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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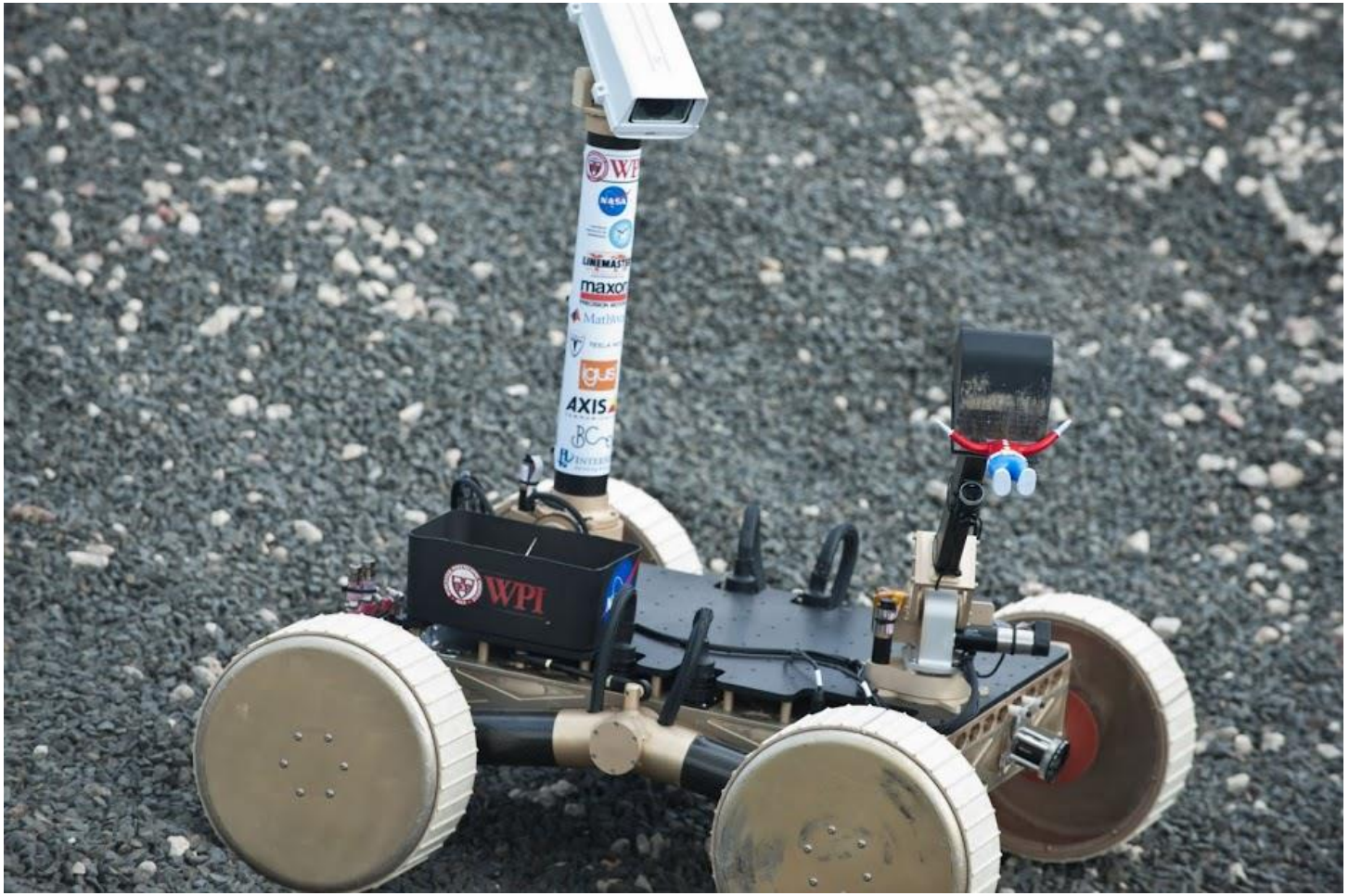


AERO Sample Return Challenge

Sample Return Robot Challenge

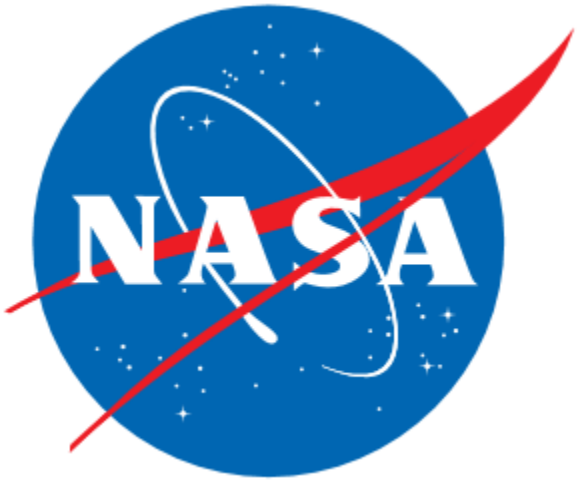
DEMONSTRATE A ROBOT

that can

LOCATE AND RETRIEVE GEOLOGIC SAMPLES

from a

WIDE AND VARIED TERRAIN WITHOUT HUMAN CONTROL



Geologic Samples

Easy Samples
Pre-cached sample

Pink Tennis Ball

Red Hockey Puck

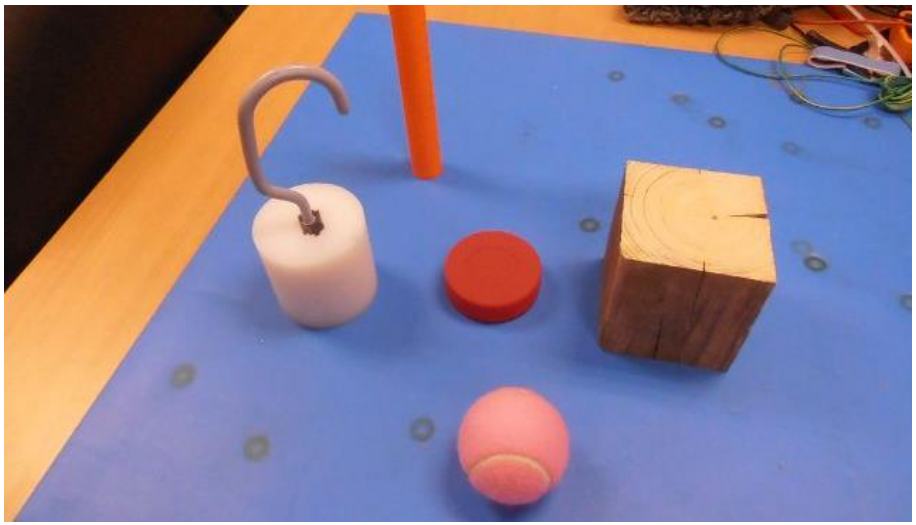
Orange PVC Pipe

Intermediate Samples
Uniquely Colored Spherical Object 20-60mm

Purple Rock 6-10cm

Wooden Cube ~10cm

Hard Samples
Non ferrous metal object with engraving x3



AERO Platform

Clearpath Husky A200

- 4 wheel differentially driven platform

Kinova Jaco 6-DOF Arm

- Harmonic drive modules with absolute encoders

Initial Design

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

Cameras

- 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

LIDAR

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

IMU

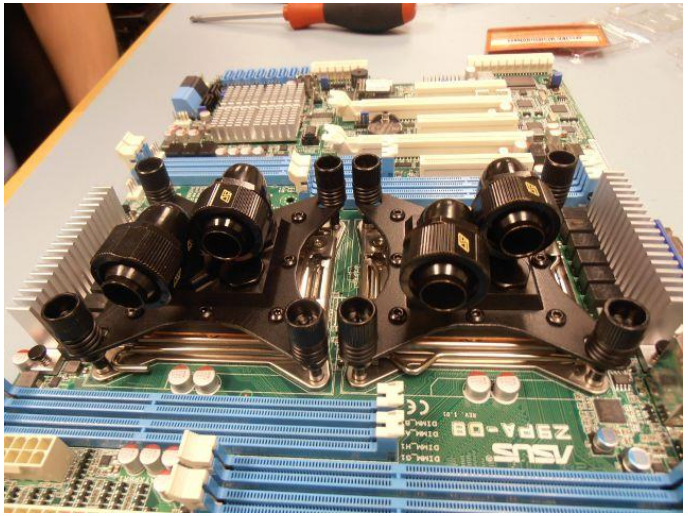
- KVH 1750 IMU
- Fiber optic gyros
- MEMS acc.
- RS-422 interface for 1kHz update rate
- Bias stability 0.05°/h
- 480°/s

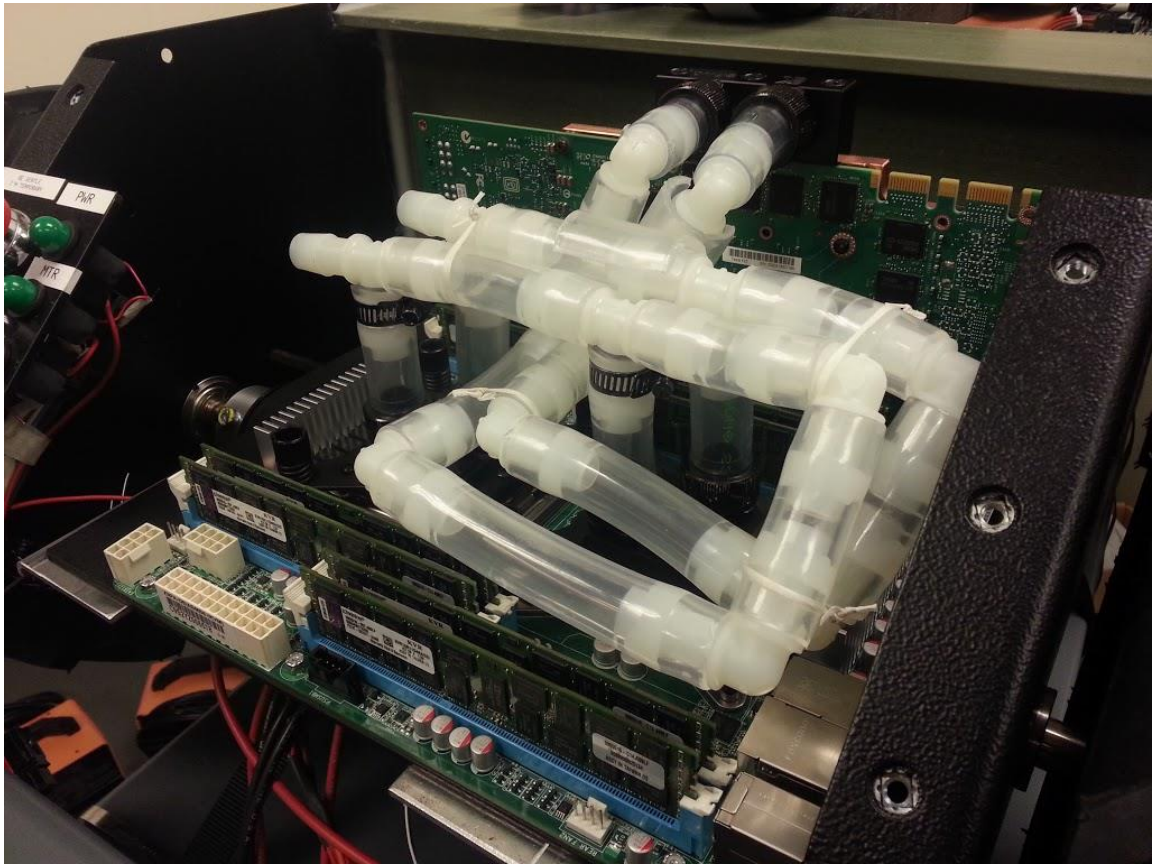
Data transfer is a significant issue.

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

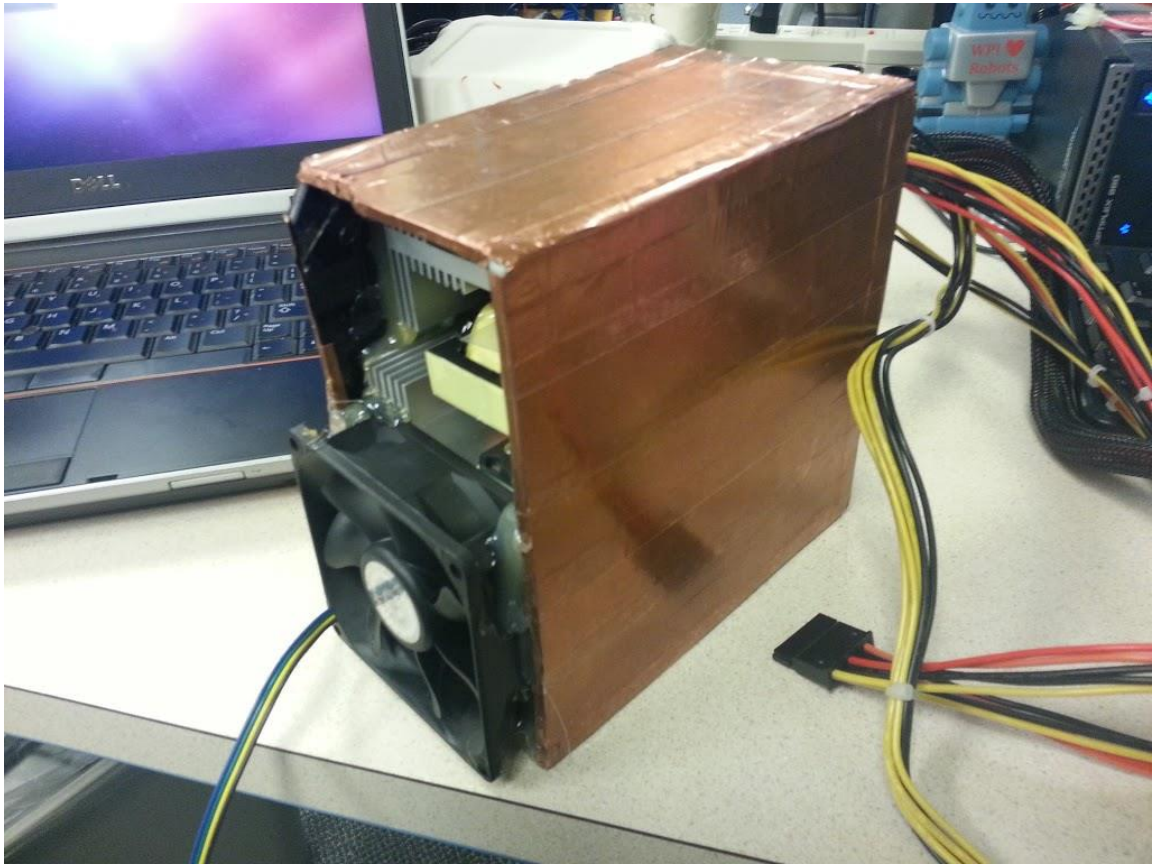
Computer System

Water Cooling

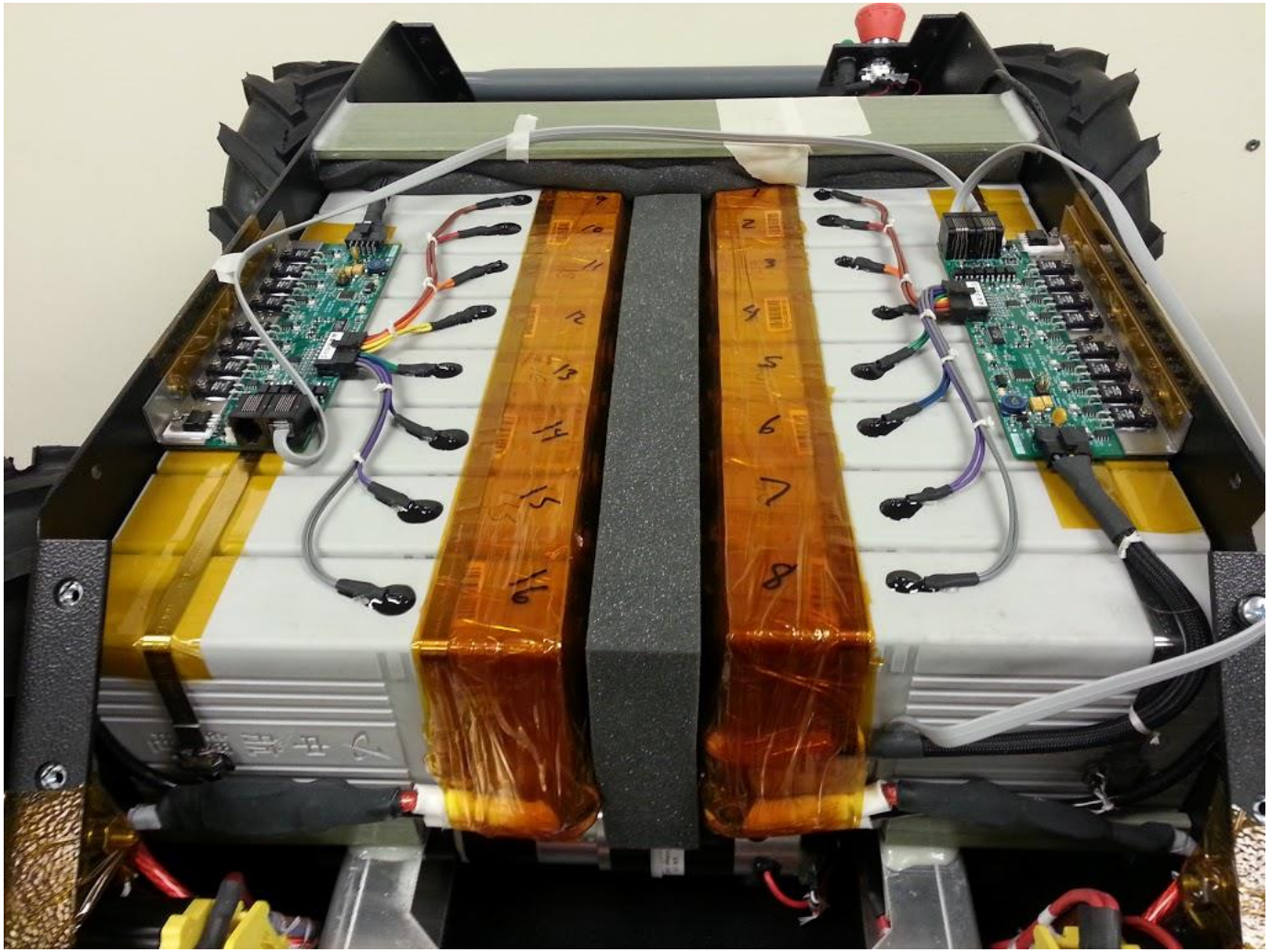




DC-DC Power Supply



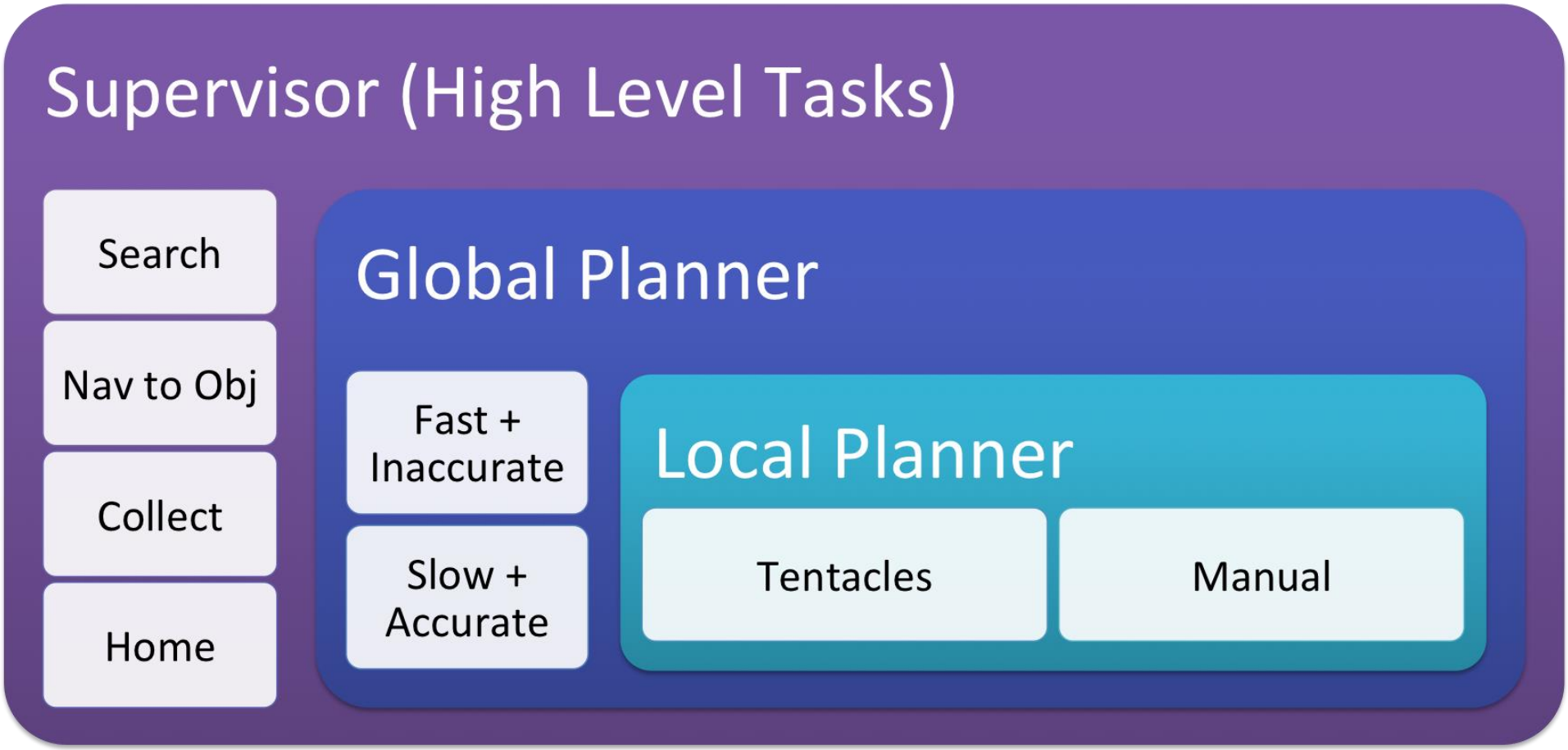
Batteries



Lateral Stability

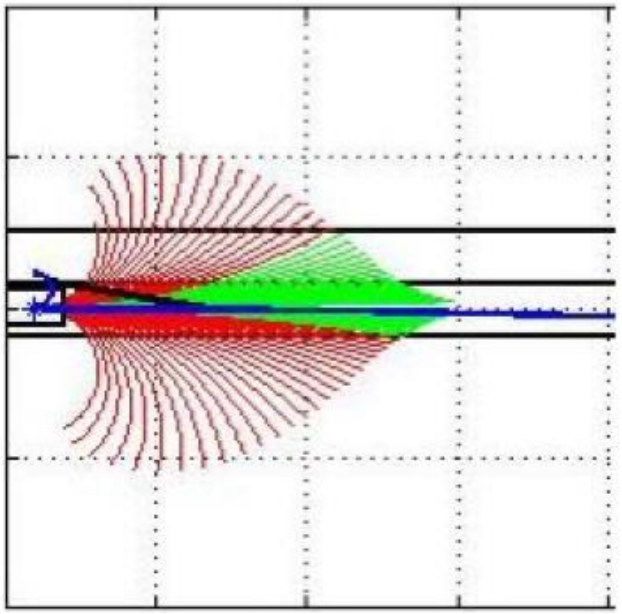
Current Design

Navigation Architecture



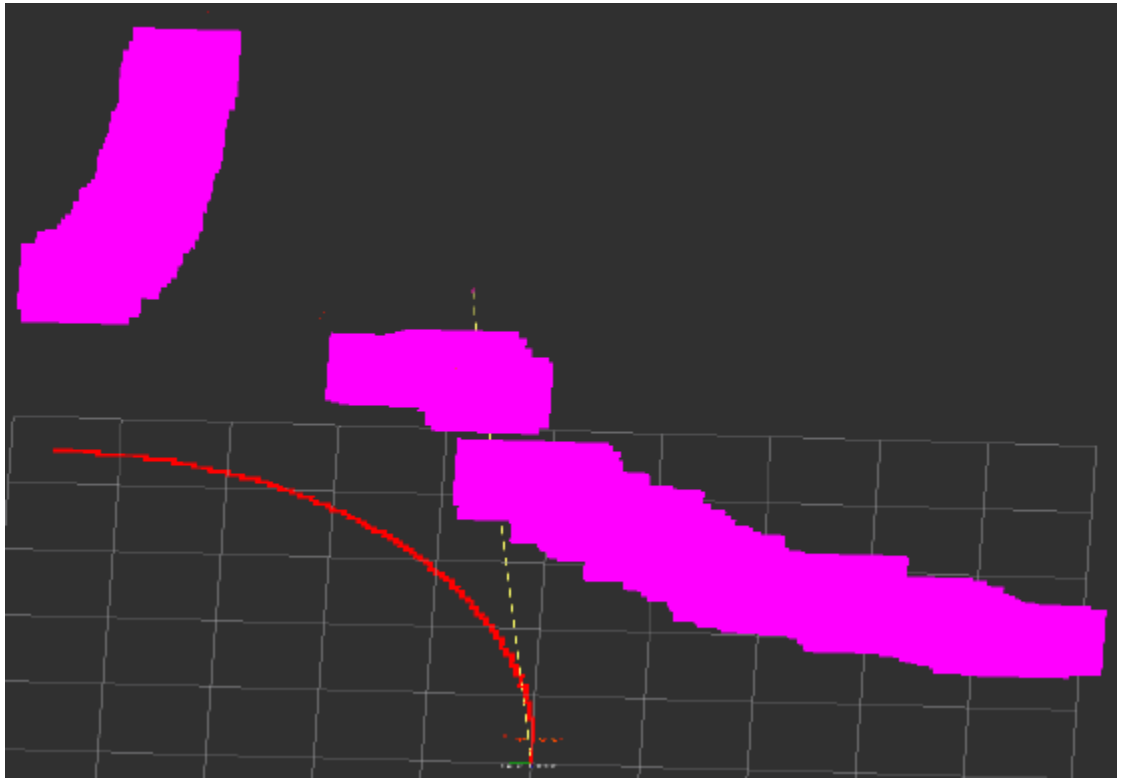
Driving with Tentacles

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



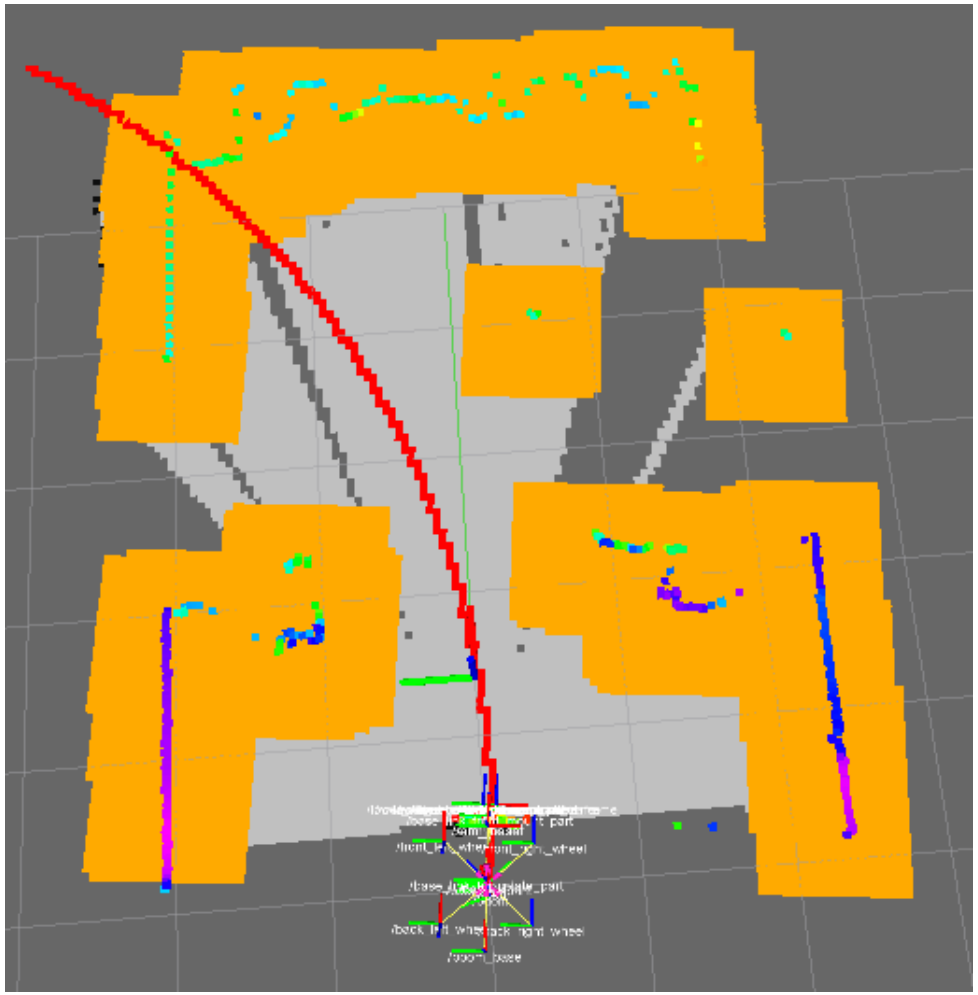
Driving with Tentacles - Integral Structures for Sensing and Motion
Felix v. Hundelshausen, Michael Himmelsbach, Falk Hecker, Andre Mueller, Hans-Joachim Wuensche

Our Implementation



Global Planner and SLAM

- ROS gmapping
- Utilized LIDAR and IMU sensors
- Small modification for inverted LIDAR



Tree Detection

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

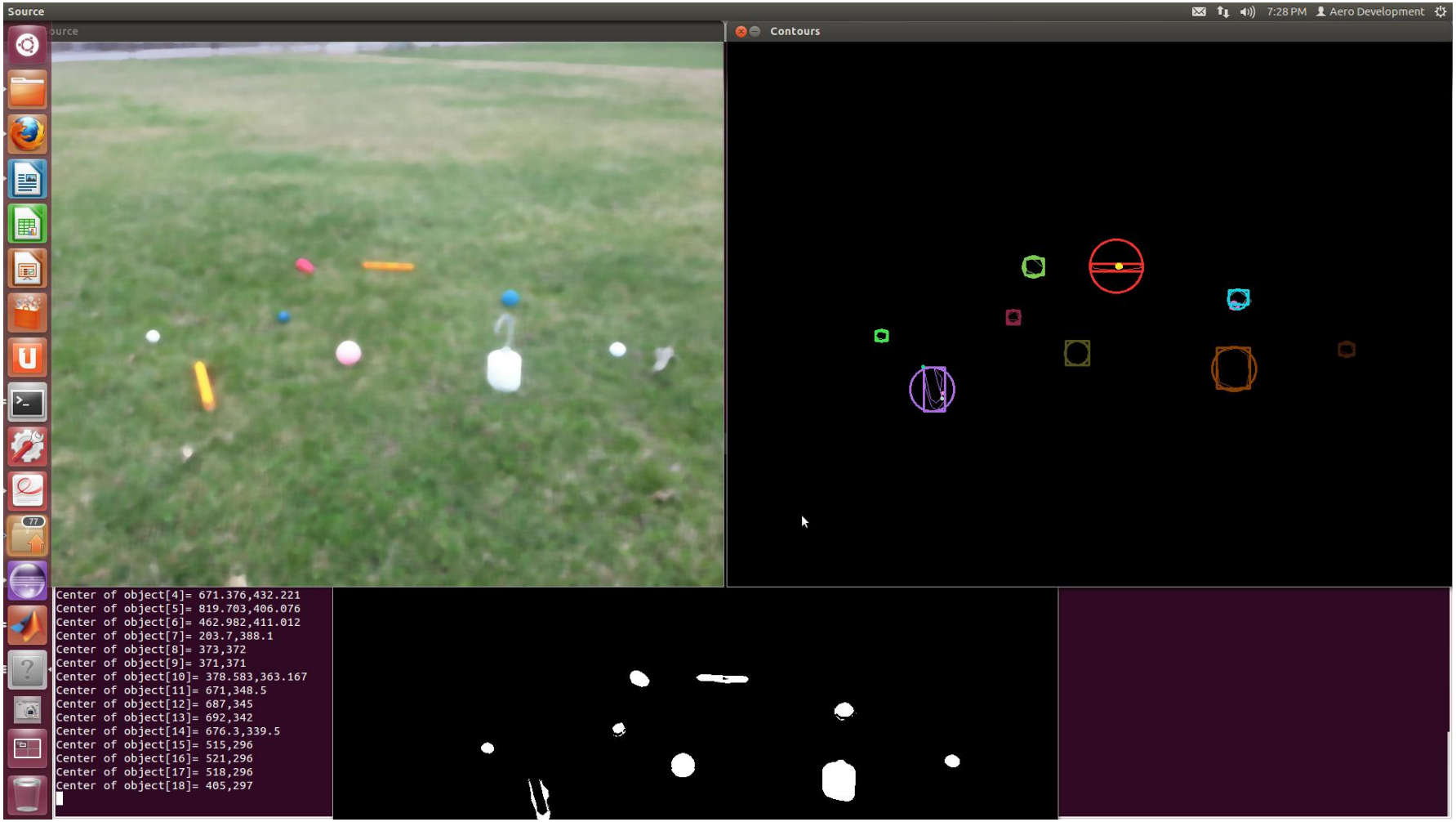
Sample Detection with Vision System

1. **Mast cameras identify anomalies in the grass using simple normalized RGB thresholding.**

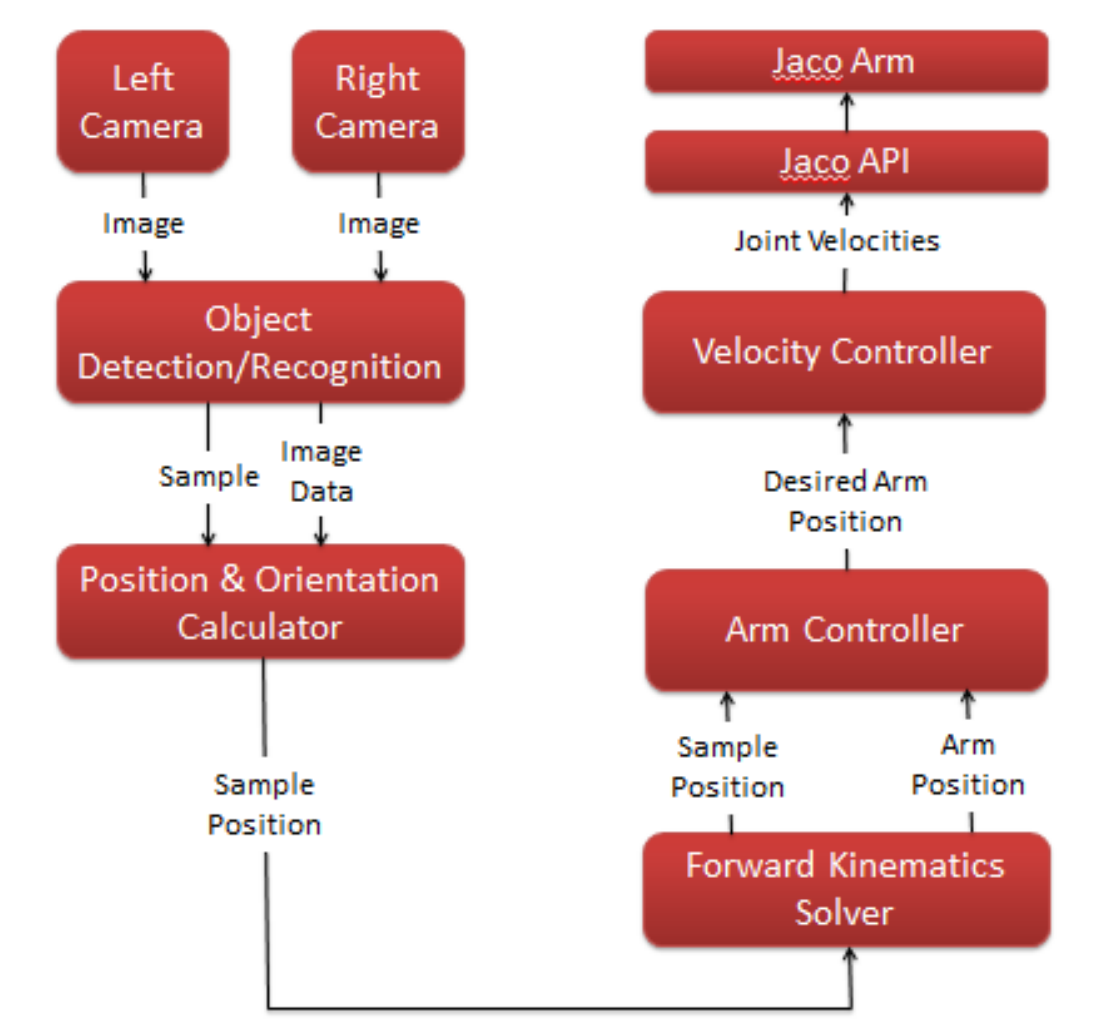
2. **Fixed cameras identify samples using OpenCV cascade classifier. Disparity map provides range to sample.**

Background noise for training sets for the classifier are critical.

Anomaly Detection from Mast Cameras

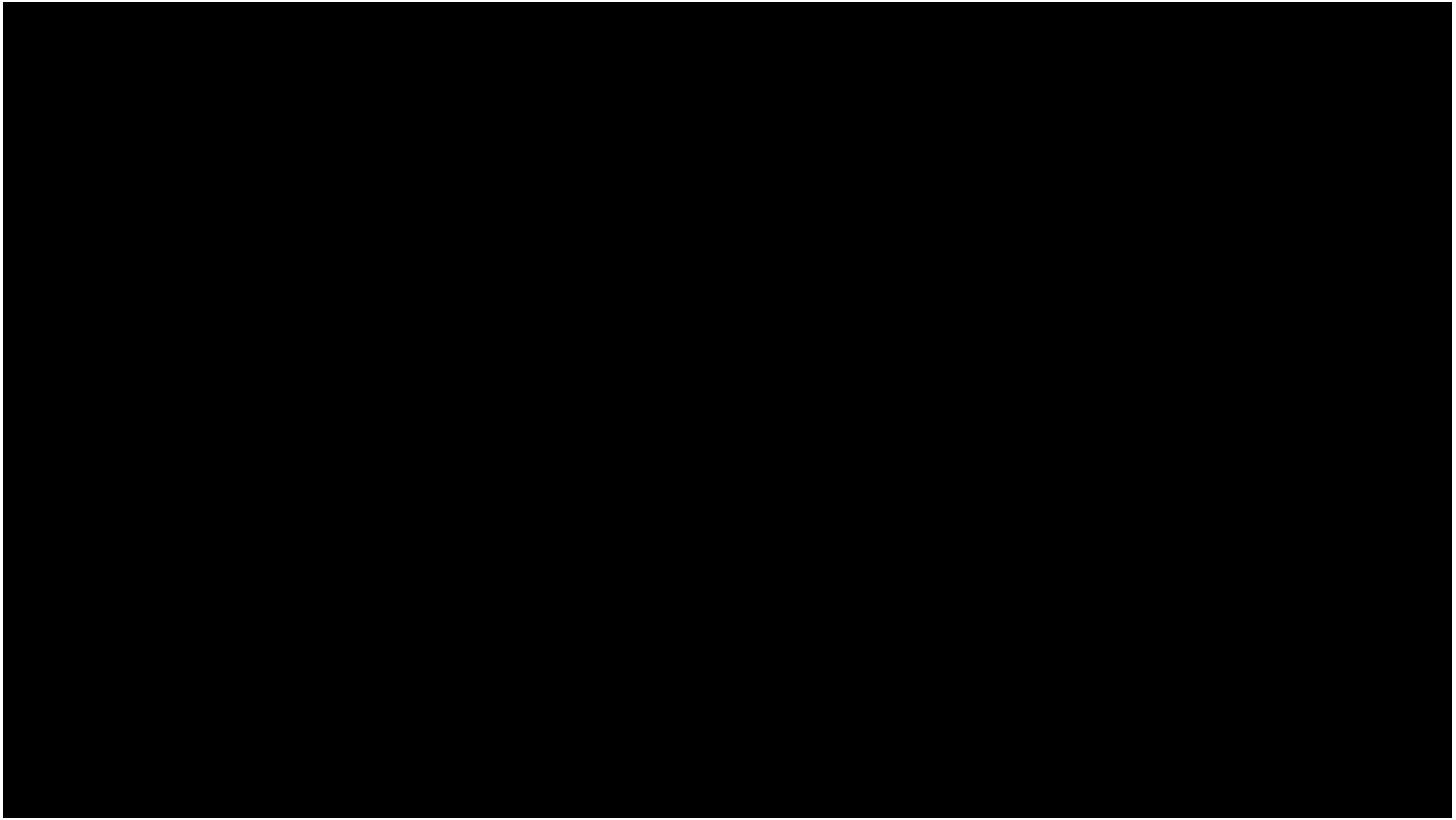


Sample Detection from Fixed Cameras

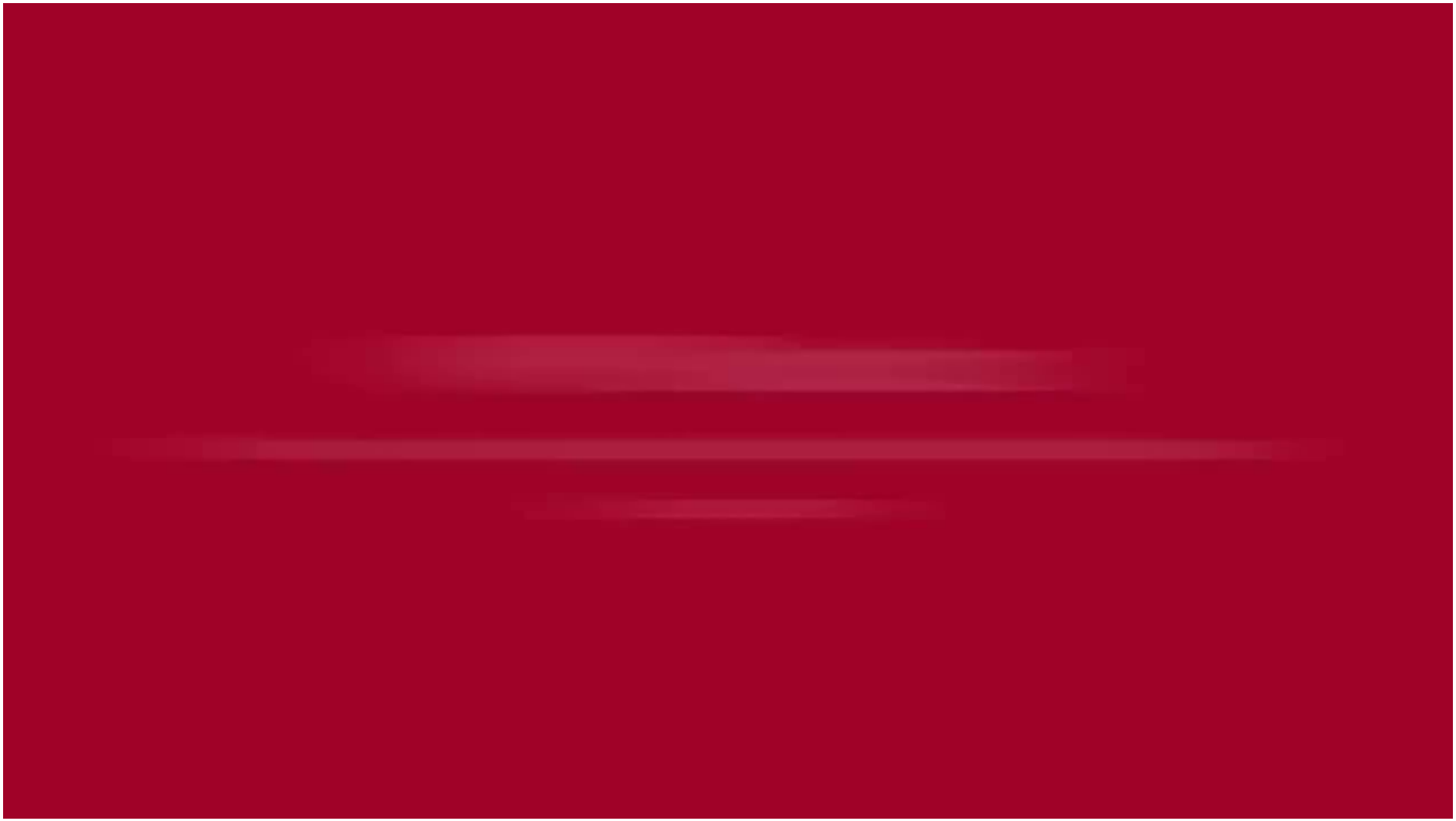


Sample Detection Results

Perturbations in the Cameras



System Test



Questions and Comments

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