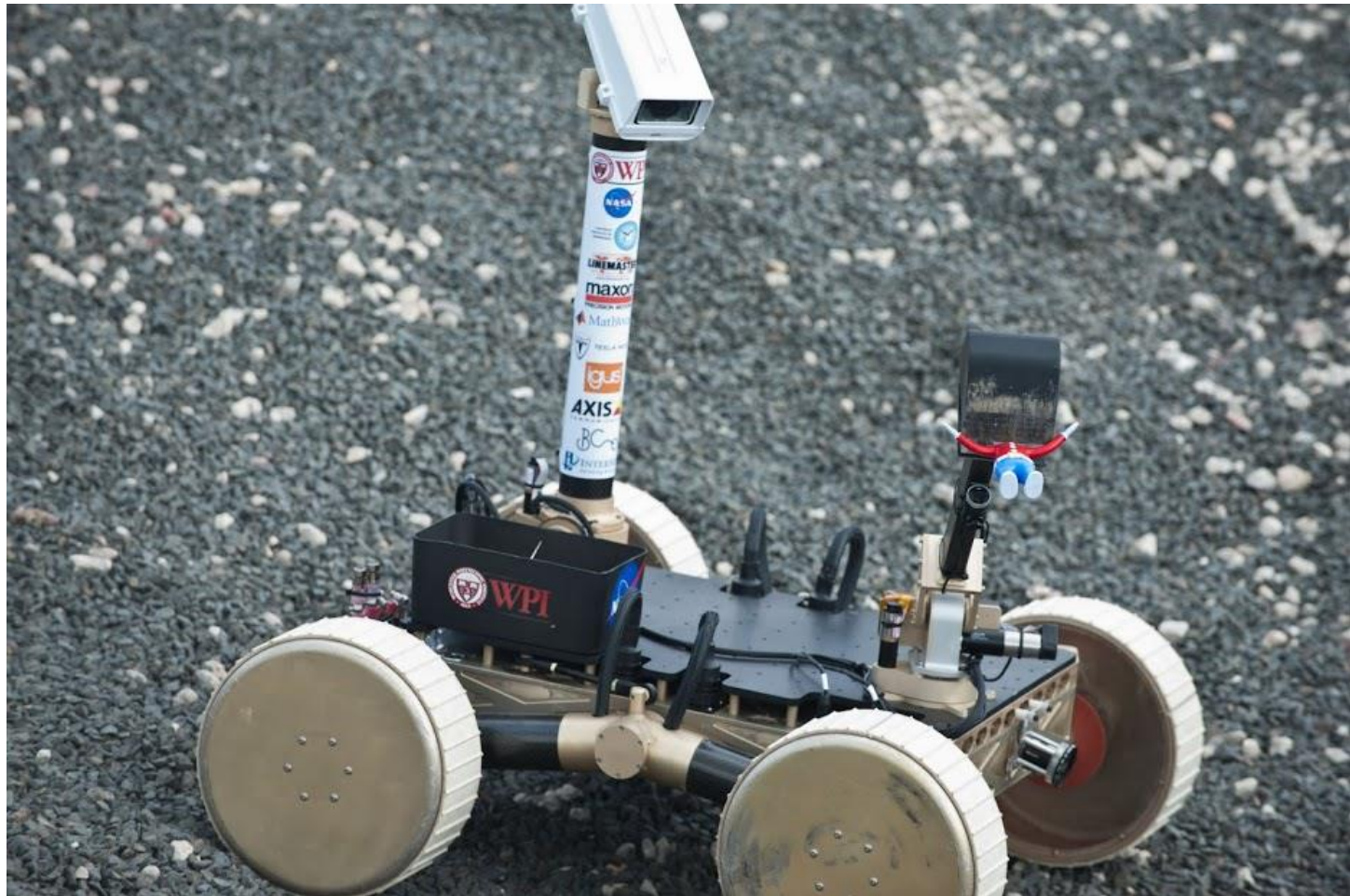
Motivation for AERO



AERO Sample Return Challenge



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AERO Sample Return Challenge



Sample Return Robot Challenge



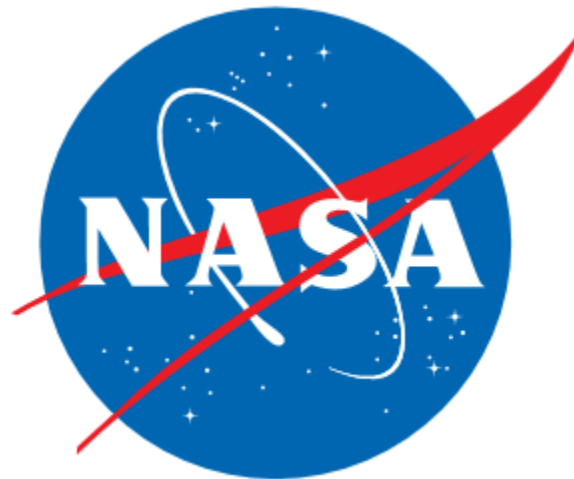
DEMONSTRATE A ROBOT

that can

LOCATE AND RETRIEVE GEOLOGIC SAMPLES

from a

WIDE AND VARIED TERRAIN WITHOUT HUMAN CONTROL



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Geologic Samples



Easy Samples

Pre-cached sample

Pink Tennis Ball

Red Hockey Puck

Orange PVC Pipe

Intermediate Samples

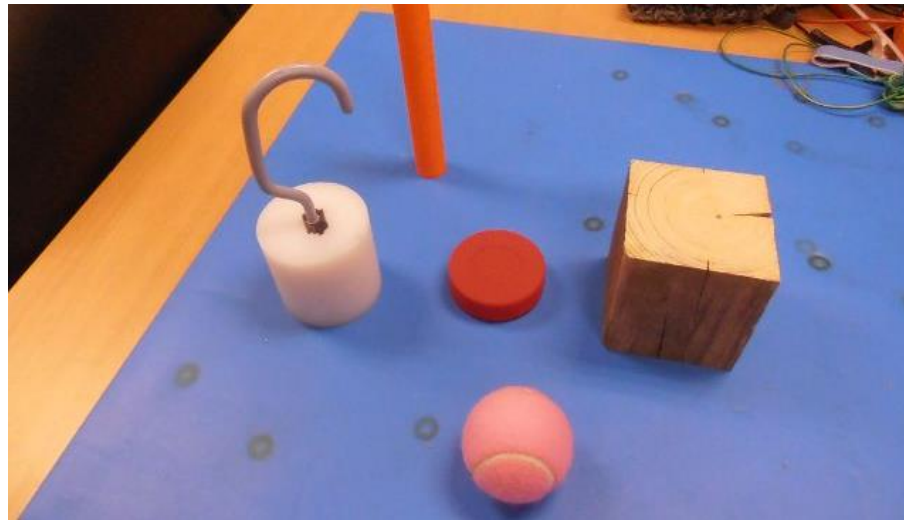
Uniquely Colored
Spherical Object 20-
60mm

Purple Rock 6-10cm

Wooden Cube ~10cm

Hard Samples

Non ferrous metal object
with engraving x3



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Clearpath Husky A200

- 4 wheel differentially driven platform



Kinova Jaco 6-DOF Arm

- Harmonic drive modules with absolute encoders



SPECIFICATION	
Dimensions (LxWxH)	99 x 67 x 56 cm
Mass	60 kg
Rated Payload	20 kg
Maximum Speed	100 cm/sec
Maximum Obstacle	13 cm
Operating Time	3 hrs typical
Maximum Drive Power	800 W
Battery	25.6V 80 Ah LiFePO4
Software	 ROS Enabled



**Only space compatible technologies
are allowed for the competition.**

1. Cameras
2. LIDAR
3. IMU
4. Wheel Encoders

- Allied Vision Manta G-095C – Qty 4
- Arranged in stereo pairs – near/far
- 1292 x 734 pixels
- Sony ICX692 sensor
- Pentax 4.8mm C-mount lens
- External trigger



- SICK LMS151
- 50m range
- 20m at 10% reflect
- Excellent outdoor performance



- KVH 1750 IMU
- Fiber optic gyros
- MEMS acc.
- RS-422 interface for 1kHz update rate
- Bias stability $0.05^\circ/\text{h}$
- $480^\circ/\text{s}$



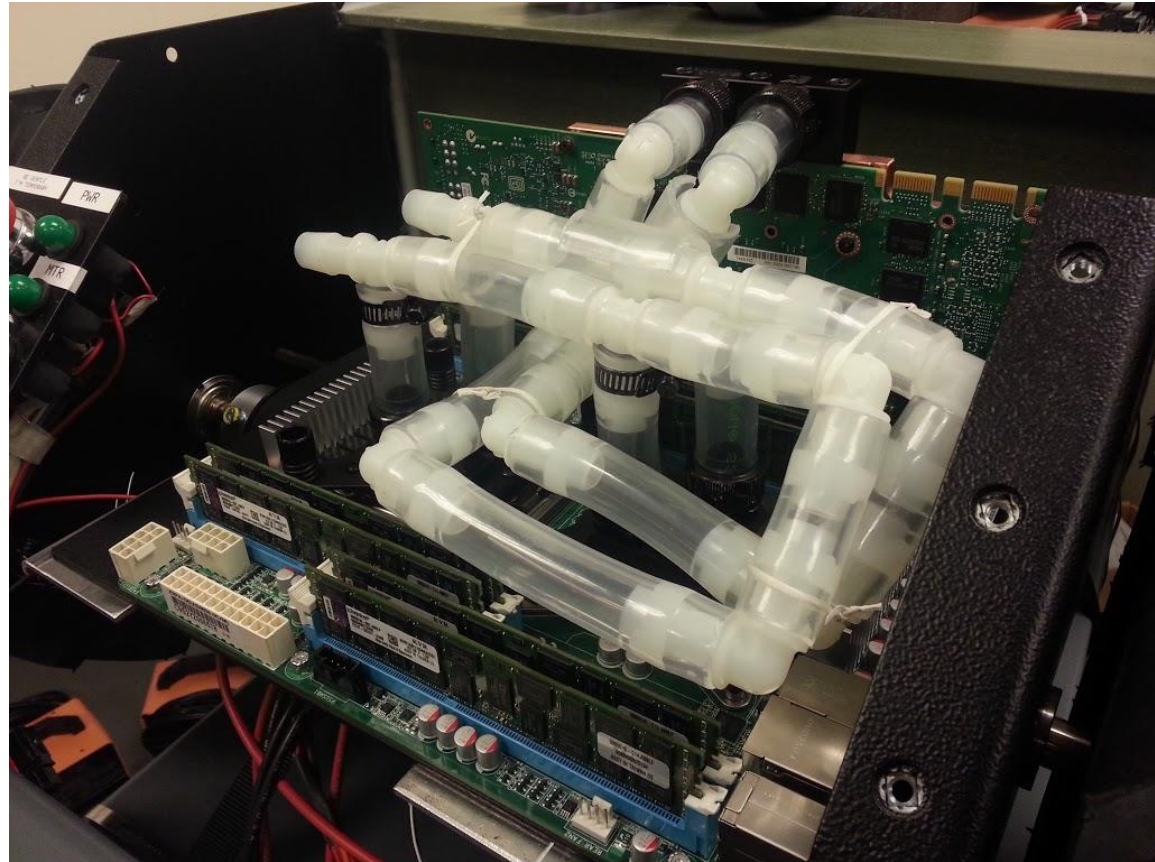
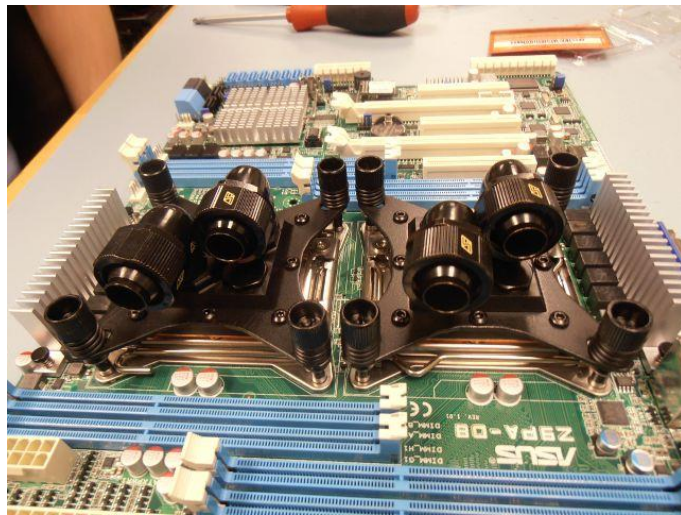
Data transfer is a significant issue.

1. Intel Xeon E5-2660 Qty. 2
2. Dual Processor Motherboard
3. Nvidia Tesla K20
4. 6 Independent Gig-E ports



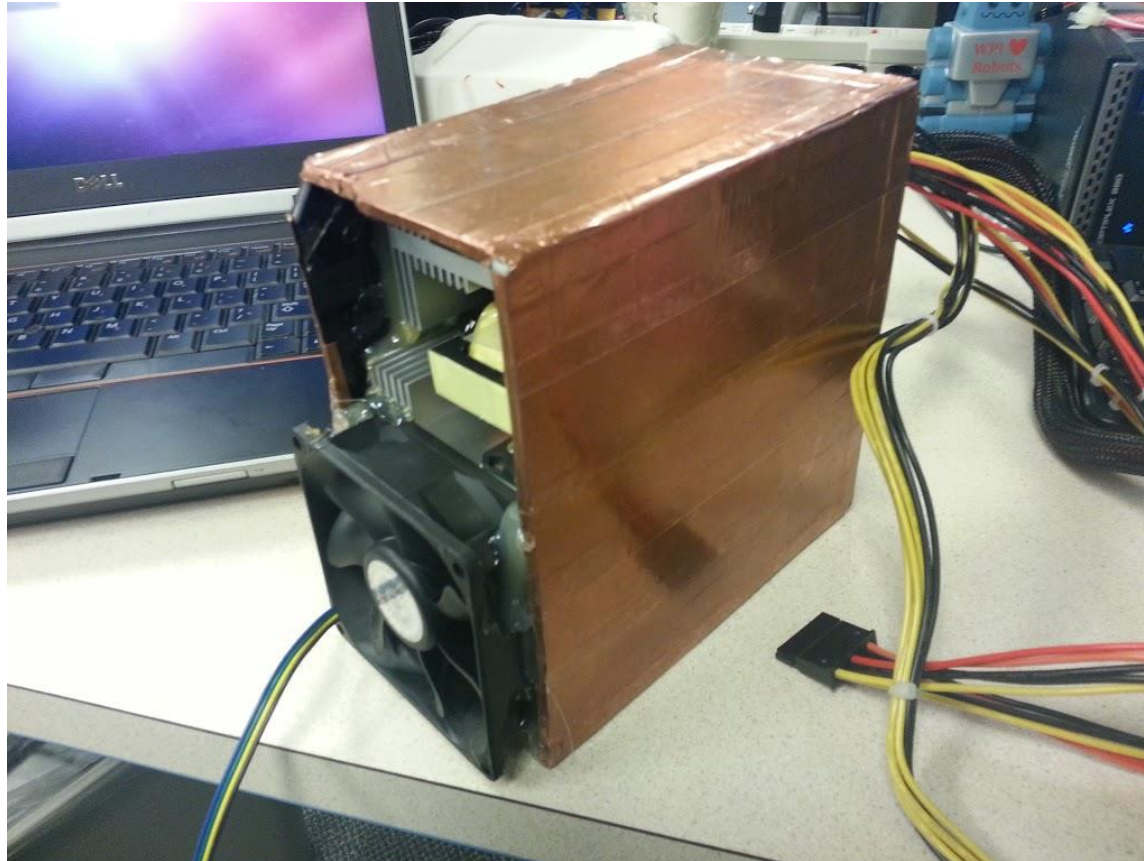
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Water Cooling



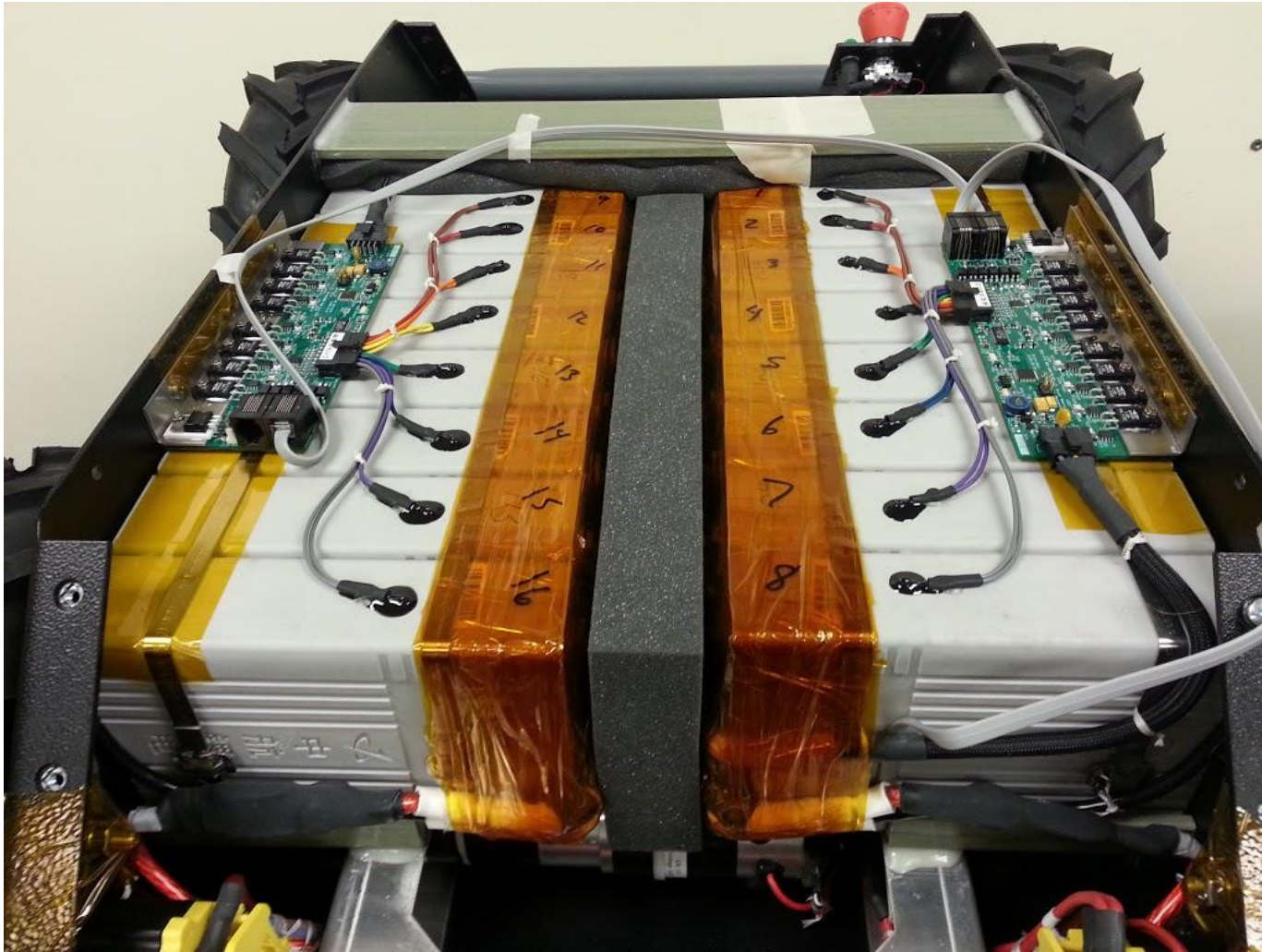
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DC-DC Power Supply



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Lateral Stability



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Current Design



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Supervisor (High Level Tasks)

Search

Nav to Obj

Collect

Home

Global Planner

Fast +
Inaccurate

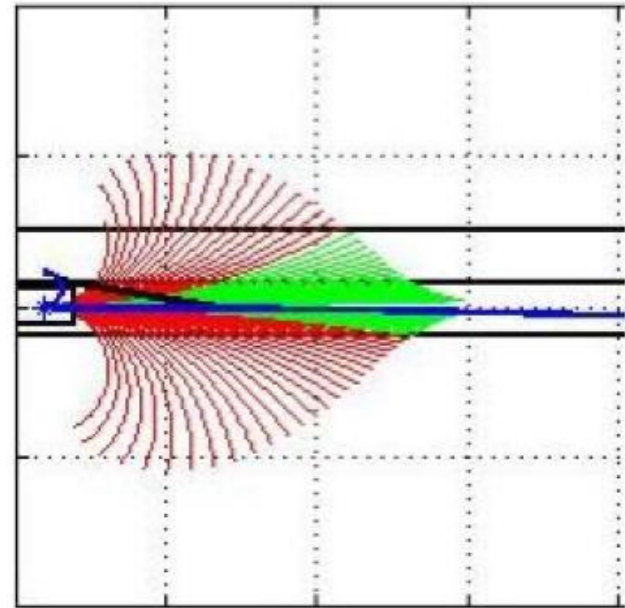
Slow +
Accurate

Local Planner

Tentacles

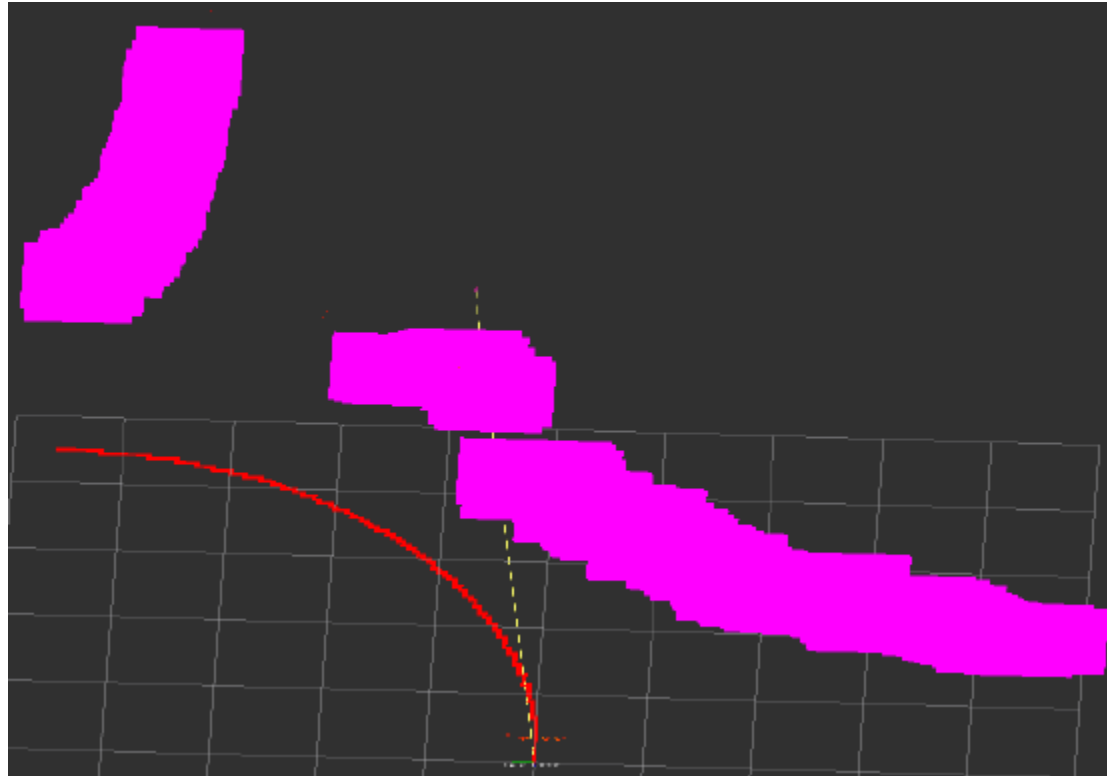
Manual

- Multiple speed sets
- Tentacle selection happens very quickly
- Requires robot to drive arc
- First used in the DARPA Urban Challenge 2007



Driving with Tentacles - Integral Structures for Sensing and Motion

Felix v. Hundelshausen, Michael Himmelsbach,
Falk Hecker, Andre Mueller, Hans-Joachim
Wuensche



- Vertical SURF features to find trees
- Generate point cloud of trees
- Fuse LIDAR and tree point clouds



- 1. Mast cameras identify anomalies in the grass using simple normalized RGB thresholding.**
- 2. Fixed cameras identify samples using OpenCV cascade classifier. Disparity map provides range to sample.**

Background noise for training sets for the classifier are critical.

Anomaly Detection from Mast Cameras

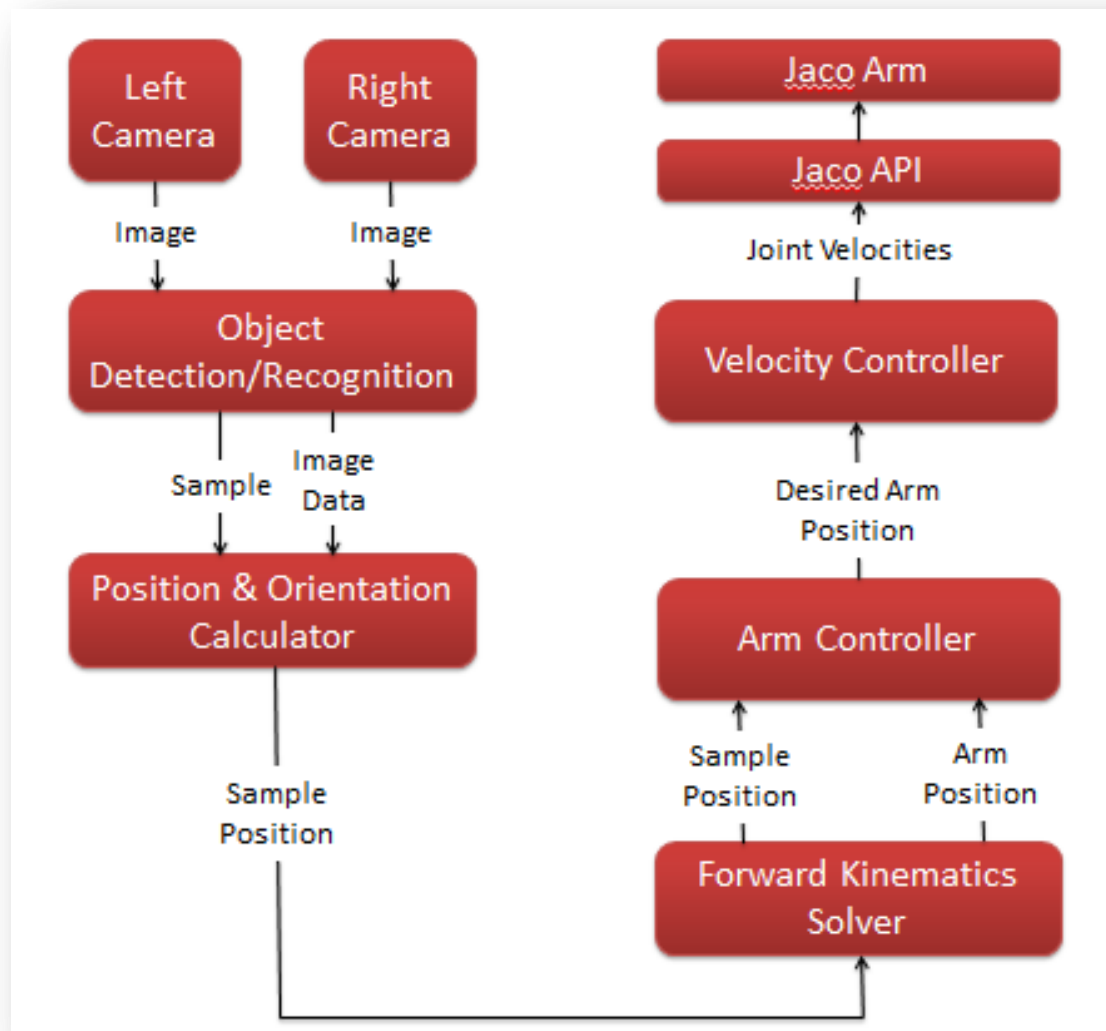
A screenshot of a computer interface for video processing. The main window is titled 'Source' and shows a video feed of a grassy field with several colorful objects (balls, sticks) scattered on it. To the right, a window titled 'Contours' shows the same video feed with various colored shapes (circles, squares, rectangles) overlaid on the objects, representing detected contours. Below the video feed, a terminal window displays a list of object centers with their coordinates. The terminal output is as follows:

```
Center of object[4]= 671.376,432.221
Center of object[5]= 819.703,406.076
Center of object[6]= 462.982,411.012
Center of object[7]= 203.7,388.1
Center of object[8]= 373,372
Center of object[9]= 371,371
Center of object[10]= 378.583,363.167
Center of object[11]= 671,348.5
Center of object[12]= 687,345
Center of object[13]= 692,342
Center of object[14]= 676.3,339.5
Center of object[15]= 515,296
Center of object[16]= 521,296
Center of object[17]= 518,296
Center of object[18]= 405,297
```

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Sample Detection from Fixed Cameras



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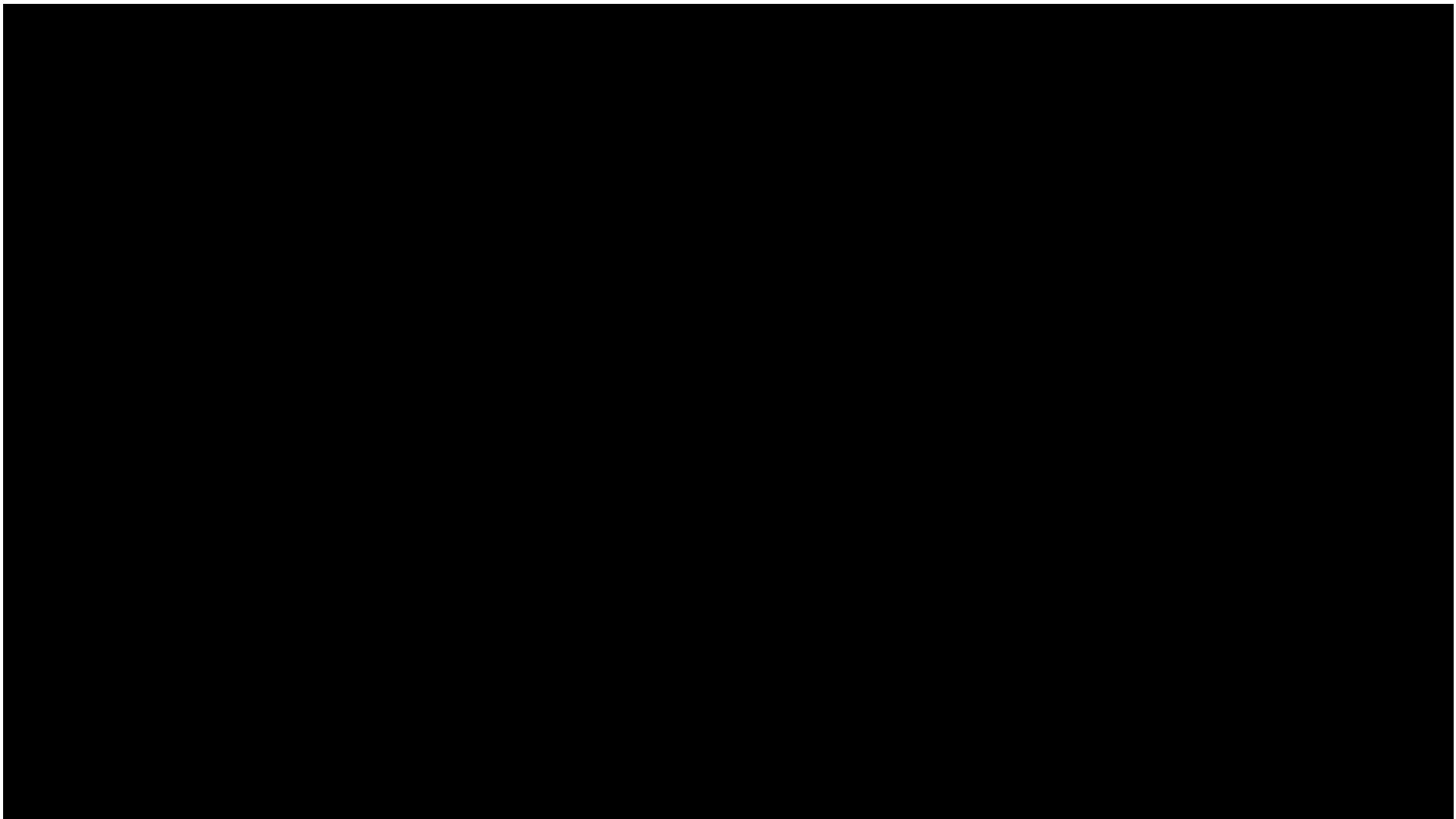
Sample Detection Results



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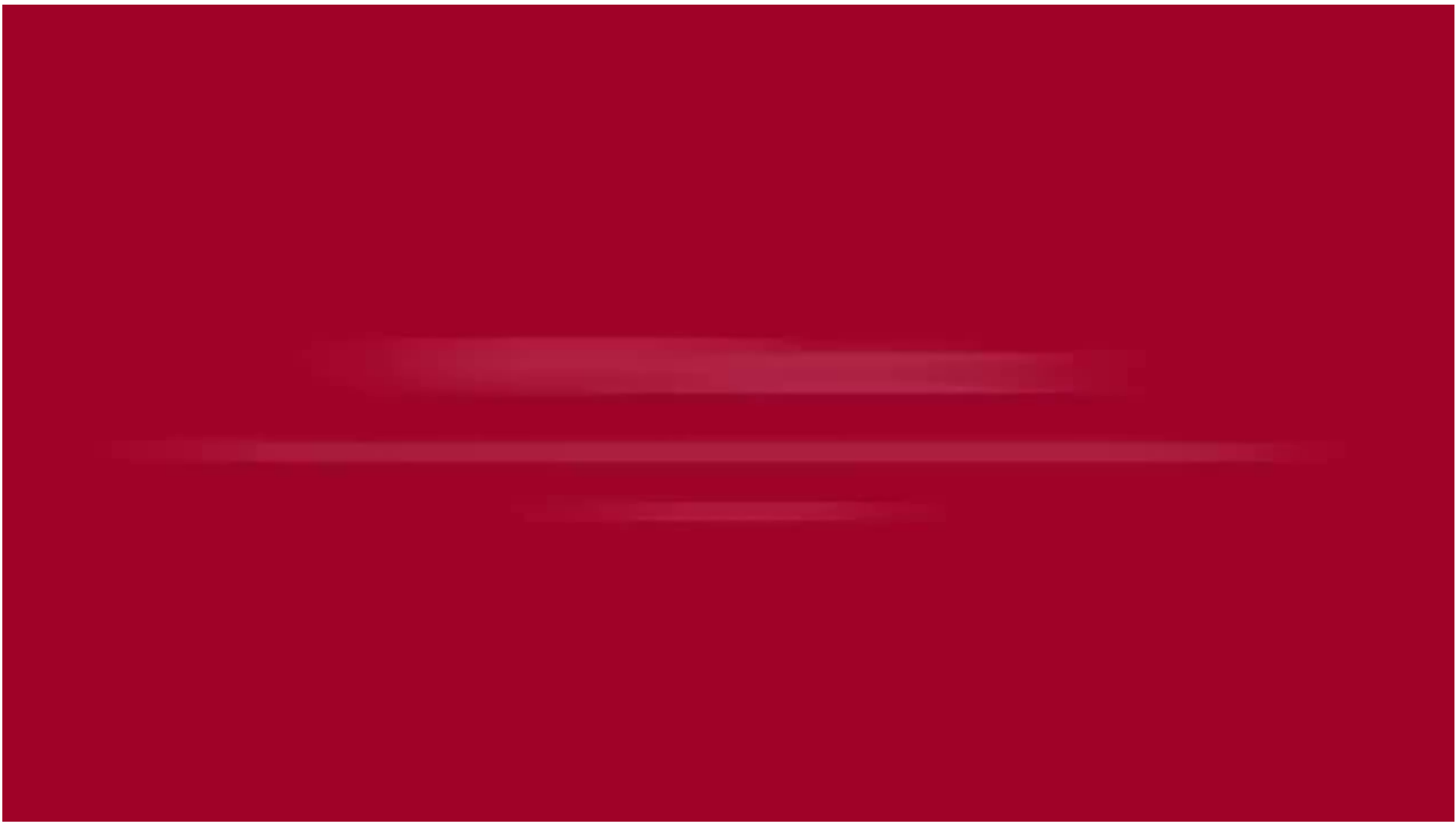


Perturbations in the Cameras



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Questions and Comments



<http://robot.wpi.edu/rover>
rover@wpi.edu



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