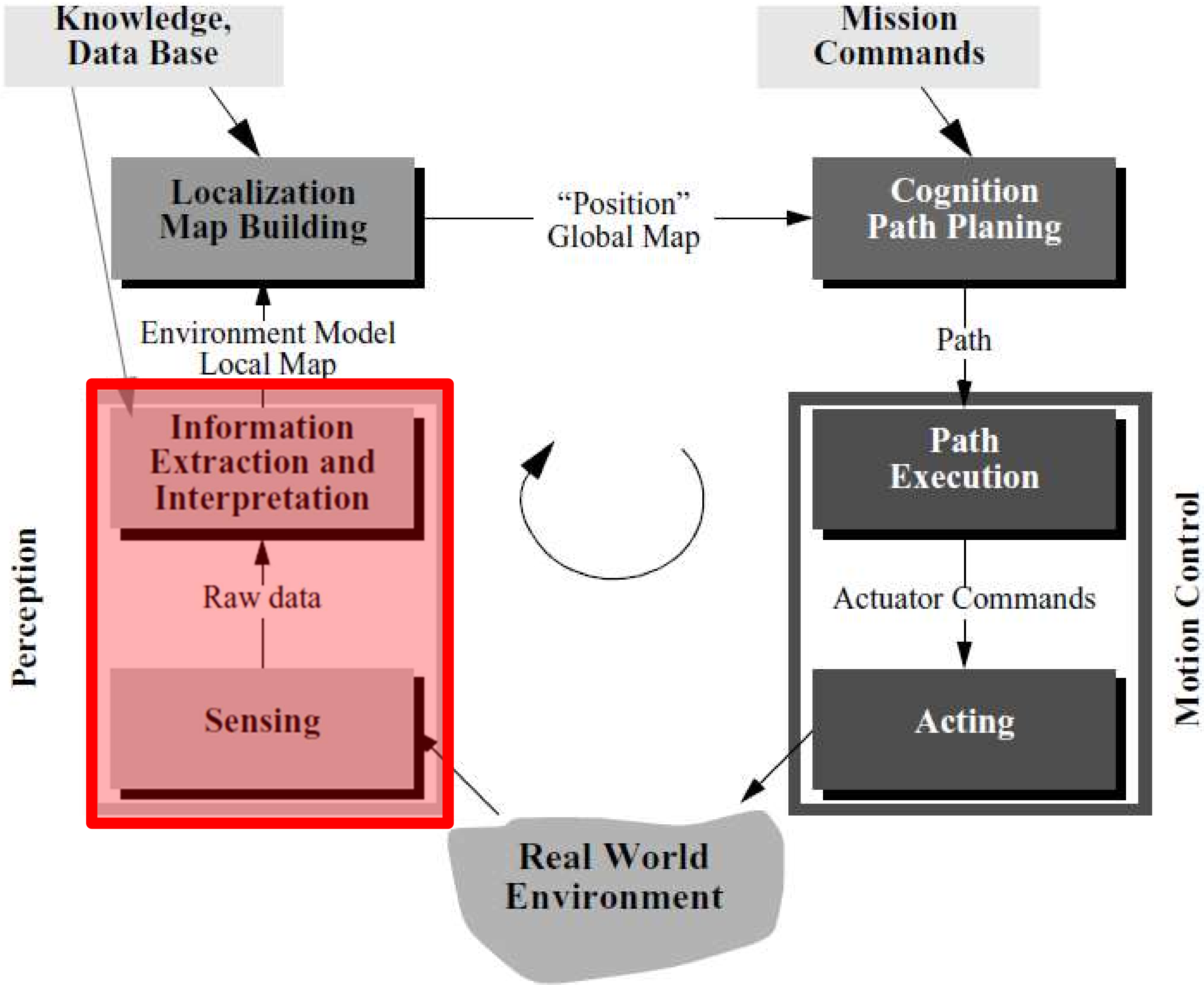
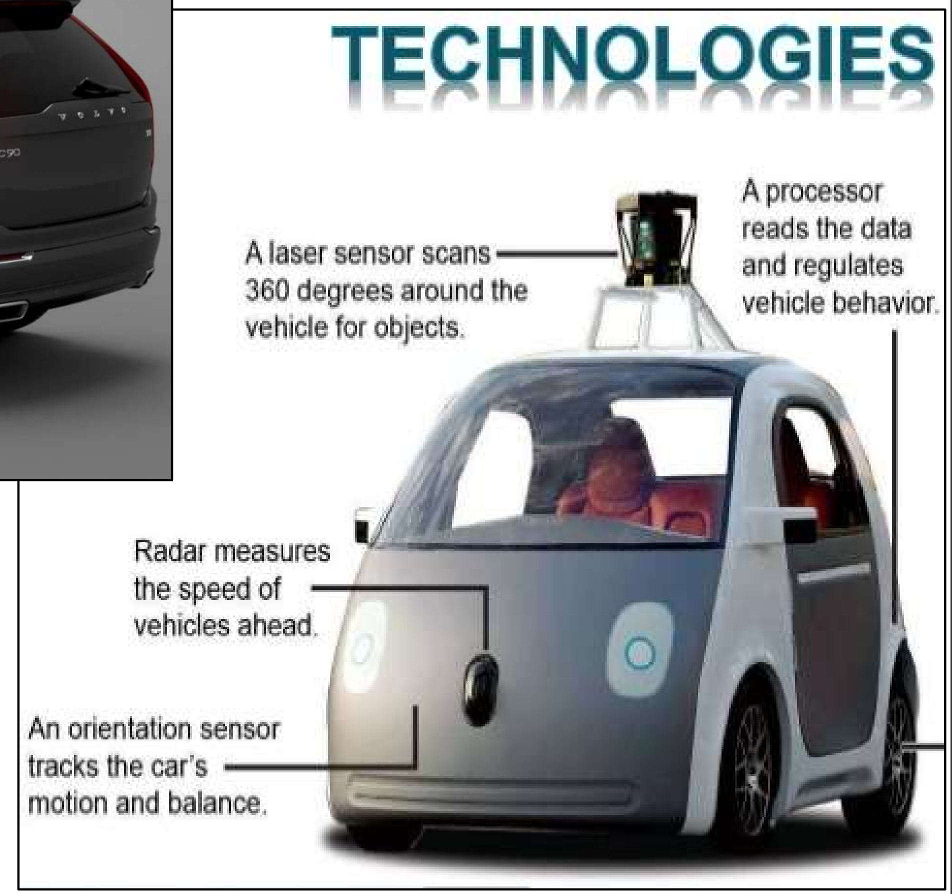
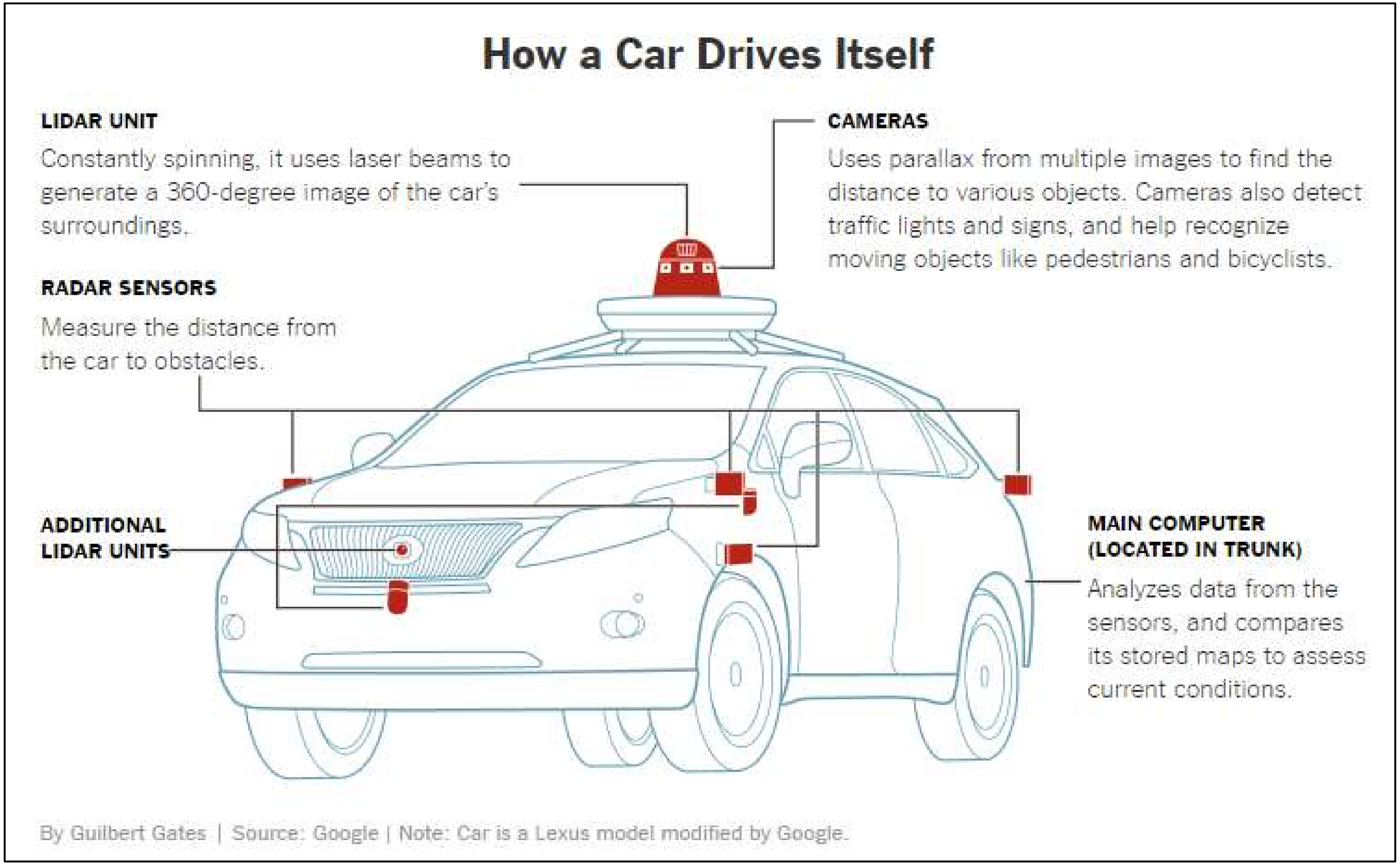
ENPM 809T

UMCP, Mitchell


Knowledge,
Data Base
Mission
Commands
Localization
Map Building
"Position"
Global Map
Cognition
Path Planing
Environment Model
Local Map
Path
Information
Extraction and
Interpretation
Path
Execution
Perception
Raw data
Actuator Commands
Motion Control
Sensing
Acting
Real World
Environment

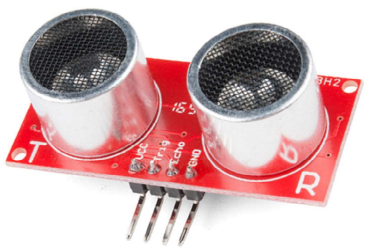

UBER


TECHNOLOGIES
A processor reads the data and regulates vehicle behavior.
A laser sensor scans 360 degrees around the vehicle for objects.
Radar measures the speed of vehicles ahead.
An orientation sensor tracks the car's motion and balance.


How a Car Drives Itself
LIDAR UNIT
Constantly spinning, it uses laser beams to generate a 360-degree image of the car's surroundings.
CAMERAS
Uses parallax from multiple images to find the distance to various objects. Cameras also detect traffic lights and signs, and help recognize moving objects like pedestrians and bicyclists.
RADAR SENSORS
Measure the distance from the car to obstacles.
ADDITIONAL LIDAR UNITS
MAIN COMPUTER (LOCATED IN TRUNK)
Analyzes data from the sensors, and compares its stored maps to assess current conditions.
By Guilbert Gates | Source: Google | Note: Car is a Lexus model modified by Google.

Robotic Sensors

- Encoders
- Accelerometers & IMU
- Beacons
- Remote sensing
  - Passive
  - Active

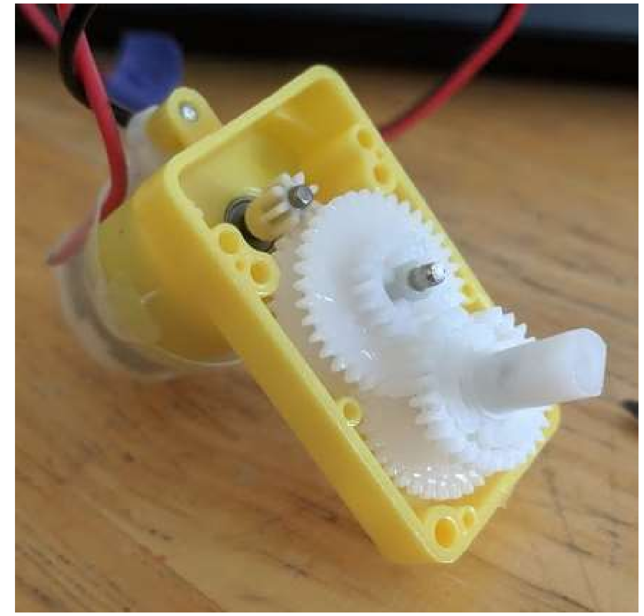


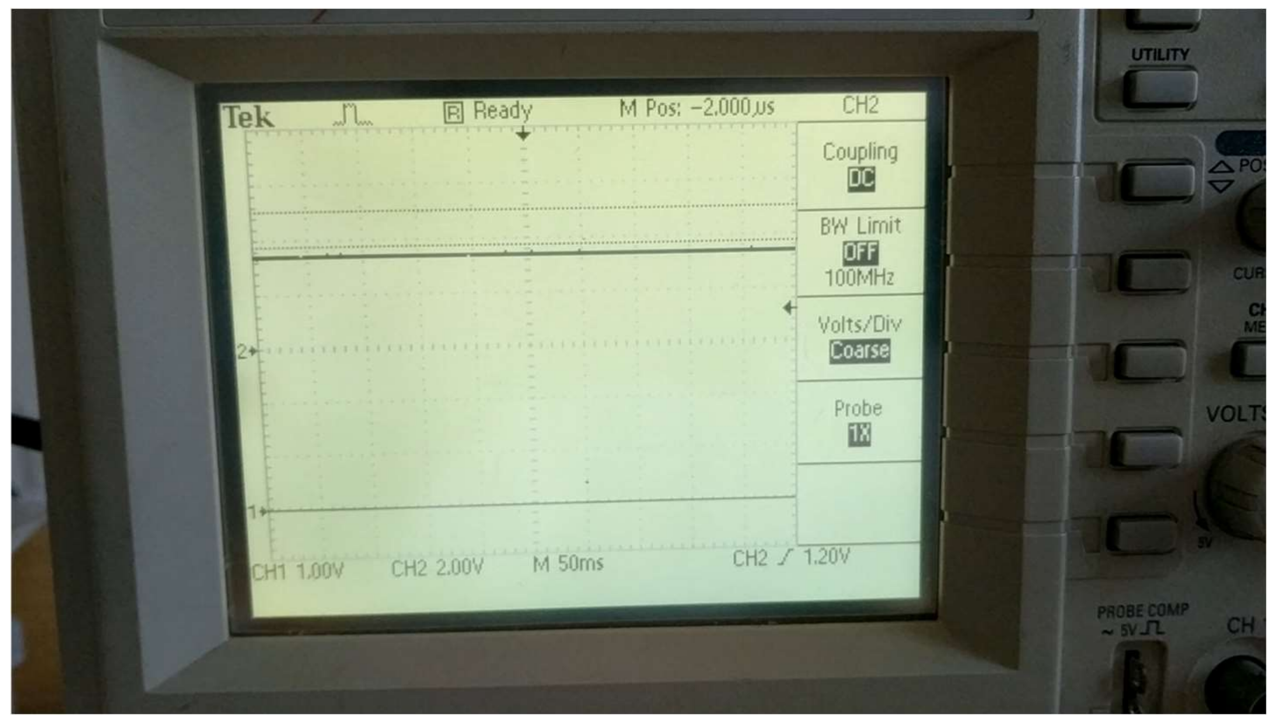
General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Tactile sensors (detection of physical contact or closeness; security switches)	Contact switches, bumpers Optical barriers Noncontact proximity sensors	EC EC EC	P A A
Wheel/motor sensors (wheel/motor speed and position)	Brush encoders Potentiometers Synchros, resolvers Optical encoders Magnetic encoders Inductive encoders Capacitive encoders	PC PC PC PC PC PC PC	P P A A A A A
Heading sensors (orientation of the robot in relation to a fixed reference frame)	Compass Gyroscopes Inclinometers	EC PC EC	P P A/P
Ground-based beacons (localization in a fixed reference frame)	GPS Active optical or RF beacons Active ultrasonic beacons Reflective beacons	EC EC EC EC	A A A A
Active ranging (reflectivity, time-of-flight, and geometric triangulation)	Reflectivity sensors Ultrasonic sensor Laser rangefinder Optical triangulation (1D) Structured light (2D)	EC EC EC EC EC	A A A A A
Motion/speed sensors (speed relative to fixed or moving objects)	Doppler radar Doppler sound	EC EC	A A
Vision-based sensors (visual ranging, whole-image analysis, segmentation, object recognition)	CCD/CMOS camera(s) Visual ranging packages Object tracking packages	EC	P

Encoders

- Electro-mechanical device
- Converts motion into sequence of digital pulses
- Pulse train converted to position measurements
  - Robot localization
- Typically magnetic or optical

Proprioceptive Sensor

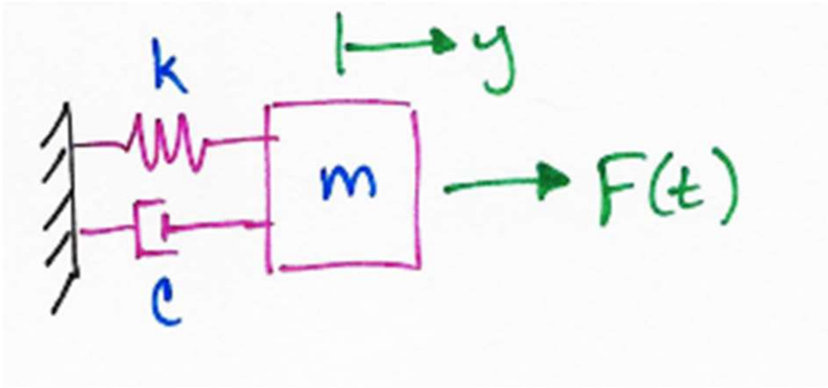


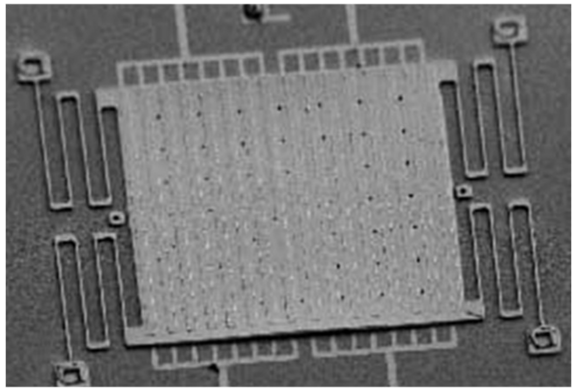


https://www.pololu.com/product/2590

Accelerometers & IMU

- Accelerometer measures external forces acting upon it
  - Mass-spring-damper
  - Typically capacitive measurement
- Inertial Measurement Unit (IMU) uses gyroscopes & accelerometers to estimate the relative position, orientation, velocity, and acceleration of a moving vehicle





https://makersportal.com/blog/2017/9/25/accelerometer-on-an-elevator

https://www.analog.com/media/en/technical-documentation/data-sheets/adxl327.pdf

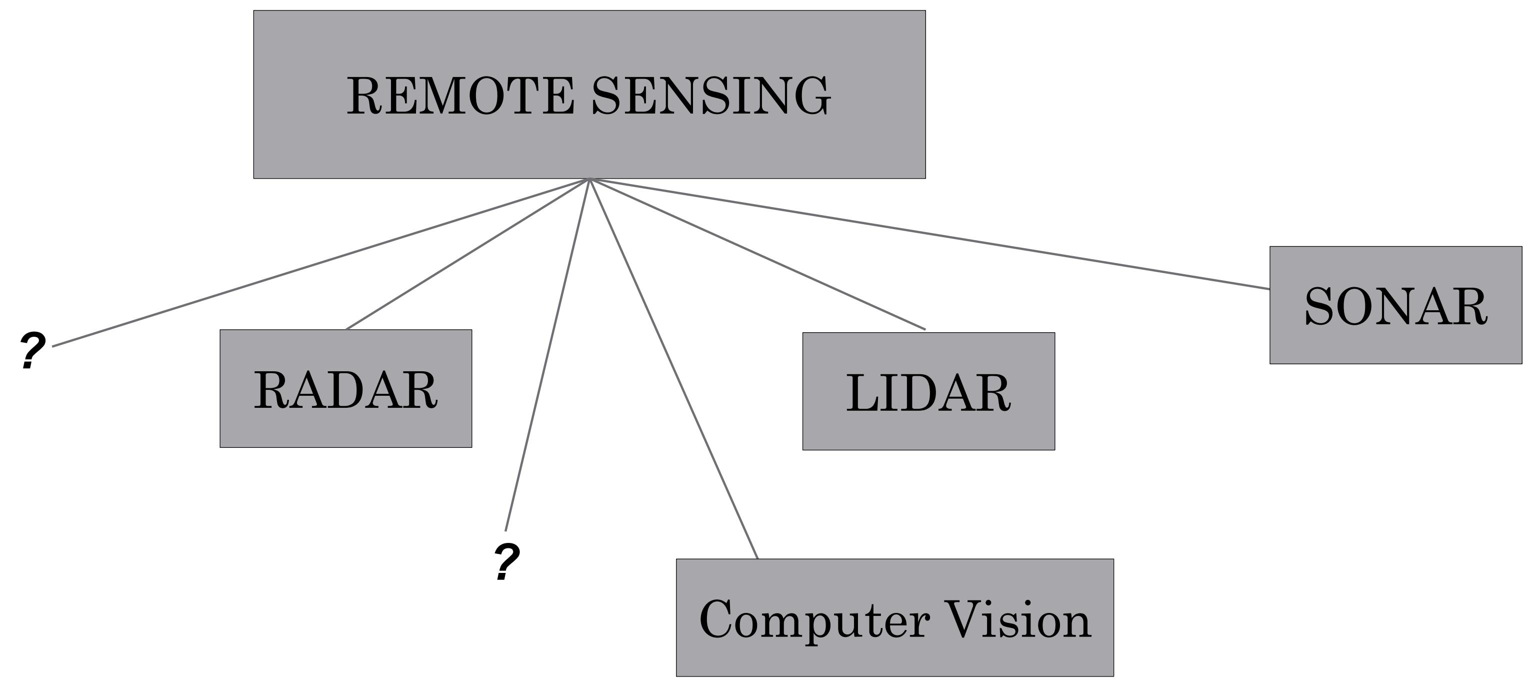
Beacons

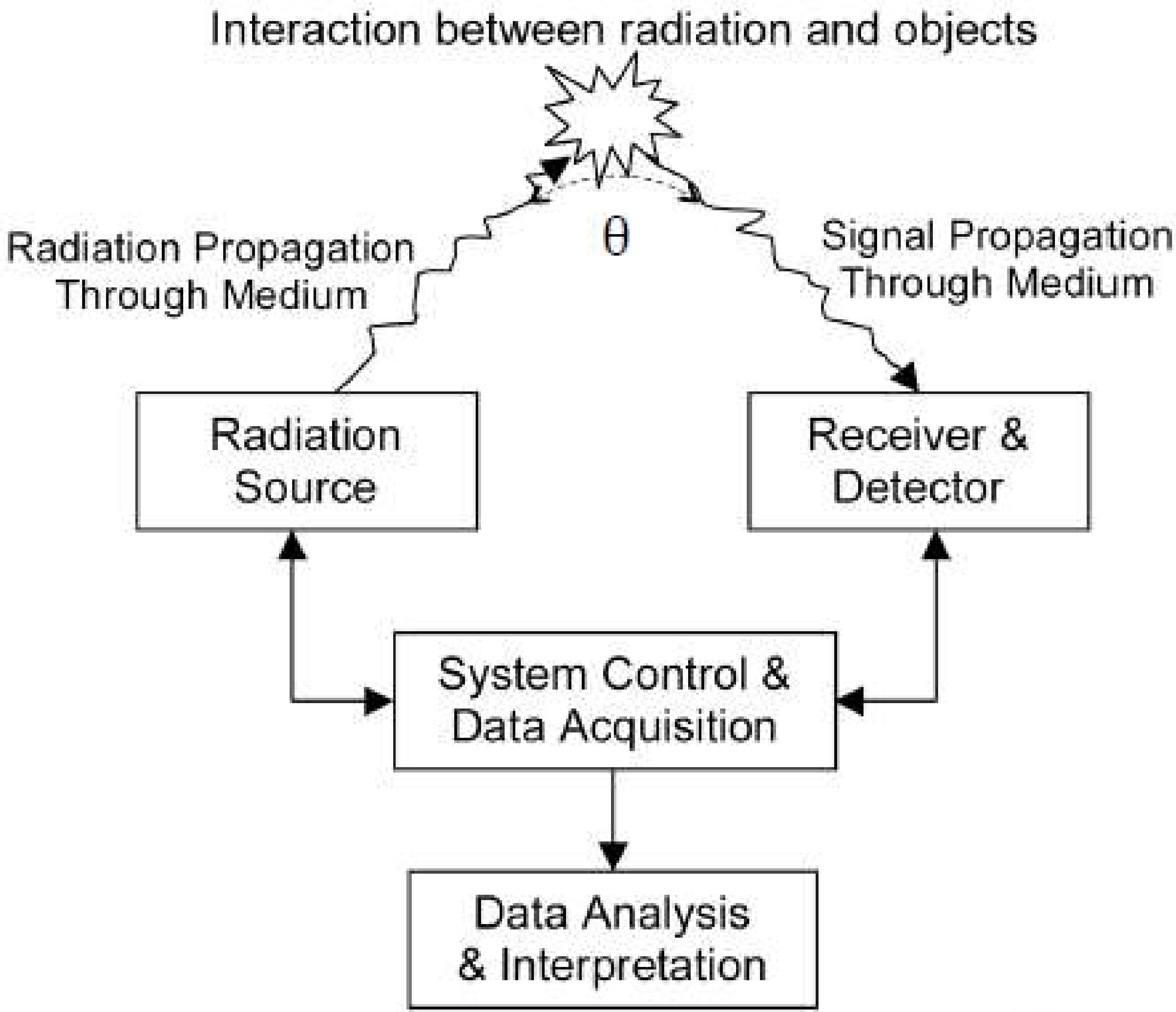
- Signaling devices with precisely known positions
- Stars
- GPS

Exteroceptive Sensors

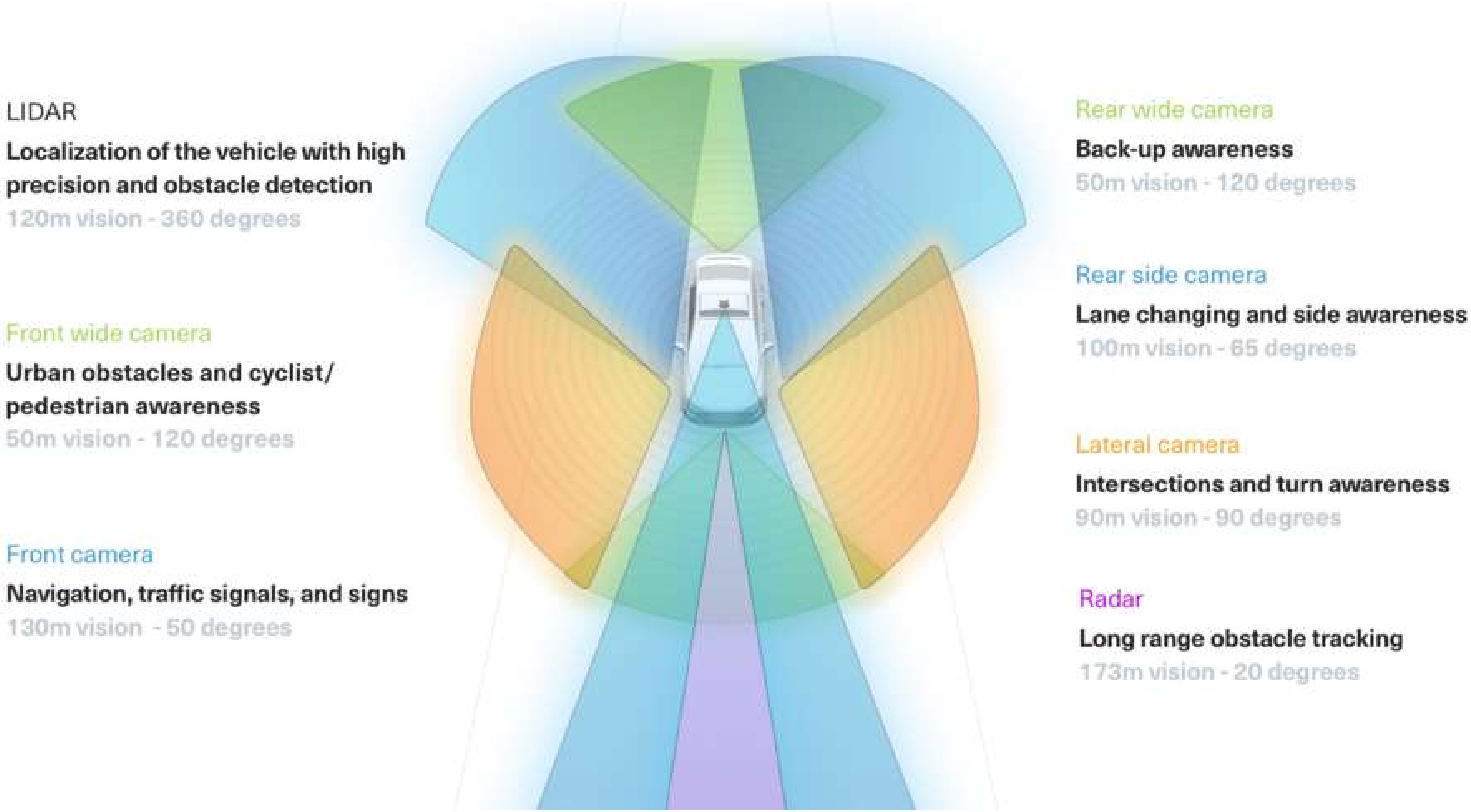
Remote Sensing

- Remote sensing is the science, technology of **obtaining information** about a target **without** having a sensor in direct, **physical contact**
- Remote sensing is the **opposite** of ***in situ*** measurement methods





Interaction between radiation and objects
Radiation Propagation Through Medium
θ
Signal Propagation Through Medium
Radiation Source
Receiver & Detector
System Control & Data Acquisition
Data Analysis & Interpretation



https://news.voyage.auto/the-story-of-homer-voyages-first-self-driving-taxi-f0a6466718af

Remote Sensing

- Requires an **interaction** between the target and the sensor in order to acquire information about the target
- The interaction between **radiation** and the target is the most common interaction used in remote sensing
- The radiation includes **electromagnetic radiation** and **acoustic waves**

Remote Sensing

- During the interaction, radiation properties are **modified** by the object

  …thus containing information about the object

- Through **recording** and **analyzing** the modifications of the radiation, the object information can be retrieved

Classification

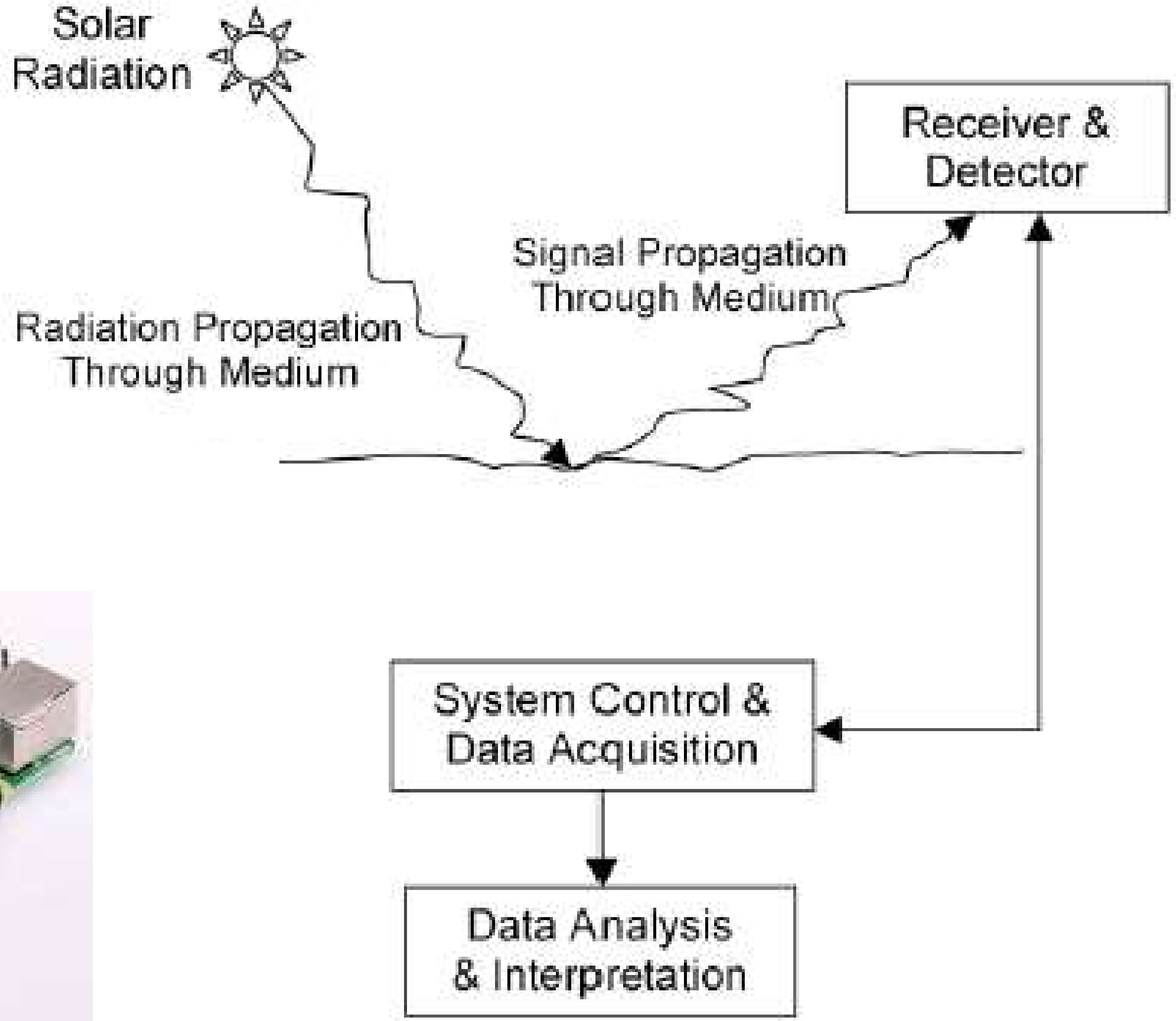
- **Passive** remote sensing: no self-generated radiation is used in the sensing process
- Naturally occurring radiation such as sunlight or nightglow emission (or "naturally" such as GPS)
- **Active** remote sensing: self-generated radiation used in the sensing process
- Laser light, radio- and micro-wave, acoustic wave

Classification

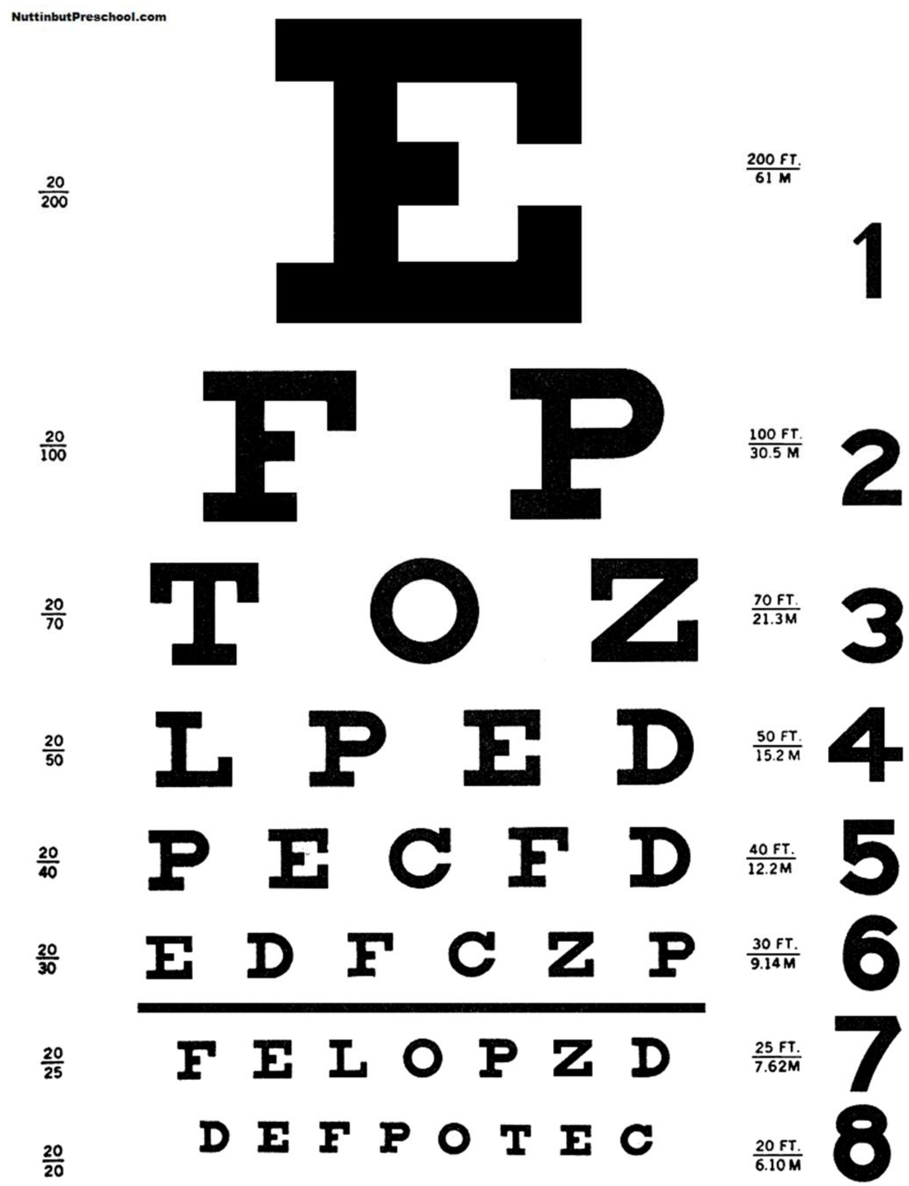
- **Optical** remote sensing: probing and detecting in the optical frequency range
- **Radio** remote sensing: probing and detecting in the radio and microwave frequency range
- **Acoustic** remote sensing: probing and detecting in the acoustic frequency range

Passive Remote Sensing

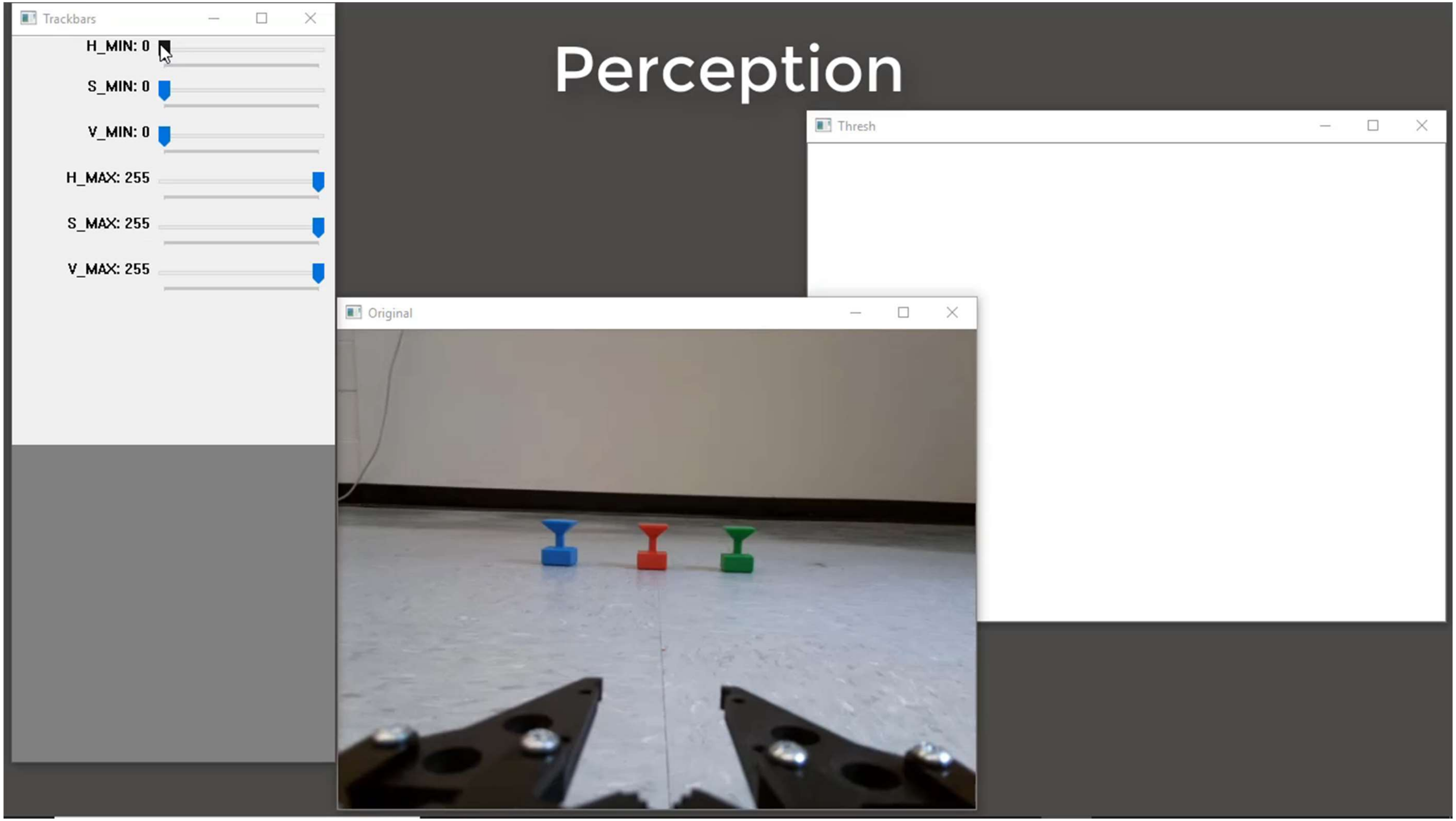
- No self-generated radiation is used in the sensing process
- Naturally occurring radiation such as sunlight or nightglow emission
- Cameras



Passive Remote Sensing




Width: 108 px
Height: 112 px
Center: (205,-174) px
STOP


Perception
Trackbars
H_MIN: 0
S_MIN: 0
V_MIN: 0
H_MAX: 255
S_MAX: 255
V_MAX: 255
Thresh
Original

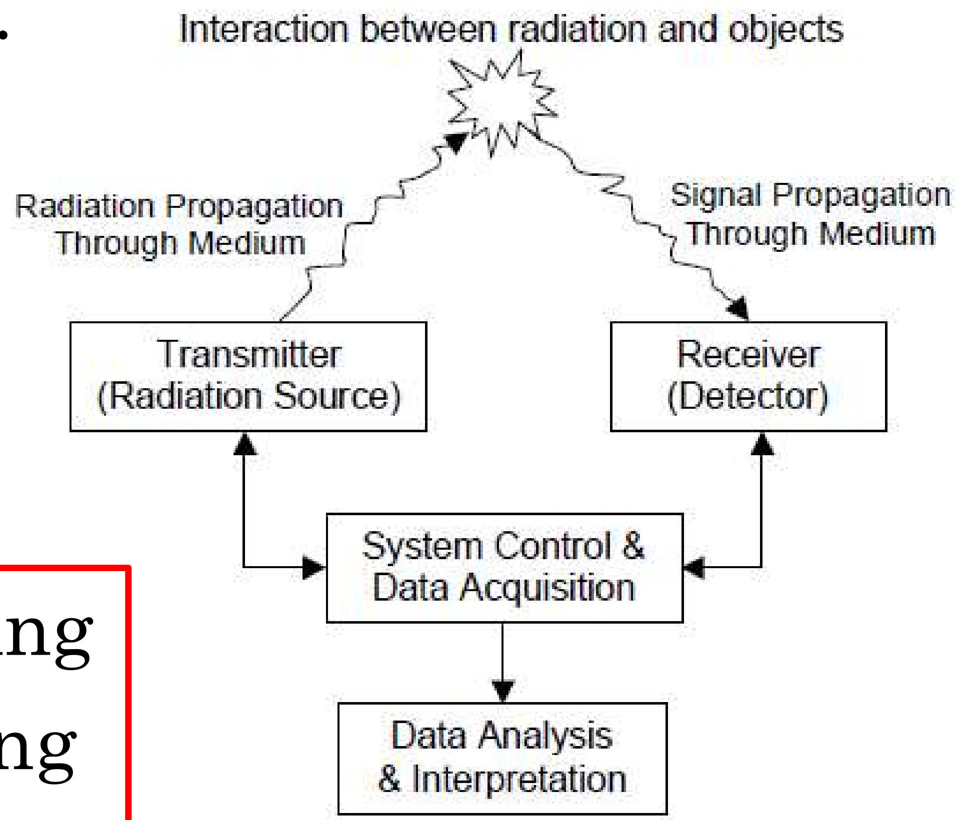
HACKERS STICK TAPE ON SPEED SIGN, TRICK TESLAS INTO GOING FASTER

https://futurism.com/the-byte/hackers-trick-teslas-going-faster

Active Remote Sensing

- **Governing principle**: radiation is…

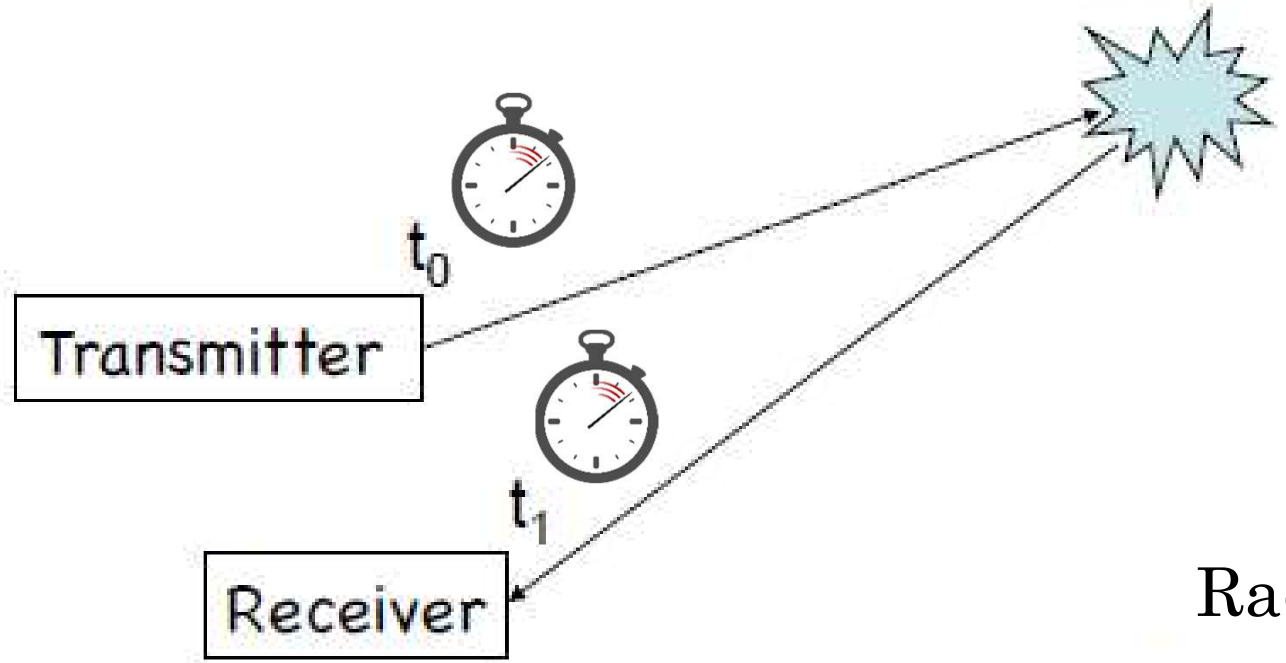
1. transmitted into environment
2. backscattered by target
3. detected and received by analyzers



SODAR: Sound Detection And Ranging
RADAR: Radio Detection And Ranging
LIDAR: Light Detection And Ranging

Active Remote Sensing

- Fundamental principle of operation: **time of flight** Δt



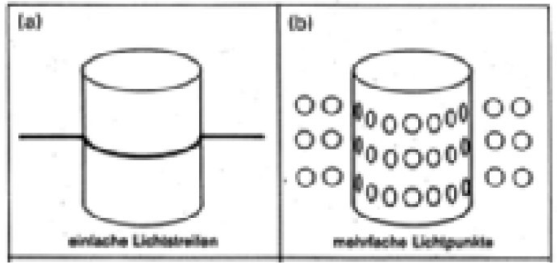
$$\Delta t = t_1 - t_0$$

$$R = \frac{c(\Delta t)}{2}$$

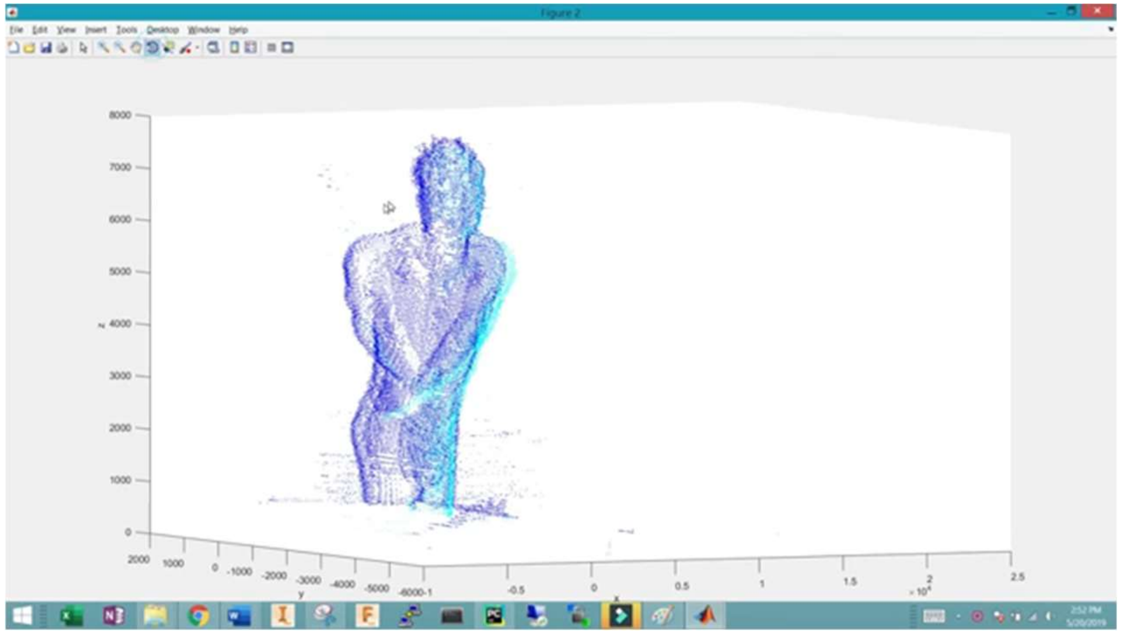
Radar & Lidar: c = $3\text{x}10^8$ m/sec

Sodar: c = speed of sound = 340 m/sec

Active Remote Sensing



- Geometrical range measurement
- Projects known light pattern (e.g. line) and estimates range using triangulation and known sensor geometry

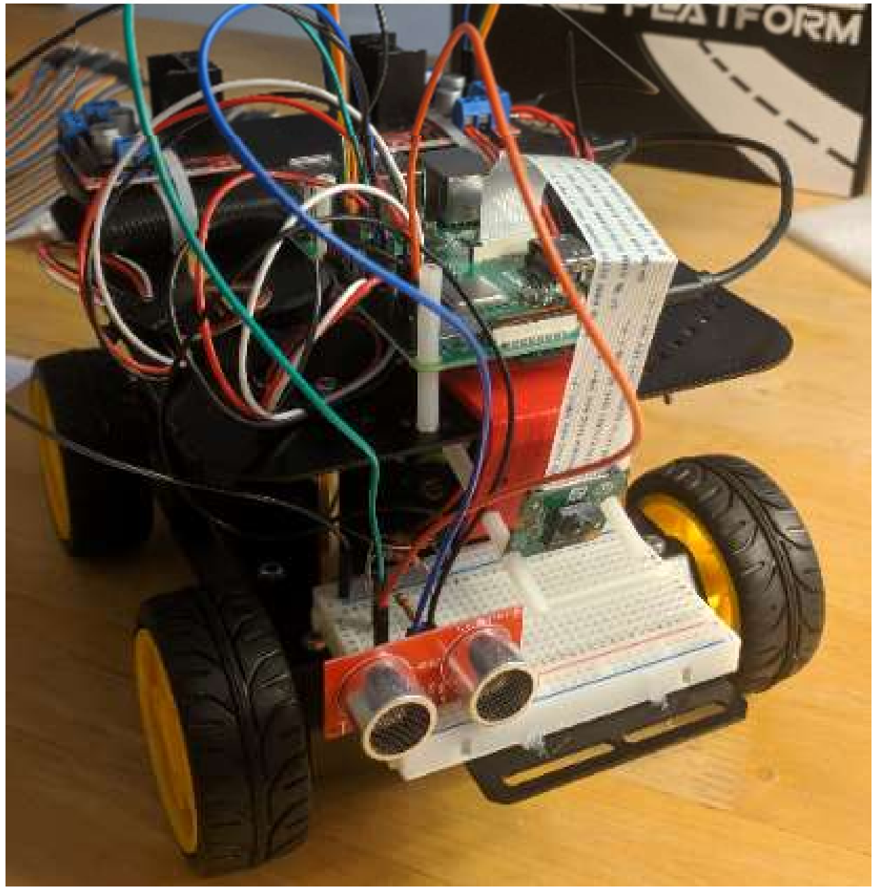


Advantages: Active Remote Sensing

- **Independent** of natural radiation sources & time of day
- Reduced sensitivity to background light
- High intensity of stimulating signal
- Knowledge/control of stimulating signal

SODAR

- Sound (**acoustic**) waves used in the sensing, produced by compressing the **atmosphere**
  - 1913
- Speed of sound (340 m/sec)
- Operating range typically limited to a few hundred meters
- **SONAR** is Sound Navigation and Ranging, used **underwater** for ocean detection such as in submarines



Active Remote Sensing

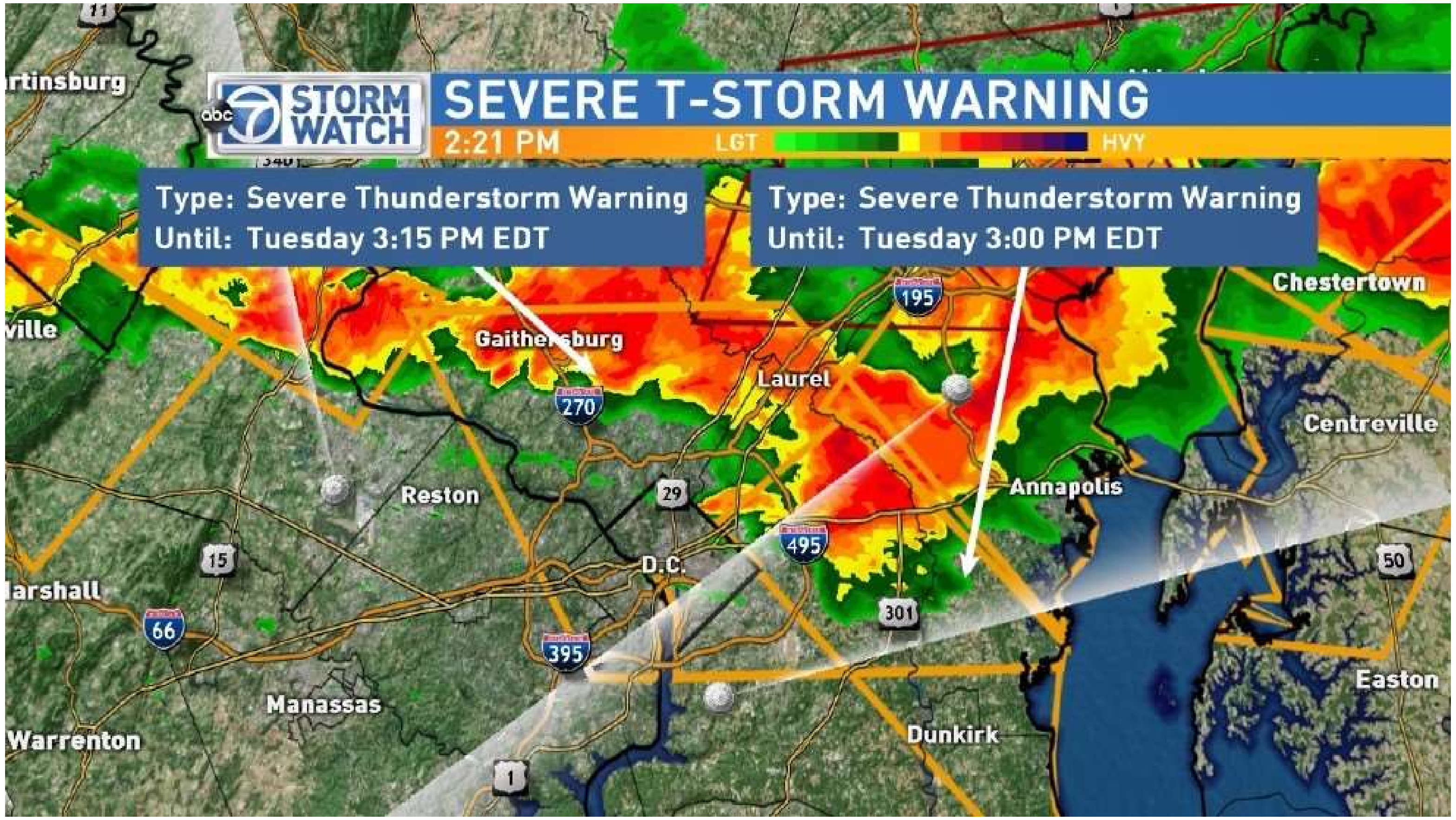
http://www.sciencemag.org/news/2014/11/how-blind-people-use-batlike-sonar

RADAR

- Electromagnetic waves in the **radio** and **microwave frequency** range are used in the sensing
  - 1904
- Speed of light ($3x10^8$ m/sec)
- **Large divergence** compared to Lidar sensors
- Depending on wavelength, less susceptible to weather (rain) than Lidar sensors

Active Remote Sensing

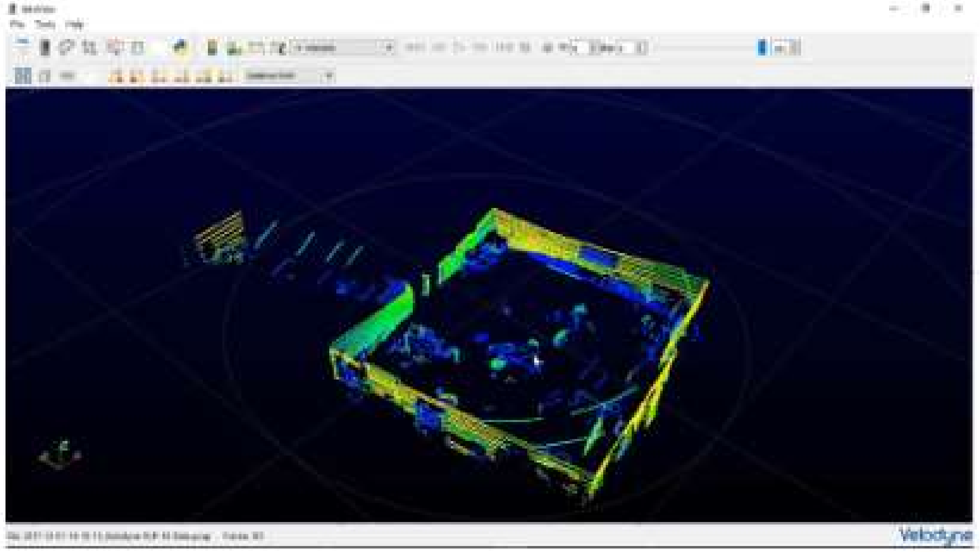
- RADAR

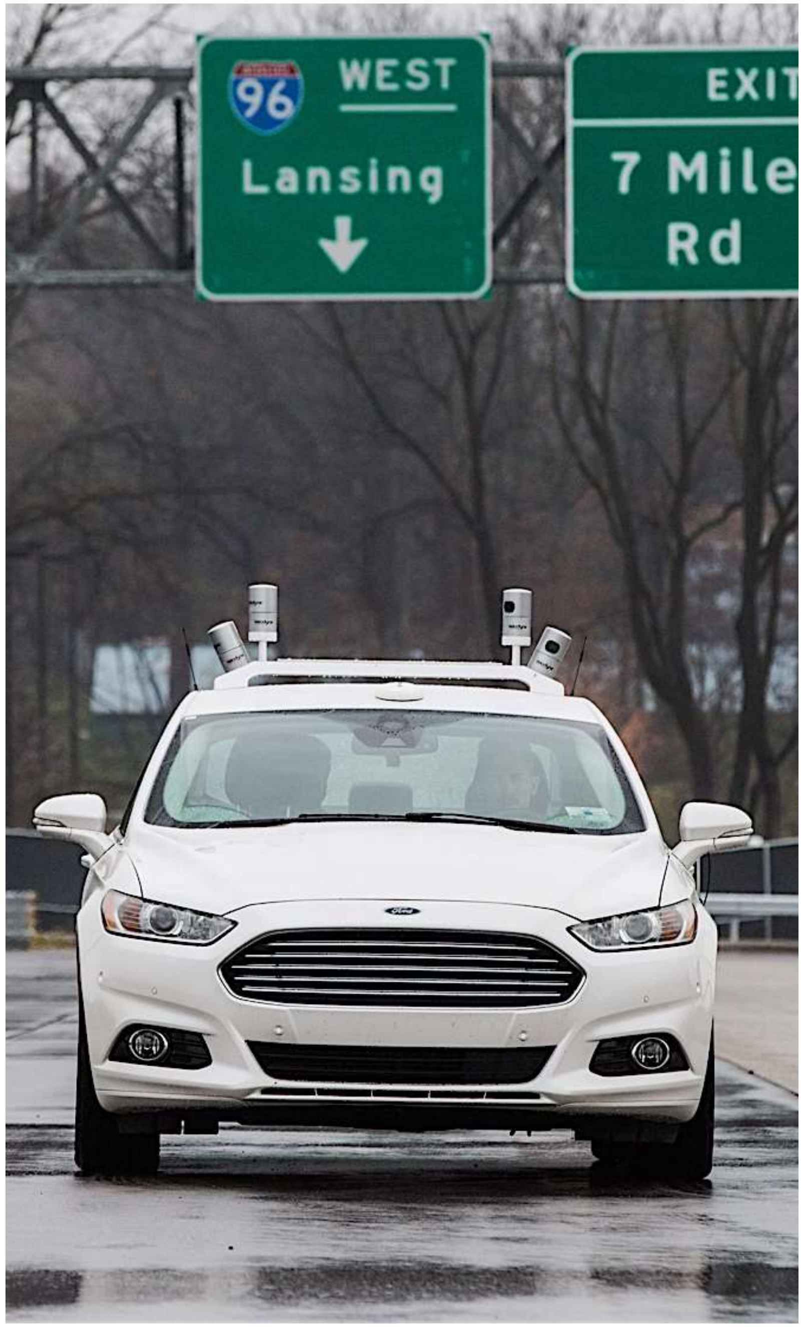



ITT GILFILLA

LIDAR

- Electromagnetic waves oscillating in the **optical frequency** range (**photons**) are used in the sensing
  - 1960
- Traditionally refer to “laser light” used in the sensing
- Speed of light ($3x10^8$ m/sec)
- **Less divergence** than sodar and radar systems
- Relatively poor performance in degraded weather conditions




96
WEST
Lansing
EXIT
7 Mile
Rd


Velodyne
CLEARPATH


Velodyne

3D Mapping & Navigation

Safe & Autonomous Vehicles

Fleets

Terrestrial & Aerial Robotics

3D LiDAR sensors enable safety and efficiency in areas unserved due to:

(1) COST (2) PERFORMANCE

(3) RELIABILITY (4) SIZE

(5) WEIGHT (6) POWER

Smart Cities

Industrial (Mining, Logistics, etc.)

Smart Homes

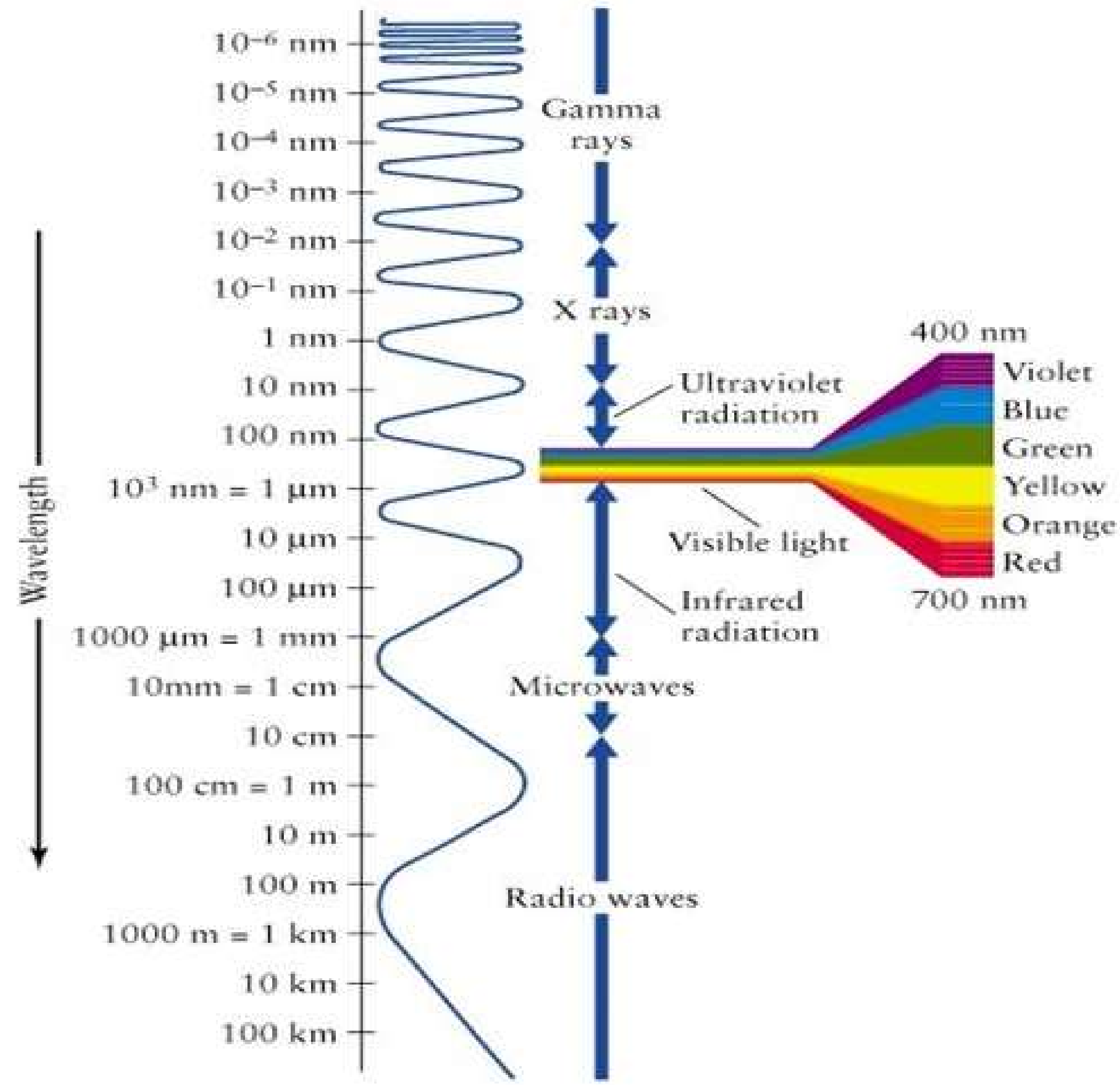
3D-Aware Smart Devices

Hardware Comparison

	SODAR	RADAR	LIDAR
Transmitter	Electric-acoustic converter	Electronic circuit + Antenna	Laser Light Source
Receiver	Headphone	Antenna + RF receiver and detector	Optical telescope + Photo detector
Transmitted Energy	Acoustic Energy	Electromagnetic Waves	Light (Photons)

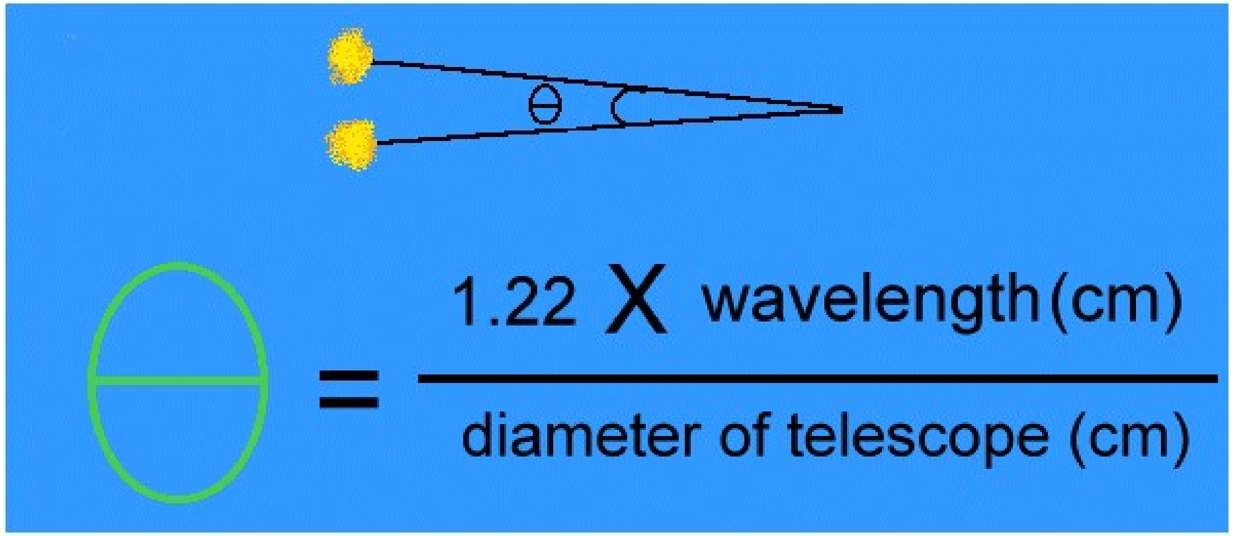
Hardware Comparison

- Commonly used -dar's
  - SONAR – acoustic waves
  - RADAR – radio waves
  - LIDAR – light waves
- Short wavelengths, pulses
  - RADAR in cm (10^{-2} m)
  - LIDAR in nm (10^{-9} m)
- Tight focus, resolution
  - **Diffraction limit** = 1.22 λ / D
- Interaction with aerosols, molecules



Hardware Comparison

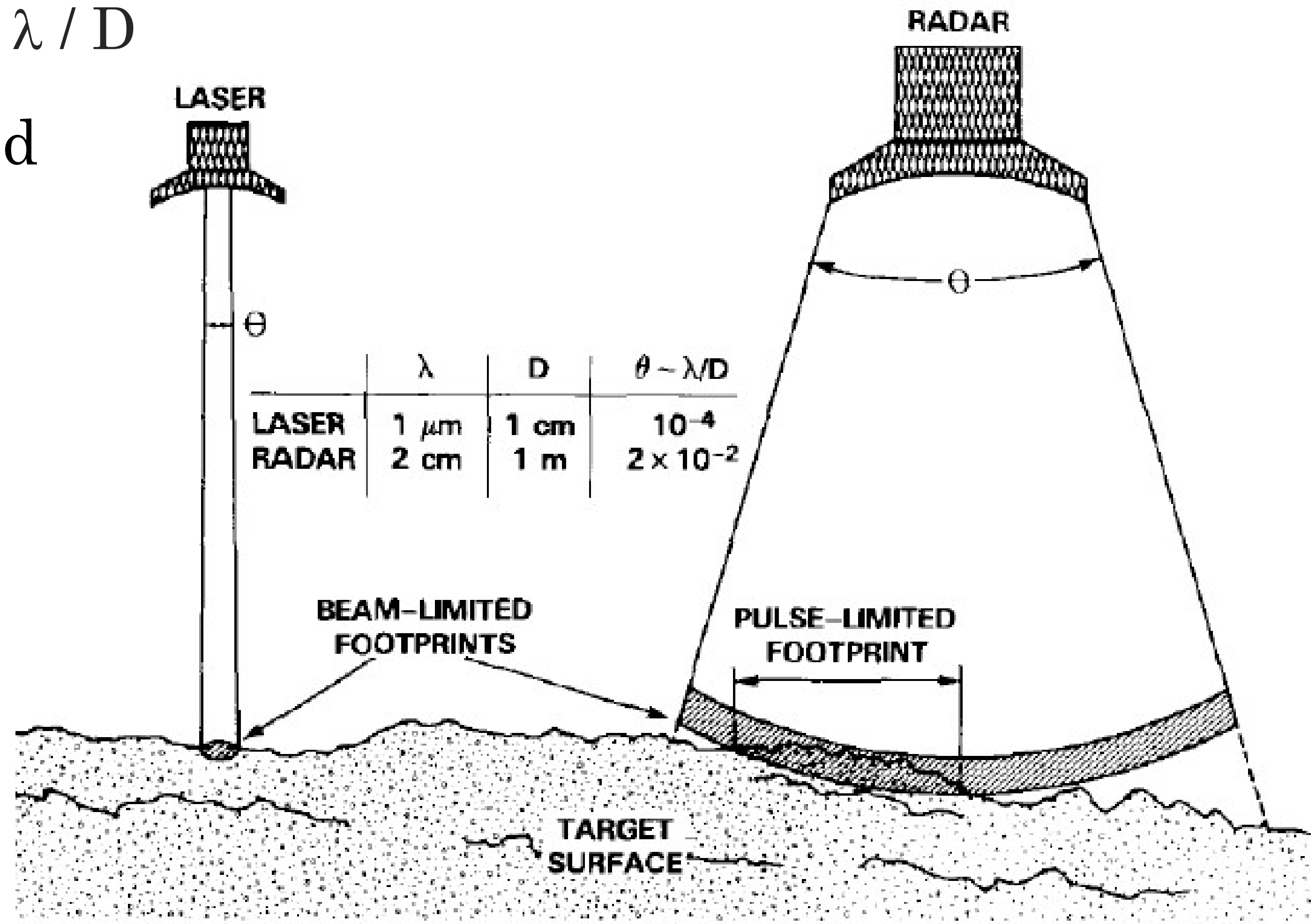
- Tight focus, resolution
  - **Diffraction limit** = 1.22 λ / D
- Minimum angular separation of two sources that can be distinguished by a telescope
- Function of
  - Wavelength
  - Telescope diameter



http://www.astro.cornell.edu/academics/courses/astro201/diff_limit.htm

Hardware Comparison

- Tight focus, resolution
  - **Diffraction limit** = 1.22 λ / D
- LIDAR provides enhanced range resolution and precision



Hardware Comparison

- Advantages

Passive	Active
Low power requirement (long life)	Measurement req's matched to transmitter characteristics
Difficult to detect (covert)	Range measurement by temporal correlation
Simple principles (sometimes)	Radiation pattern constrains observation
Good reliability due to simplicity	High range and angle resolutions possible
Field of view constrains observation	Long-range operation possible
High angular resolution possible	
Large variety	

Hardware Comparison

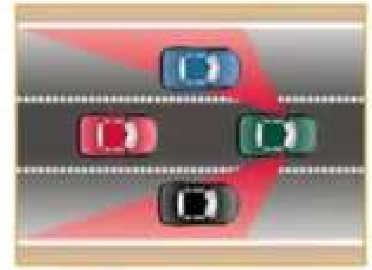
- **Disadvantages**

Passive	Active
Targets of interest must radiate or modify the incident radiation	Large power requirement
Prone to feature ambiguity and errors of scale	Often easy to detect (not covert)
Typically short range, though not always	Complex reception and transmission process
Availability not guaranteed (no light, contrast, etc.)	Reliability dictated by two elements: the transmitter and the receiver

Remote Sensing: ADAS Technologies

Lane Keeping

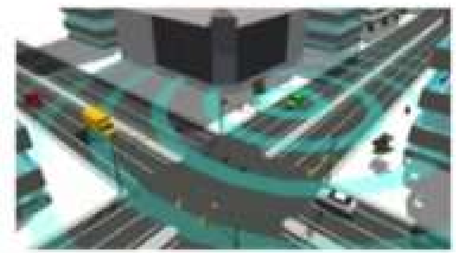
Parking Assist



Blind Spot Detection

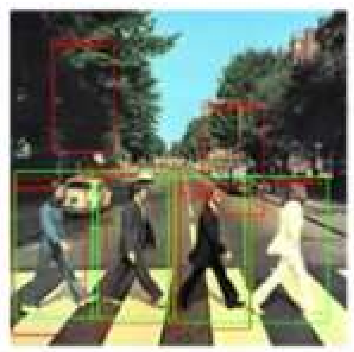
Adaptive Cruise Control
& Traffic Jam Assist

Front/Rear Collision Avoidance

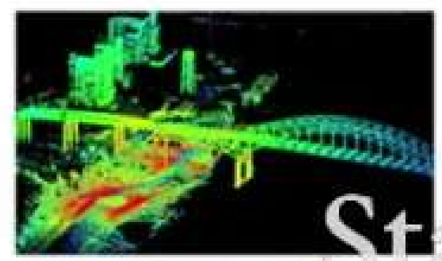


Cross Traffic Alert &
Intersection Collision Avoidance

Autonomous Emergency Braking
& Emergency Steer Assist



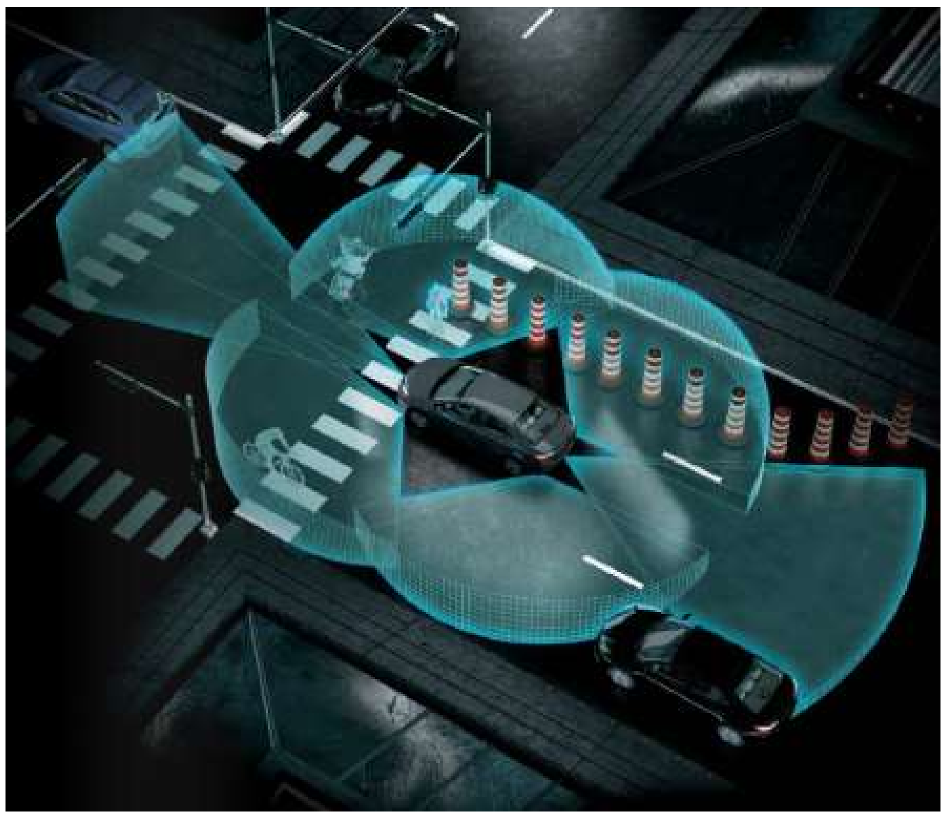
Object Detection,
Tracking, Classification



Scene Capture &
Accident Reconstruction

ADAS Technologies

- Incorporate both passive and active remote sensing techniques



	Lidar	Radar	Cameras
Range			
Measurement Rate			
Field of View			
3D Shape			
Objects at Long Range			
Accuracy			
Rain, Snow, Dust			
Fog			
Night Time			
Identify Signs			
Distinguish Color			

ADAS Technologies

- Incorporate both passive and active remote sensing techniques

Lidar

Precise 3D map of car's surroundings

- Generates large amount of data
- Requires clear weather conditions
- Relatively expensive

Radar

Velocity & range of surrounding objects

- Minimal computational demand
- Functions in "all" weather conditions
- Less angular sensitivity

Cameras

Classification of surrounding objects

- Massive amounts of data
- Cheapest, readily available
- Distinguish color, scene interpretation

References

- *Introduction to Autonomous Mobile Robots*, Siegwart
  - Chapter 4
- *ENME 489Y: Remote Sensing*, S. Mitchell