Design and Development of AERO

Autonomous Exploration Rover

2013 Sample Return Robot Centennial Challenge
Motivation for AERO

AERO Sample Return Challenge

Planetary Rovers Workshop – ICRA 2013 – Karlsruhe, Germany
Motivation for AERO
Sample Return Robot Challenge

DEMONSTRATE A ROBOT

that can

LOCATE AND RETRIEVE GEOLOGIC SAMPLES

from a

WIDE AND VARIED TERRAIN WITHOUT HUMAN CONTROL

NASA
# 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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**AERO Sample Return Challenge**

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AERO Platform

Clearpath Husky A200
• 4 wheel differentially driven platform

Kinova Jaco 6-DOF Arm
• Harmonic drive modules with absolute encoders
## Initial Design

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Dimensions (LxWxH)</td>
<td>99 x 67 x 56 cm</td>
</tr>
<tr>
<td>Mass</td>
<td>60 kg</td>
</tr>
<tr>
<td>Rated Payload</td>
<td>20 kg</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>100 cm/sec</td>
</tr>
<tr>
<td>Maximum Obstacle</td>
<td>13 cm</td>
</tr>
<tr>
<td>Operating Time</td>
<td>3 hrs typical</td>
</tr>
<tr>
<td>Maximum Drive Power</td>
<td>800 W</td>
</tr>
<tr>
<td>Battery</td>
<td>25.6V 80 Ah LiFePO4</td>
</tr>
<tr>
<td>Software</td>
<td><img src="https://example.com/robotics-os" alt="ROS Enabled" /></td>
</tr>
</tbody>
</table>

**AERO Sample Return Challenge**
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
• KVH 1750 IMU
• Fiber optic gyros
• MEMS acc.
• RS-422 interface for 1kHz update rate
• Bias stability 0.05°/h
• 480°/s
Computing System

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

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DC-DC Power Supply
Batteries
Lateral Stability

AERO Sample Return Challenge
Current Design

AERO Sample Return Challenge
Supervisor (High Level Tasks)

- Search
- Nav to Obj
- Collect
- Home

Global Planner

- Fast + Inaccurate
- Slow + Accurate

Local Planner

- Tentacles
- Manual
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
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

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Sample Detection Results
Perturbations in the Cameras
System Test
Questions and Comments

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