HyperSpectral Technology For Autonomous Vehicles

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Executive Summary

1. HyperSpectral (HS) imaging technology crucial for ‘better than human’ safety in Autonomous Vehicles (AV)

2. HS imaging technology allows players to catch-up with AV industry leaders (Tesla/Waymo)

3. Investment opportunities exist in hardware & software enabling HyperSpectral technology

4. Cost, privacy concerns & government regulations inhibitors to fast adoption

5. Key Takeaways and Predictions
Safety Of Autonomous Vehicles

Autonomous vehicle accidents in the news...

Current camera technology is a limiter for fully autonomous driving
Why HyperSpectral Cameras?

See in the Dark
Why HyperSpectral Cameras?

Ignore Shadows
Why HyperSpectral Cameras?

See Through Fog
Why HyperSpectral Cameras?

Avoid Sun and Headlight Glare

Safer than the Human Eye (or 🔴)
**How HyperSpectral Technology Works?**

**Spectrum Range of HS Cameras**

- Ultraviolet
- Visible light
- Near infrared

200 nm to 1300 nm

**Example Use Case**

*Discriminate objects using spectral signature*

1. **Focus on Building**
2. **Focus on Doors**
3. **Focus on Person**

Simple **filtering** to focus on various parts of the frame

**More data & better data needing less processing**
HS Technology Could Disrupt AV Market

*HSCBOC: Hyper-Spectral Camera Based Object Classification*

Opportunity for new players to capture the AV market
Automotive Market: Ecosystem...
Automotive Market: Ecosystem... is Expanding

1. Robust ecosystem with multiple players throughout the value chain
2. ~75M cars sold in 2019 (Globally)
3. ~$4T in sales in 2019 (Globally)
HyperSpectral Market poised to **explode** in the next 5 Years

$15.1B to $23.3B automotive camera market by 2025

- **$13.6B** to **$21.0B**
- **2019** to **$8.2B**
- **2025**
- **19.0% CAGR**
- **10.8% CAGR**

**Legend**
- Automotive Camera Market
- Automotive Hyperspectral Camera Market

**Expecting 90% attach rate by 2025**

*HS camera technology key enabler for ‘better than human’ level of safety*
Challenge To Adoption: Cost

Cost vs Safety

- **Up to $5,000**
  - Vision ONLY
  - ≤ Level 3 Autonomy
- **Up to $75,000**
  - Vision + LIDAR
  - ≤ Level 4 Autonomy
- **Up to $100,000**
  - HyperSpectral
  - Level 5 Full Automation

**Perception** is better technology **cost more**....
Low Cost HyperSpectral Cameras

HS Camera System Cost: $20K – $100K Per Unit, but…

On-going research

University Of Washington
&
Microsoft Research

Goal: Develop smaller & cheaper HS cameras for Mobile devices

$800 HS camera HyperCam

In the news

Low Cost Optics MEMS technology

$150 BOM cost, with potential to reach $20

Hyperspectral imaging is to photography, what photography was to painting, a revolution.

Low Cost HS Cameras starting to hit the market
# Hyperspectral Cameras Disruptions By 2025

<table>
<thead>
<tr>
<th>Disruption</th>
<th>Likelihood</th>
<th>Enablers &amp; Inhibitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace Visible Cameras</td>
<td>75%</td>
<td>1. Improved safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Higher cost</td>
</tr>
<tr>
<td>Replace LIDAR systems</td>
<td>50%</td>
<td>1. LIDAR systems are currently expensive</td>
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<tr>
<td></td>
<td></td>
<td>2. Could be replaced by multiple HyperSpectral cameras</td>
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<tr>
<td></td>
<td></td>
<td>3. LIDAR system costs are trending down</td>
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<tr>
<td>Level Playing Field</td>
<td>75%</td>
<td>1. Reduce need for processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Limit need for complex algorithms</td>
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<tr>
<td></td>
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<td>3. Initial high costs could be a barrier to entry</td>
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<tr>
<td>Adoption in infrastructure</td>
<td>75%</td>
<td>1. Increased safety with connected vehicles</td>
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<td></td>
<td></td>
<td>2. Help with surveillance &amp; insurance claim resolutions</td>
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<tr>
<td></td>
<td></td>
<td>3. Government regulations &amp; privacy concerns</td>
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Inhibitors exist, but none appear to be show-stoppers
Key Takeaways

• HyperSpectral imaging technology delivers the safety consumers demand for autonomous vehicles

• The technology is ready… and the price is dropping!

• Provides business and investment opportunities for new players in the autonomous vehicle market
Thank You!
Estimating the Auto Camera TAM for 2019

Auto Camera Market Size for 2019:

\[ 75\text{M Cars} \times 5\% \text{ Leve2+ Cars} \times 7 \text{ Cameras} \times \$300 \text{ Cost Per Camera} = \$7.9B \]

References:
1. (Statista) # of cars sold worldwide between 2010 and 2020 – 75M cars sold globally in 2019
2. Level2 + Car Sales = 5% of 75M cars
   \[ 3.75\text{M Level2+ cars} \] (conservative estimate)
   
   Canalys Newsroom – 10% of all cars sold in US in Q2’19 at least at Level 2
3. Camera Cost Per Car = 7 Cameras X $300 Cost Per Camera
   \$2,100 Camera Cost Per Car (conservative assumption)

Cost to turn a car into a self-driving vehicle – $6,000 for cameras in a car
Importance of cameras to self-driving vehicles – 6 – 8 cameras per Level 2/3 car
Adding a backup camera to your vehicle – $150 - $400 per camera
## Matrix of Sensors Capabilities

<table>
<thead>
<tr>
<th></th>
<th>Hyperspectral Camera</th>
<th>Standard Camera</th>
<th>RADAR</th>
<th>LiDAR</th>
<th>Ultrasonic</th>
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<tbody>
<tr>
<td>Object Detection</td>
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<td><img src="image" alt="Fair" /></td>
<td><img src="image" alt="Good" /></td>
<td><img src="image" alt="Good" /></td>
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<td>Object Classification</td>
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<td><img src="image" alt="Good" /></td>
<td><img src="image" alt="Poor" /></td>
<td><img src="image" alt="Good" /></td>
<td><img src="image" alt="Poor" /></td>
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<td>Distance Estimation</td>
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<td><img src="image" alt="Fair" /></td>
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<tr>
<td>Object Edge Detection</td>
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<td><img src="image" alt="Poor" /></td>
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<tr>
<td>Lane Tracking</td>
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<td><img src="image" alt="Good" /></td>
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<tr>
<td>Current Cost</td>
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HS Cameras can solve current AV sensor deficiencies.