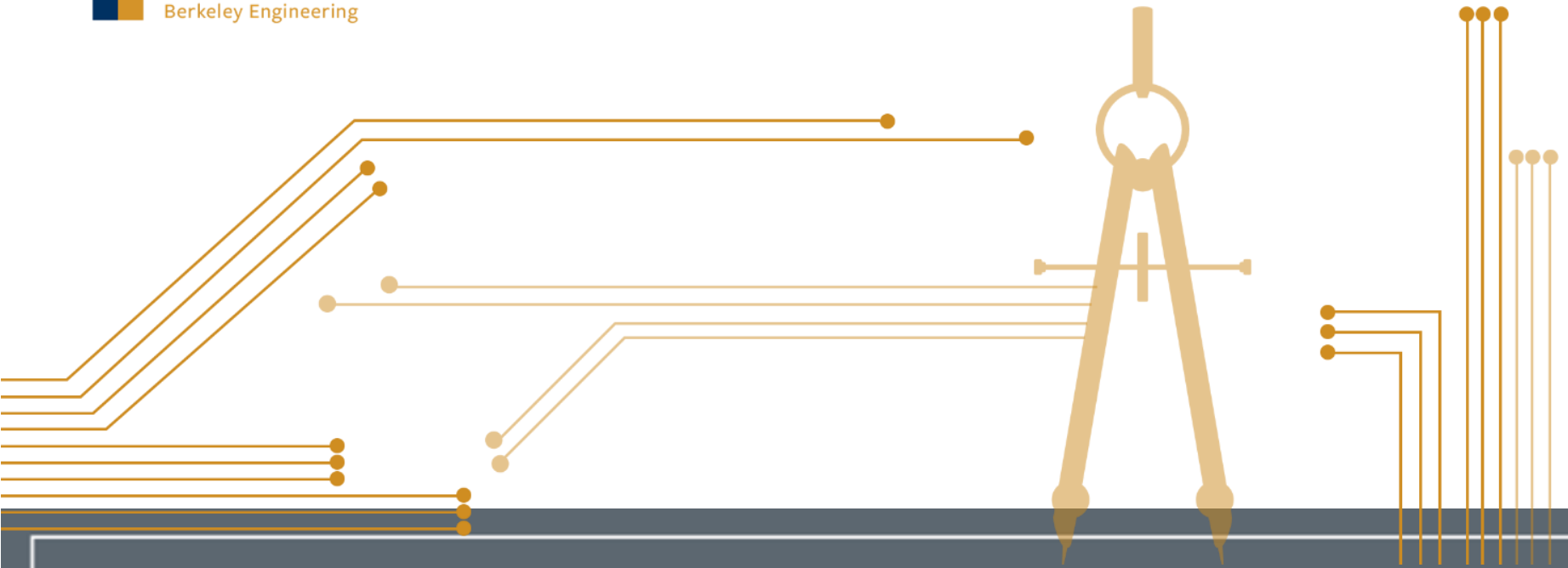




Pantas and Ting

Sutardja Center
for Entrepreneurship & Technology

Berkeley Engineering



HyperSpectral Technology For Autonomous Vehicles

Brian Brown, Bryan Meister, Chetan Mrutyunjaya, Jeff Kho, Paul Liu, Venkata Vaidyanathan, Vijay Narayanan

This work was created in an open classroom environment as part of a program within the Sutardja Center for Entrepreneurship & Technology and led by Prof. Ikhtlaq Sidhu at UC Berkeley. There should be no proprietary information contained in this paper. No information contained in this paper is intended to affect or influence public relations with any firm affiliated with any of the authors. The views represented are those of the authors alone and do not reflect those of the University of California Berkeley.

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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...




UBER




TESLA




TESLA

Current camera technology is a **limiter** for fully autonomous driving

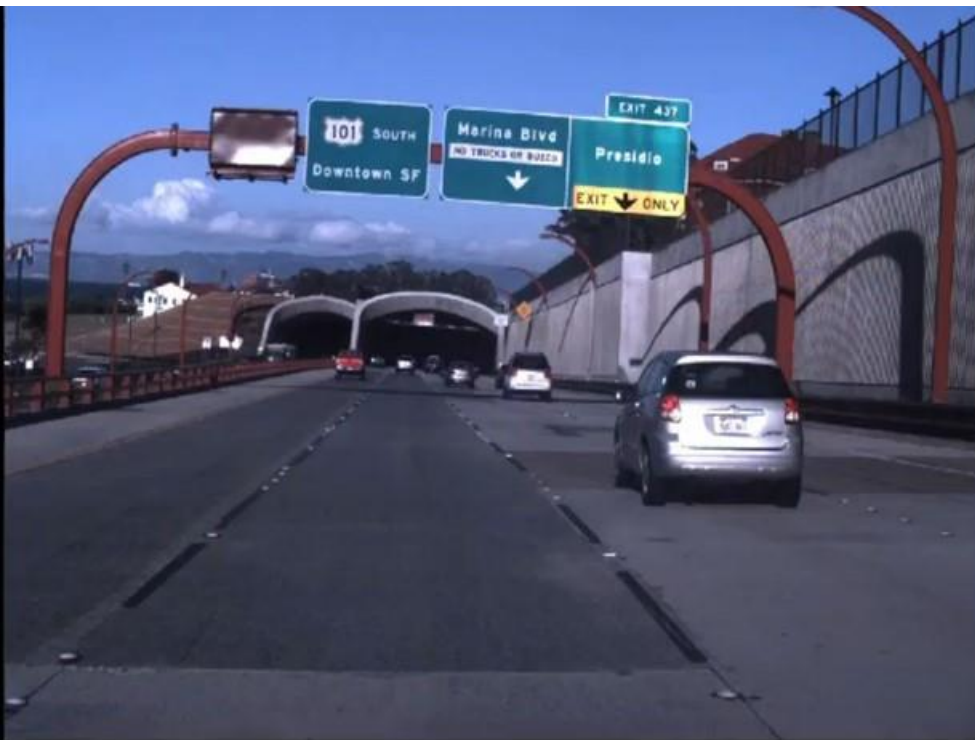
Why HyperSpectral Cameras?

See in the Dark



Why HyperSpectral Cameras?

Ignore Shadows



Why HyperSpectral Cameras?

See Through Fog

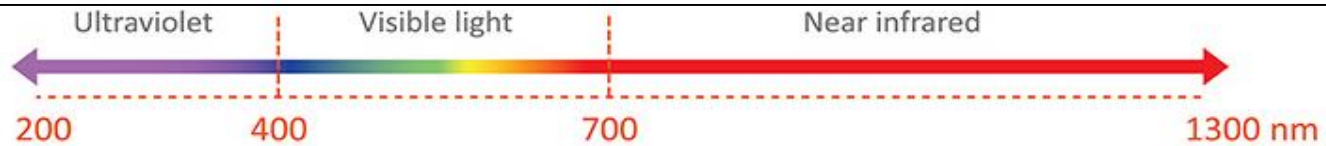


Why HyperSpectral Cameras?

Avoid Sun and Headlight Glare



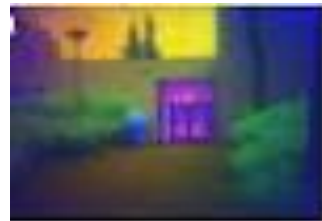
How HyperSpectral Technology Works?



Spectrum Range of HS Cameras

Example Use Case

Discriminate objects using spectral signature



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



Focus on **Building**



Focus on **Doors**

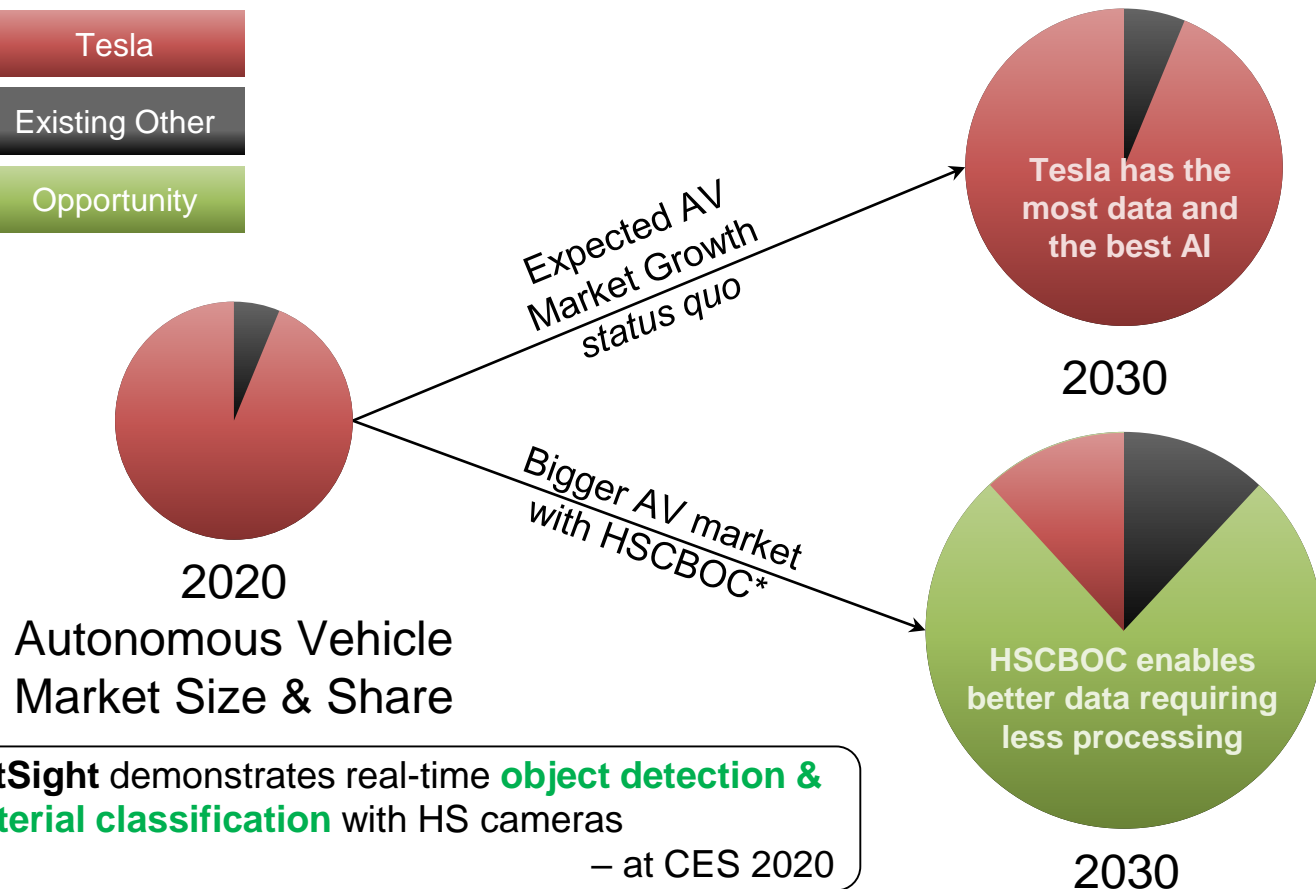
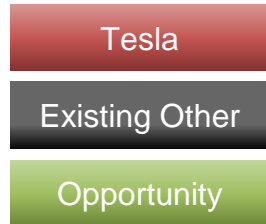


Focus on **Person**

More data & better data needing less processing

HS Technology Could Disrupt AV Market

Market Share



OutSight demonstrates real-time **object detection & material classification** with HS cameras

– at CES 2020

Opportunity for new players to capture the AV market



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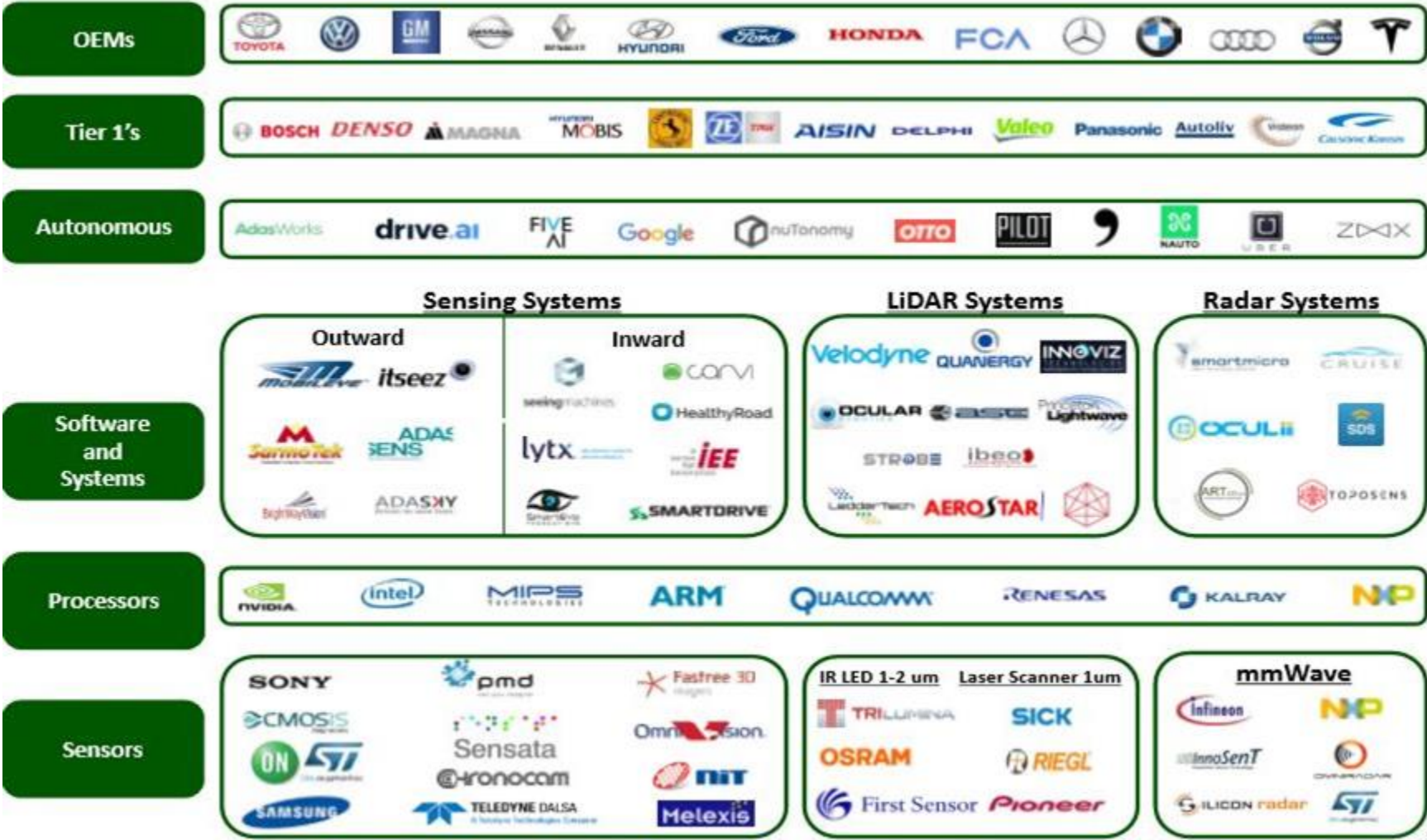
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* HSCBOC: Hyper-Spectral Camera Based Object Classification

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Automotive Market: Ecosystem...



Automotive Market: Ecosystem... is Expanding



1

Robust ecosystem with multiple players throughout the value chain

2

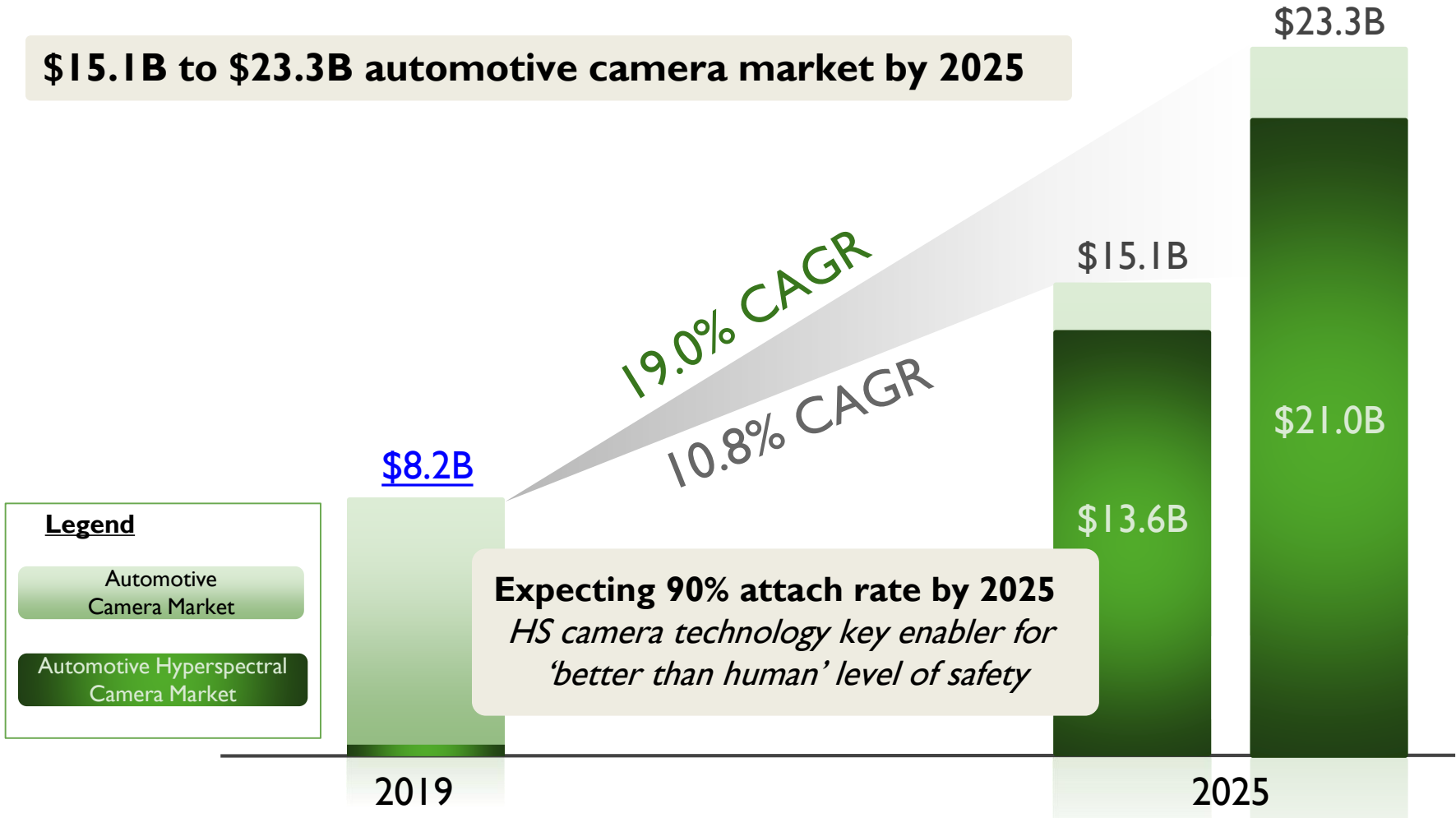
~75M cars sold in 2019
(Globally)

3

~\$4T in sales in 2019
(Globally)

What About Automotive Camera Market?

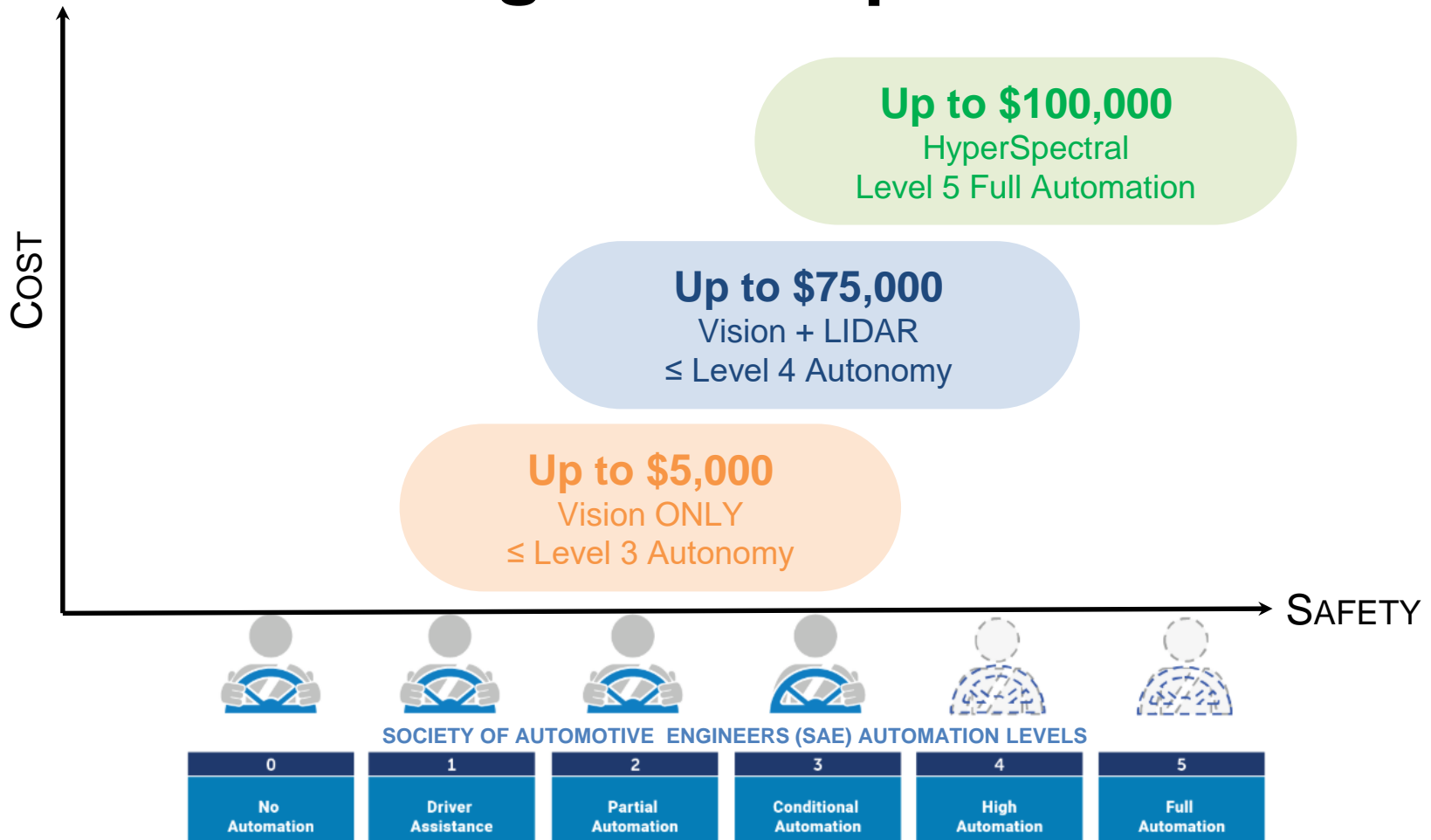
\$15.1B to \$23.3B automotive camera market by 2025



HyperSpectral Market poised to **explode** in the next 5 Years



Challenge To Adoption: Cost



Perception is better technology **cost more....**

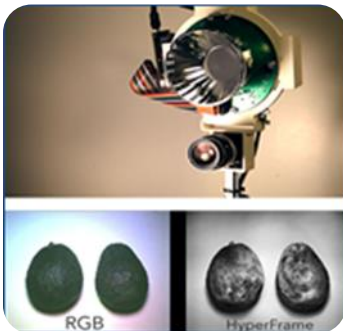
Low Cost HyperSpectral Cameras

HS Camera System Cost: **\$20K – \$100K** Per Unit, but...

On-going research



&



Goal: *Develop smaller & cheaper HS cameras for Mobile devices*

\$800 HS camera
HyperCam

In the news



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

Low Cost Optics MEMS technology

\$150 BOM cost, with potential to reach **\$20**



Low Cost HS Cameras starting to hit the market

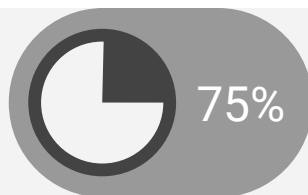
Hyperspectral Cameras Disruptions By 2025

Disruption

Likelihood

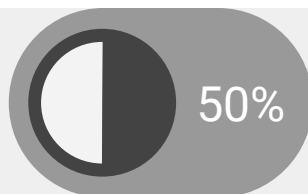
Enablers & Inhibitors

Replace Visible Cameras



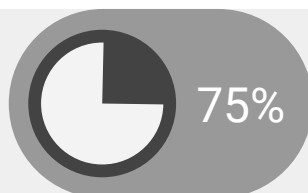
1. Improved safety
2. Higher cost

Replace LIDAR systems



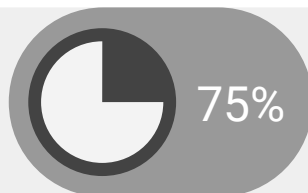
1. LIDAR systems are currently expensive
2. Could be replaced by multiple HyperSpectral cameras
3. LIDAR system costs are trending down

Level Playing Field



1. Reduce need for processing
2. Limit need for complex algorithms
3. Initial high costs could be a barrier to entry

Adoption in infrastructure



1. Increased safety with connected vehicles
2. Help with surveillance & insurance claim resolutions
3. Government regulations & privacy concerns

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:

75M Cars X **5% Level2+ Cars** X **7 Cameras** X **\$300 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
3.75M 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)

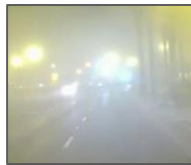
Cost to turn a car into a self-driving vehicle – [\\$6,000 for cameras in a car](#) –
Importance of cameras to self-driving vehicles – [6 – 8 cameras per Level 2/3 car](#)
Adding a backup camera to your vehicle – [\\$150 - \\$400 per camera](#)

Matrix of Sensors Capabilities

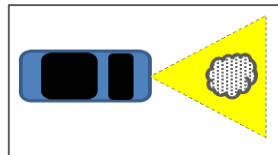
	Hyperspectral Camera	Standard Camera	RADAR	LiDAR	Ultrasonic
Object Detection	Good	Fair	Good	Good	Good
Object Classification	Good	Good	Poor	Fair	Poor
Distance Estimation	Fair	Fair	Good	Good	Good
Object Edge Detection	Good	Good	Poor	Good	Good
Lane Tracking	Good	Good	Poor	Fair	Poor
Range	Good	Fair	Good	Fair	Poor
Bad Weather	Good	Poor	Good	Fair	Good
Low Light	Good	Fair	Good	Good	Good
Current Cost	Poor	Good	Good	Poor	Good



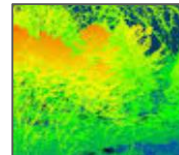
Reference: Hyperspectral camera adapted in part to <http://umich.edu/~umtriswt/PDF/SWT-2017-12.pdf>



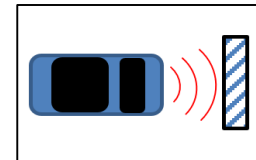
Camera Image
(Road in Fog)



Radar Data
(Unknown Object)



Lidar Image
(Trees)



Ultrasonic Data
(Unknown object)

HS Cameras can **solve** current AV sensor deficiencies