Applications of AI/ML in Remote Sensing & Autonomous Driving

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Agenda

Introduction

AI/ML in Remote Sensing

AI/ML in Autonomous Driving

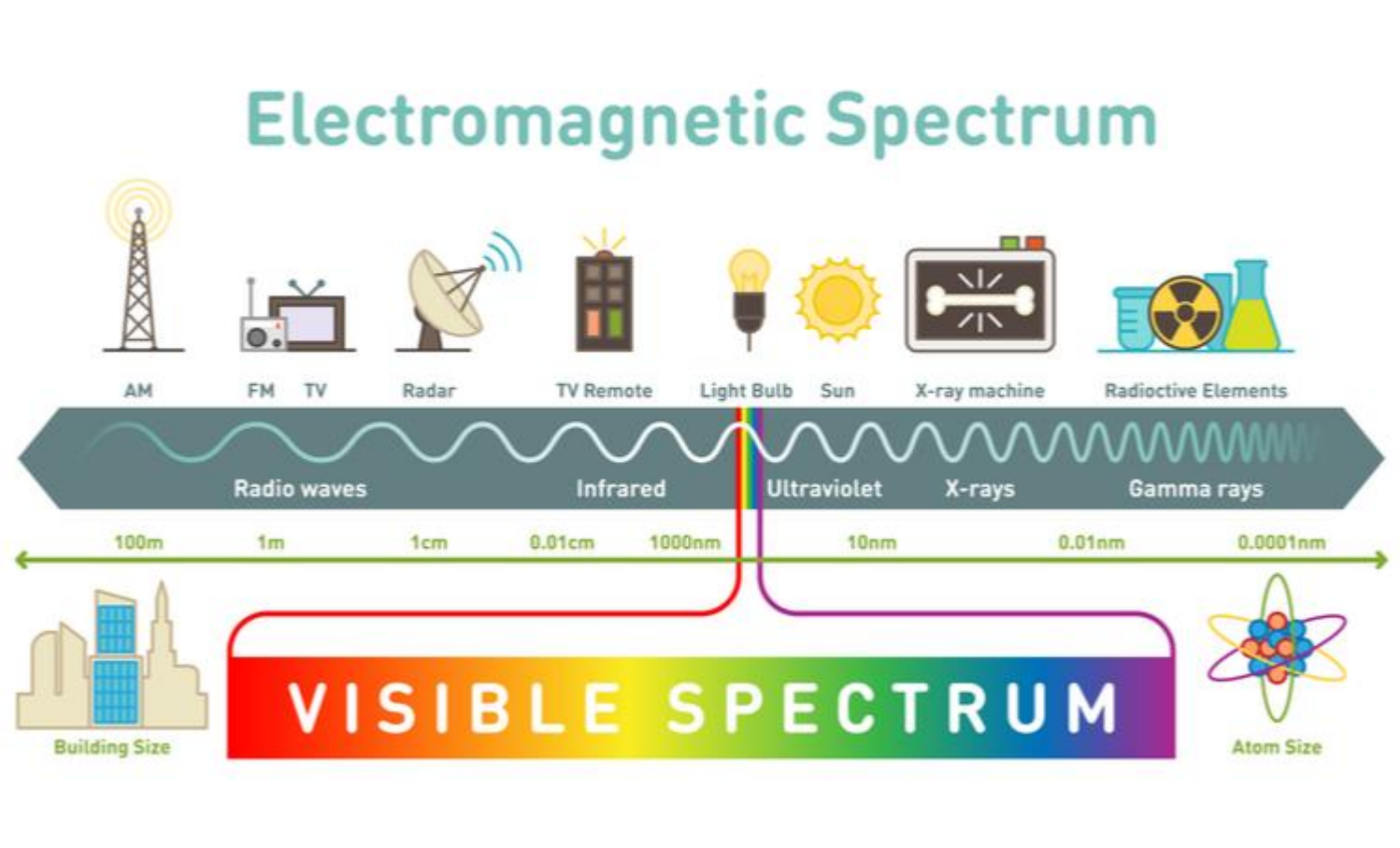
Emerging Frontiers in AI/ML

Q&A

Remote Sensing

Sensing the World Remotely

Electromagnetic Spectrum

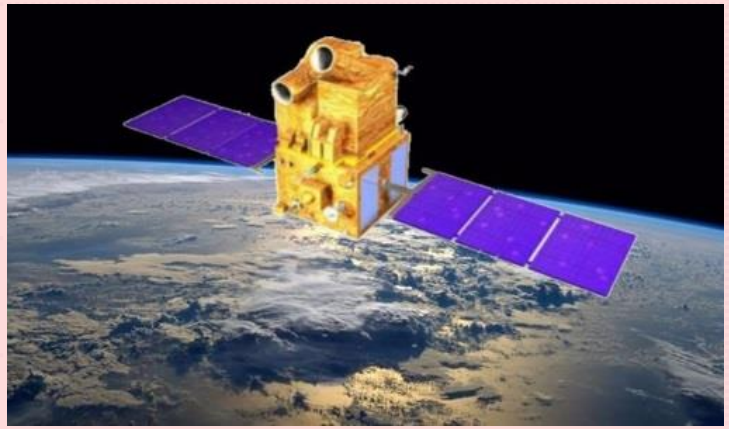


[An Overview of Frequency Bands and Their Applications]

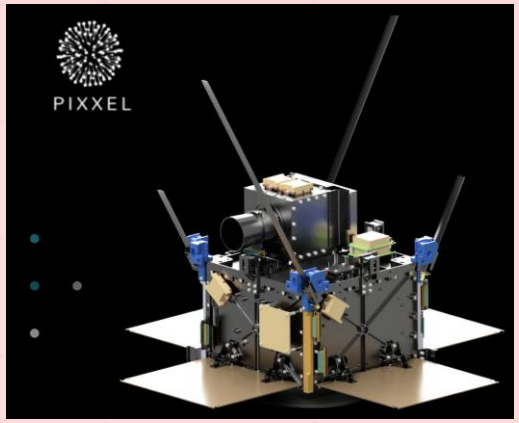
Sensor Types

Passive Sensors

- Measure the amount of electromagnetic (EM) energy **reflected** or **radiated** by the earth.
- **Optical sensors**: **visible**, **near infrared (NIR)**, and **short-wave infrared (SWIR)**.
- **Thermal** remote sensors: measure radiation being **emitted** from the earth's surface or a target body, rather than reflected



Cartosat – Visible spectrum



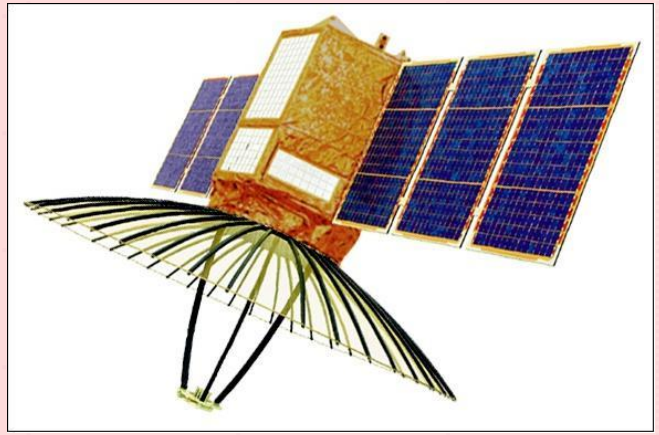
Pixxel – Hyperspectral

Satellite Vu – Thermal spectrum

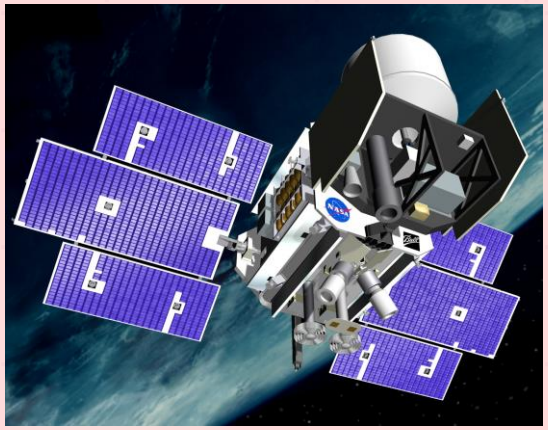
Sensor Types

Active Sensors

- **Transmit** energy and **measure** the amount of energy **reflected** back from the earth.
- Don’t rely on the energy of the sun or thermal properties of the earth.
- Examples: **RADAR** and **LiDAR**
- **RADAR**: Uses longer EM wavelength, can penetrate through atmosphere and clouds.
- **LiDAR**: Uses infrared spectrum, cannot penetrate through rain and clouds.



RISAT – Synthetic Aperture RADAR (SAR)



ICESAT –LiDAR sensor

ISS GEDI –LiDAR sensor

Aerial imagery using Drones/UAVs/Aircraft

- Aerial photography (or airborne imagery)
- Taking of **still photographs** from an aircraft or other **airborne platforms**.
- Taking **motion pictures**, it is also known as **aerial videography**.

Drones/QuadCopters

UAVs

Aircraft

Examples of remote sensing in action

Crop Monitoring: NASA Harvest

Examples of remote sensing in action

Volcano Eruption: NASA

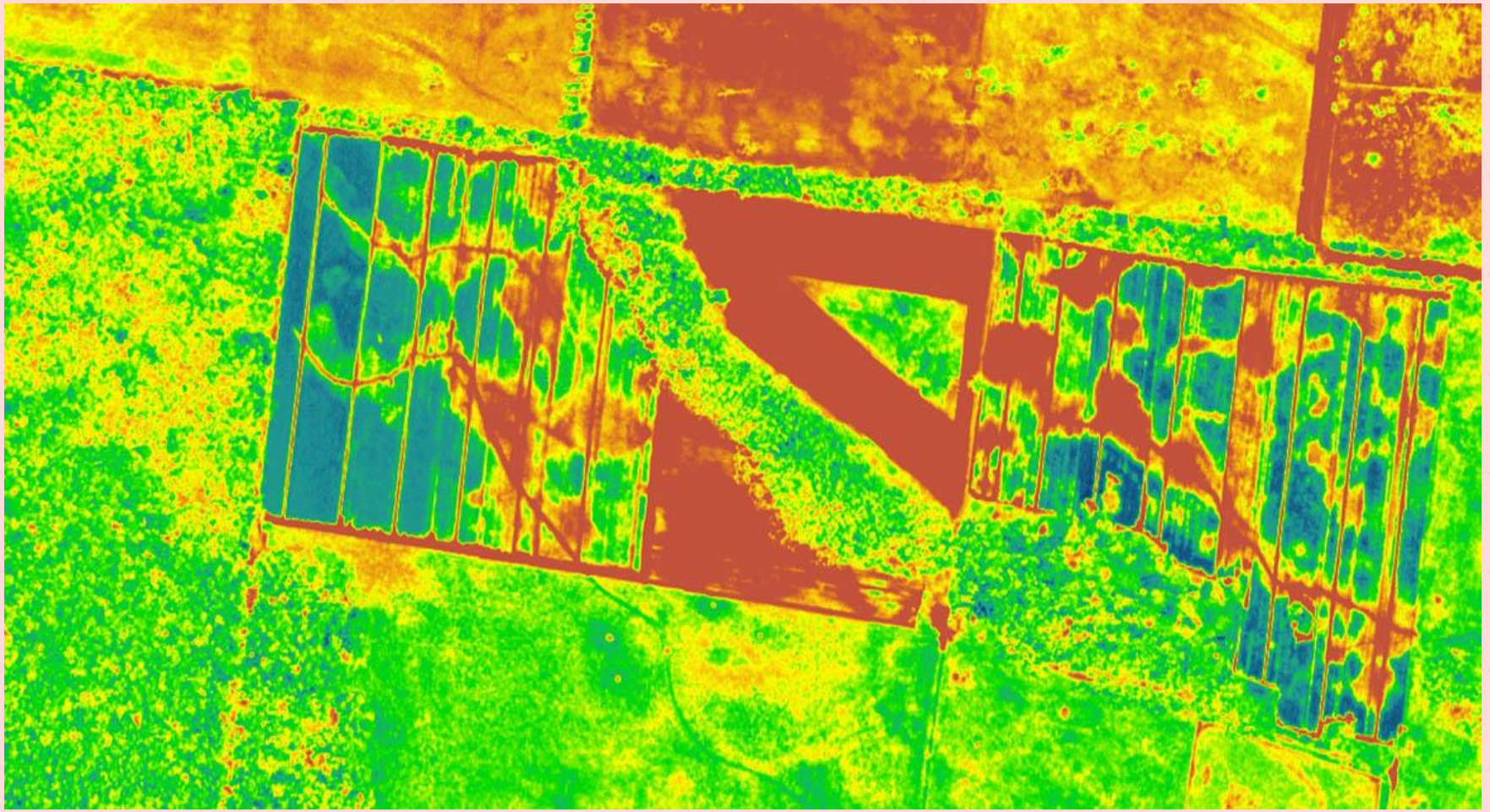
Examples of remote sensing in action

Port Monitoring: Capella Space (SAR)

Examples of remote sensing in action

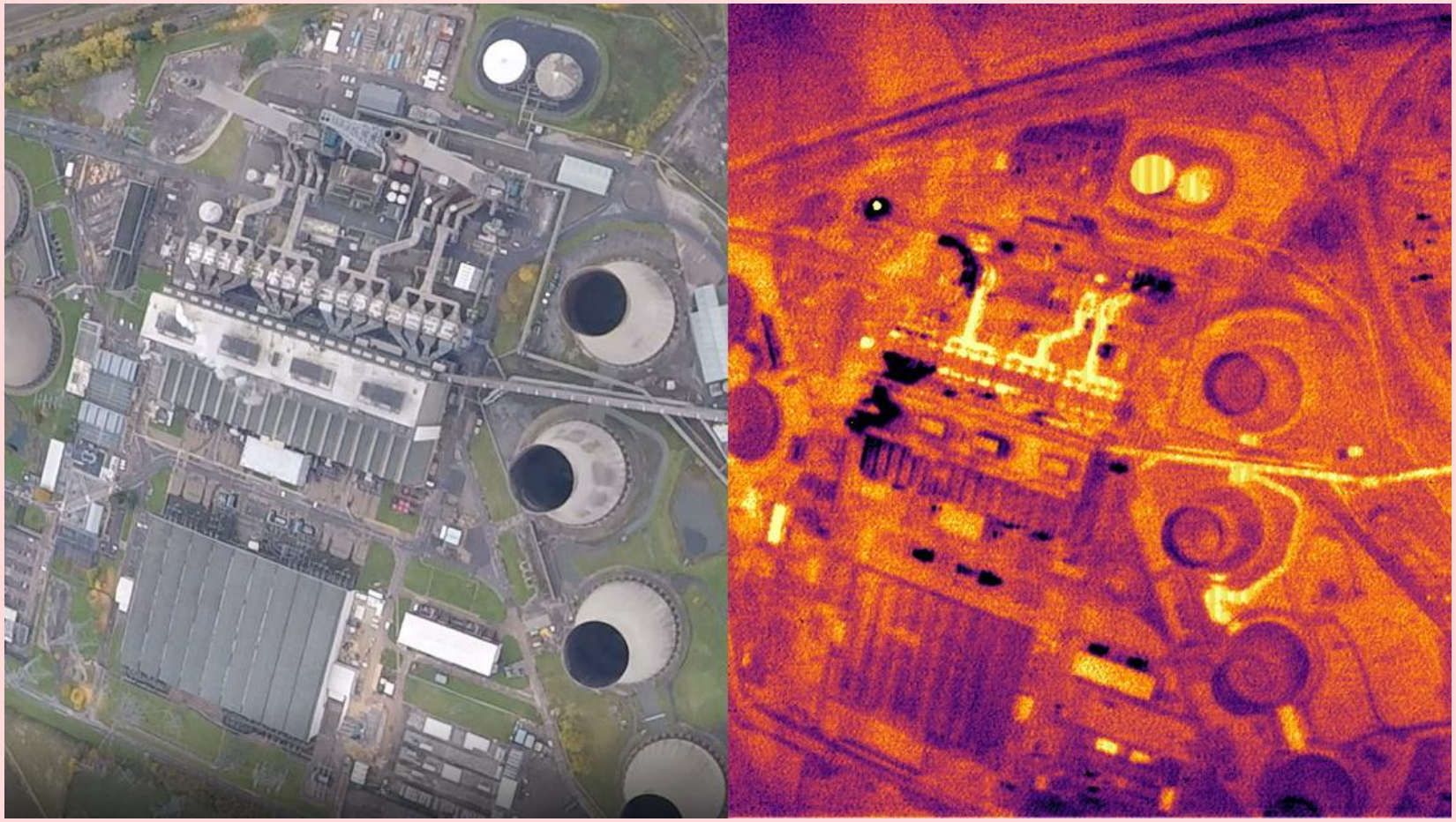
Construction site monitoring using Drones

Examples of remote sensing in action



Hyperspectral Imagery

Examples of remote sensing in action

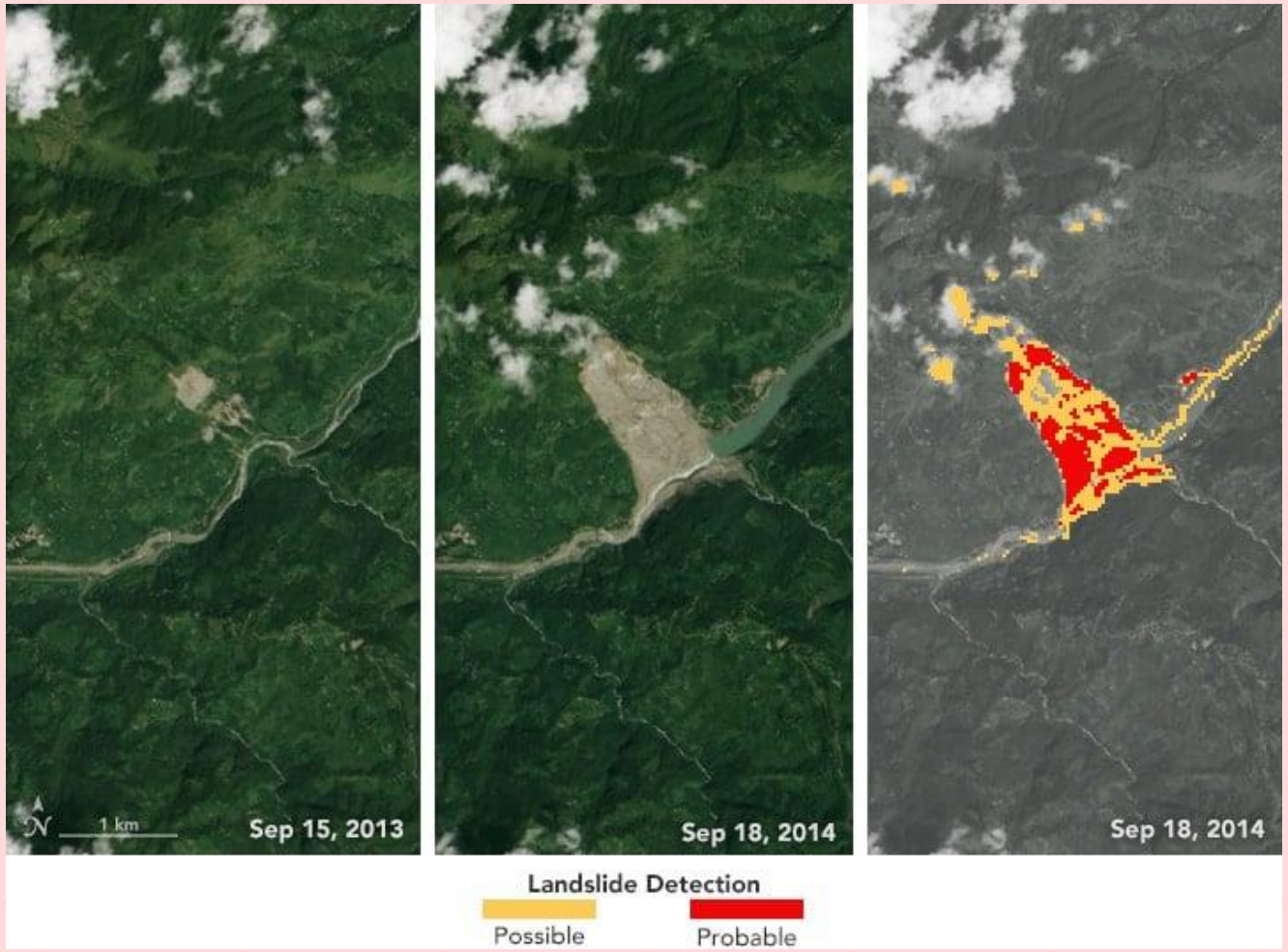


Thermal Imaging: https://www.satellitevu.com/

Examples of remote sensing in action

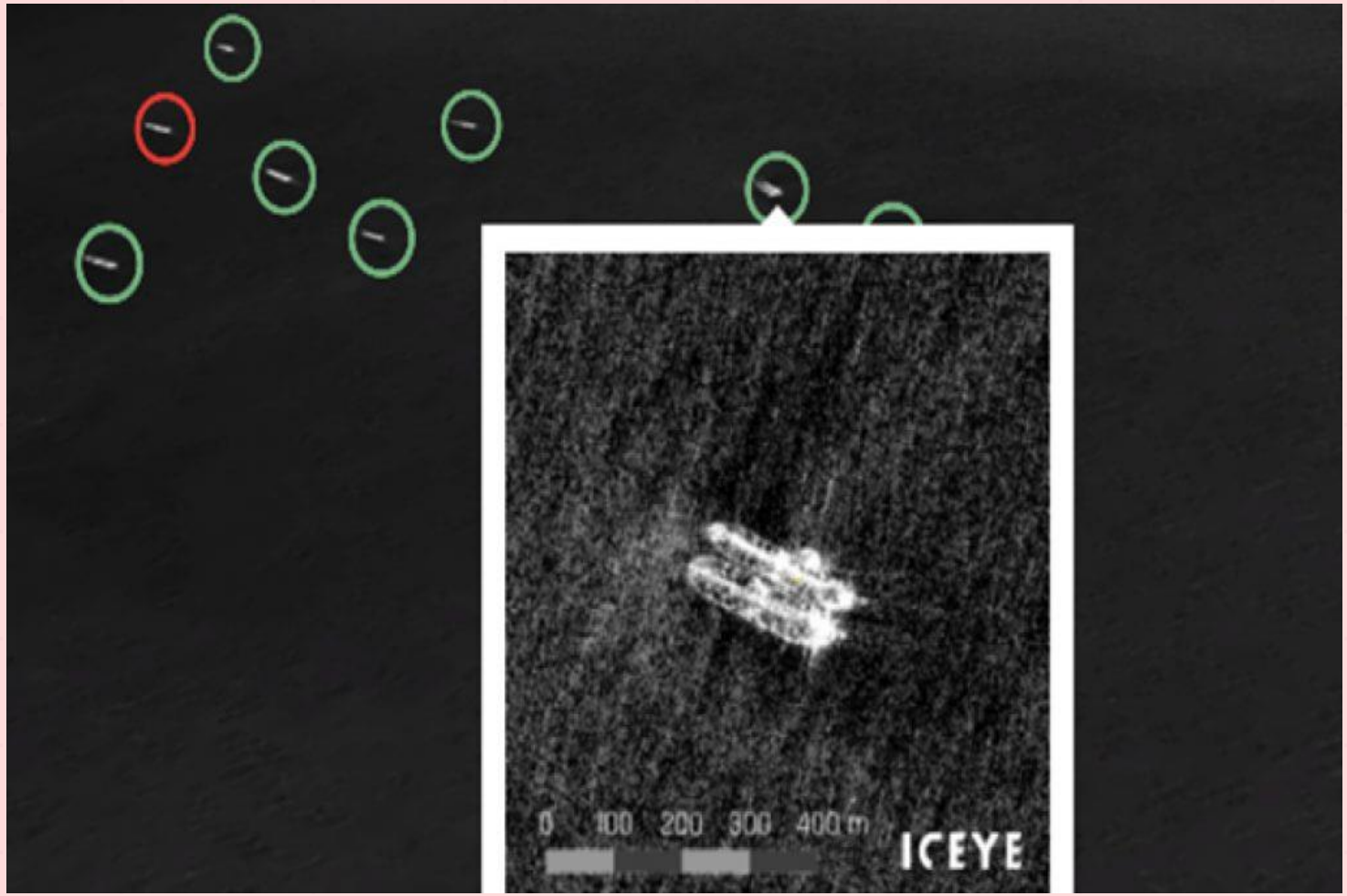
Securing the Borders

Examples of remote sensing in action



Landslide Detection

Examples of remote sensing in action

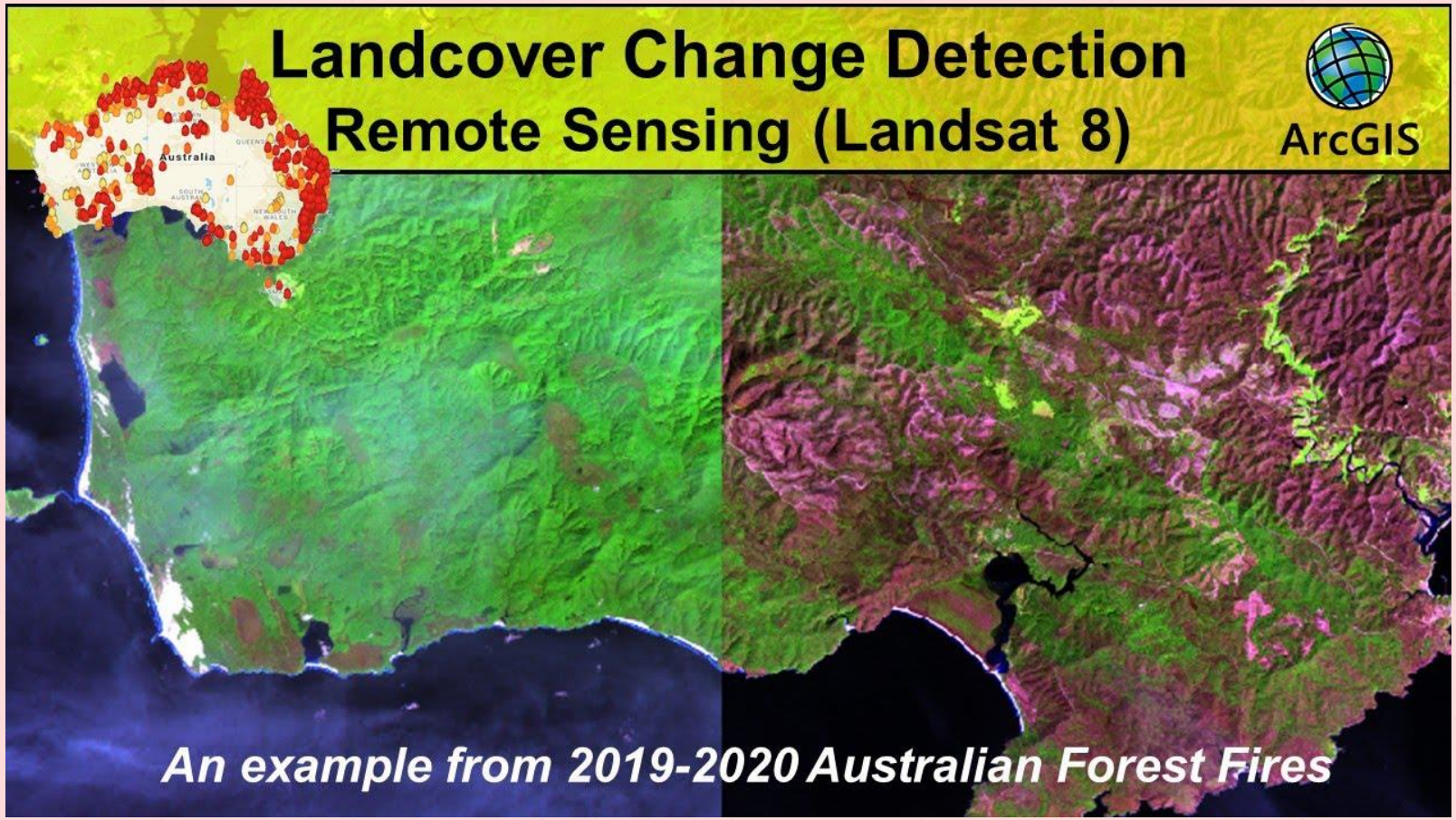


Illegal Maritime Activities

Examples of remote sensing in action

Monitoring Mangrove Forests

Examples of remote sensing in action



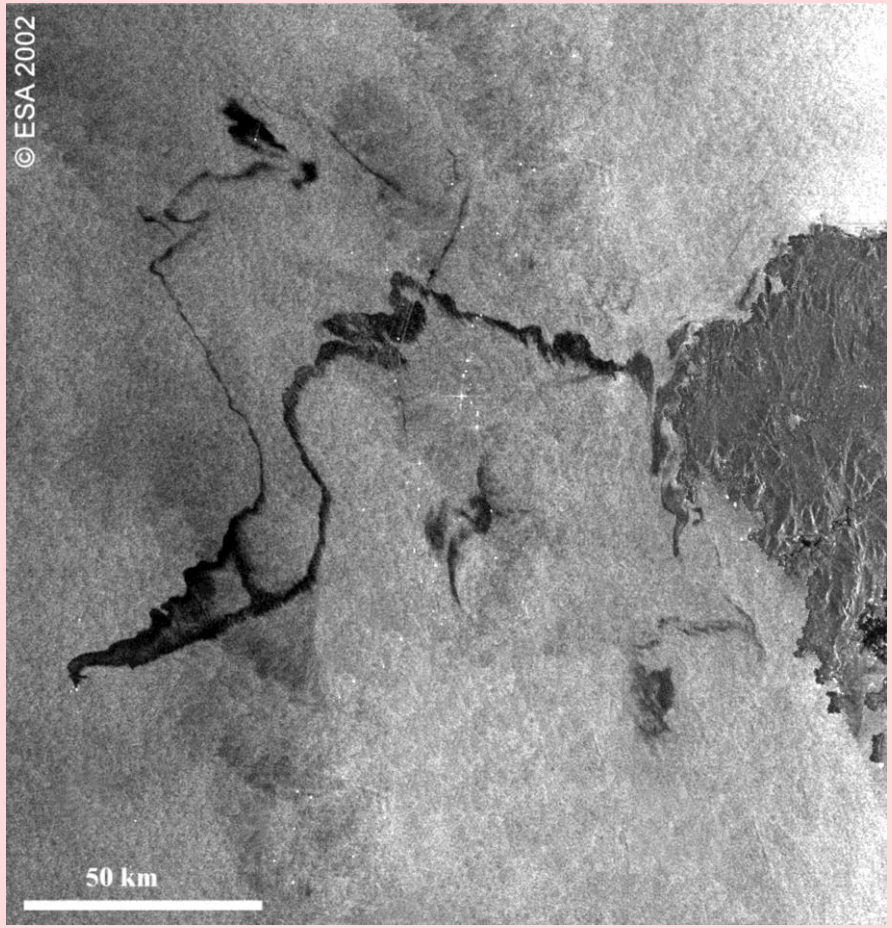
Wildfire Monitoring

Examples of remote sensing in action

Figure 6: Sentinel-2 true colour RGB composite of the study area acquired on 20210626 showing the HDPE mesh/FML target (top) and wooden planks/natural debris target (bottom).

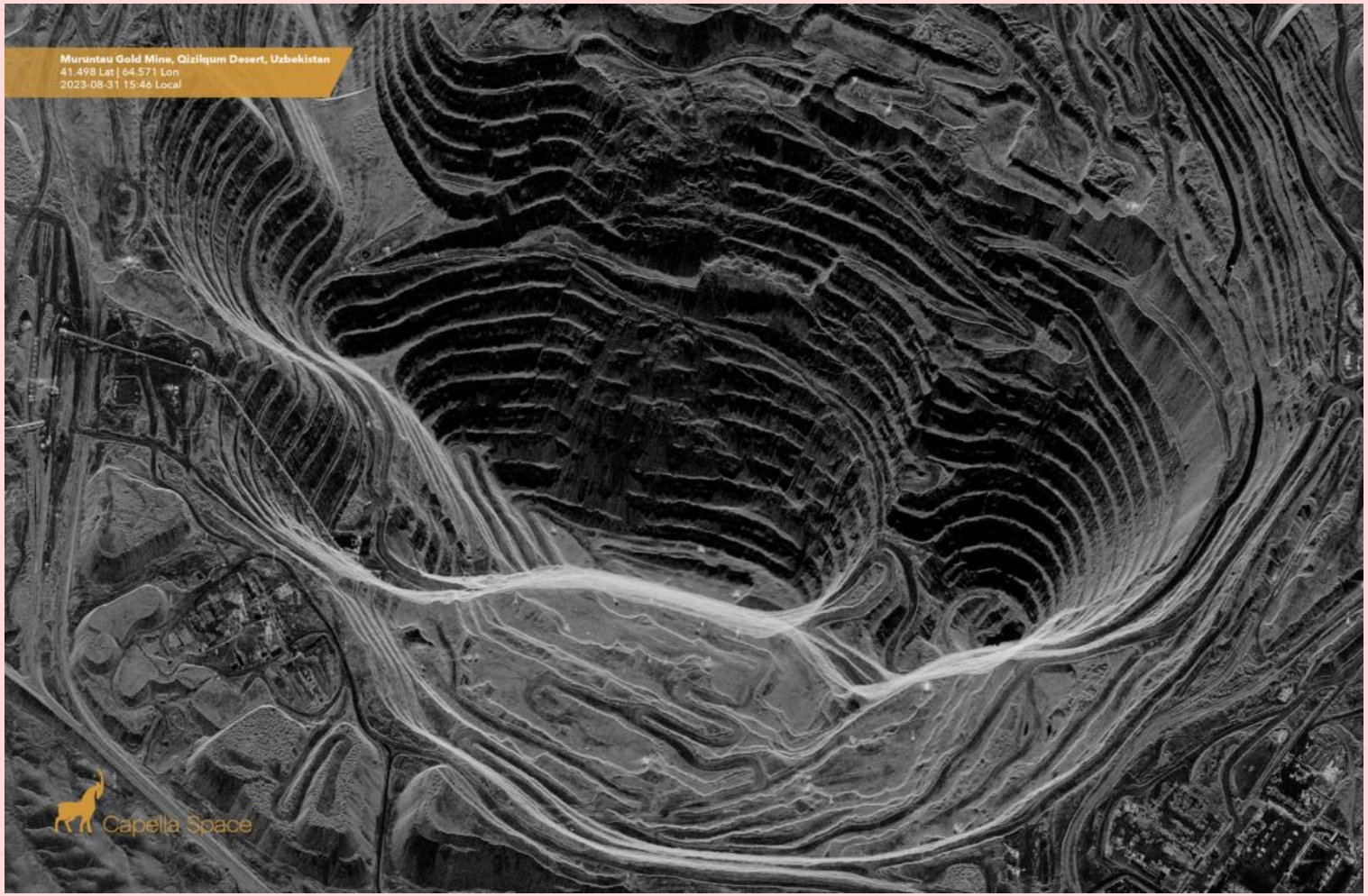
Monitoring Plastic Waste

Examples of remote sensing in action



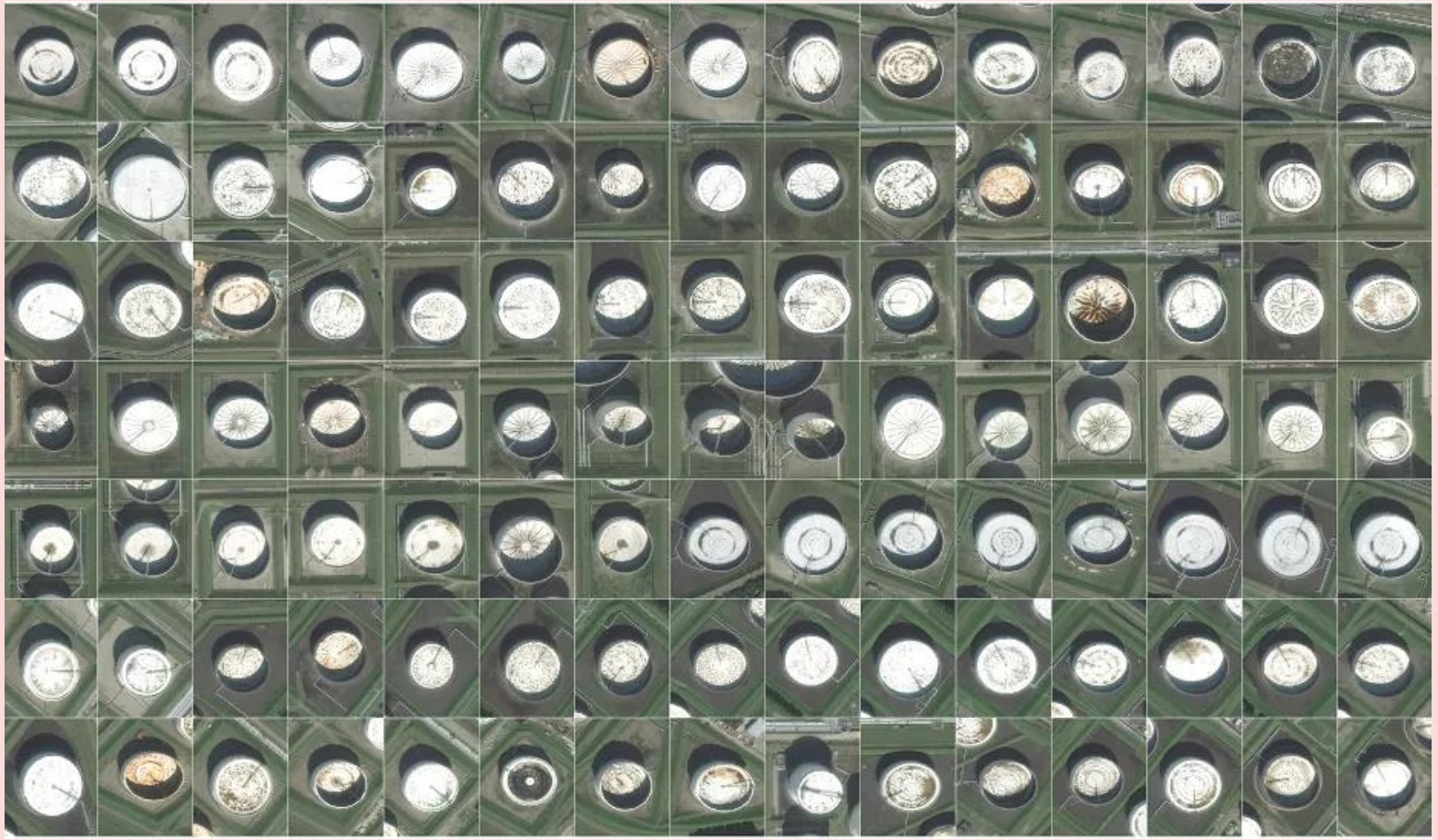
Oil Spill Detection

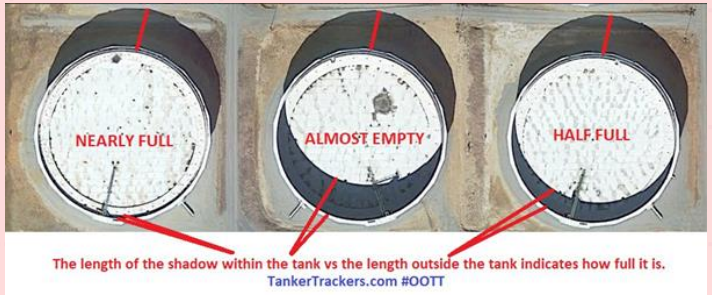
Examples of remote sensing in action



Mining

Examples of remote sensing in action





Oil Storage/Supply Monitoring

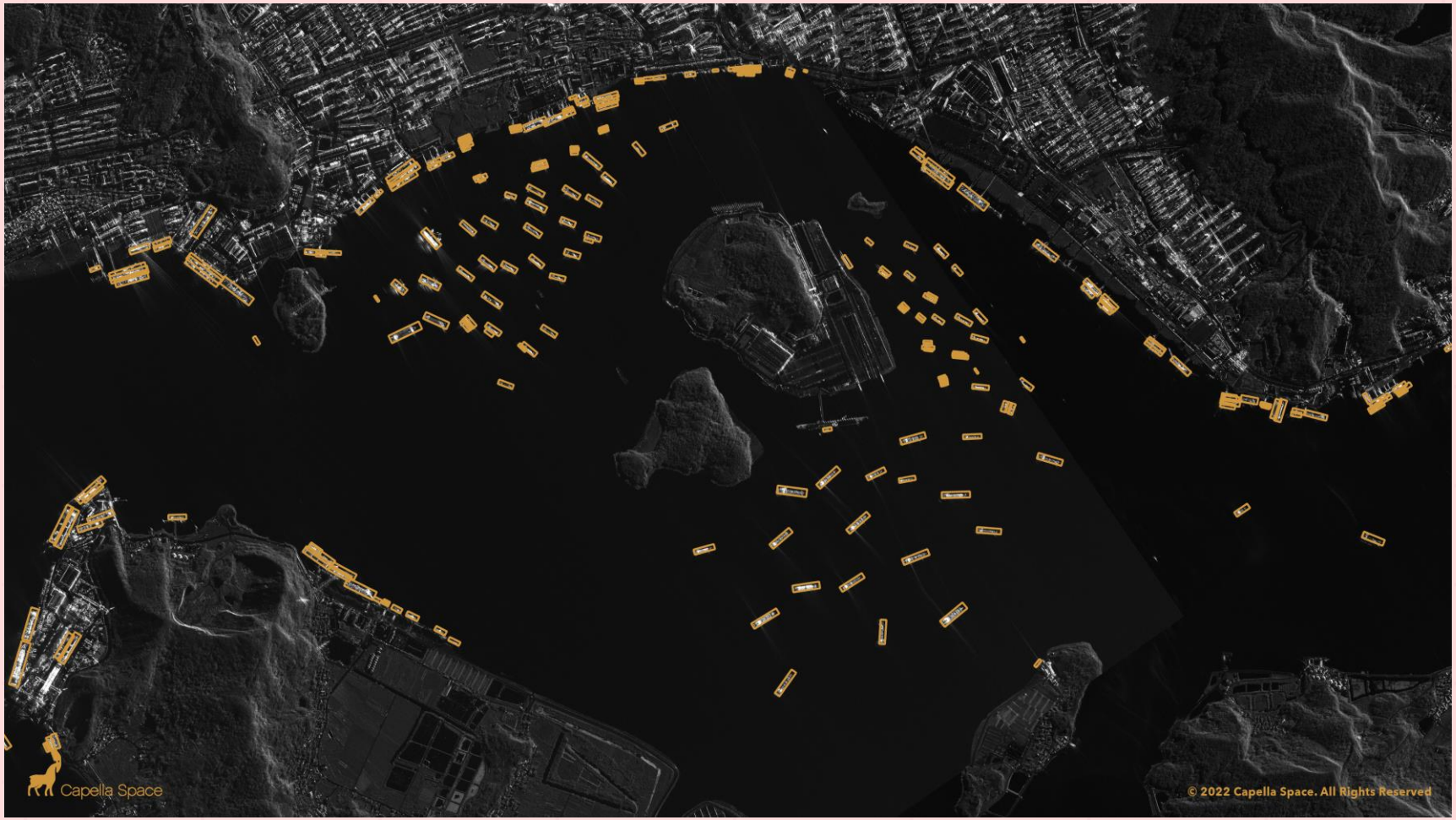
Remote Sensing

AI/ML Revolutionizing Remote Sensing

Optical Satellite- Aircraft Detection

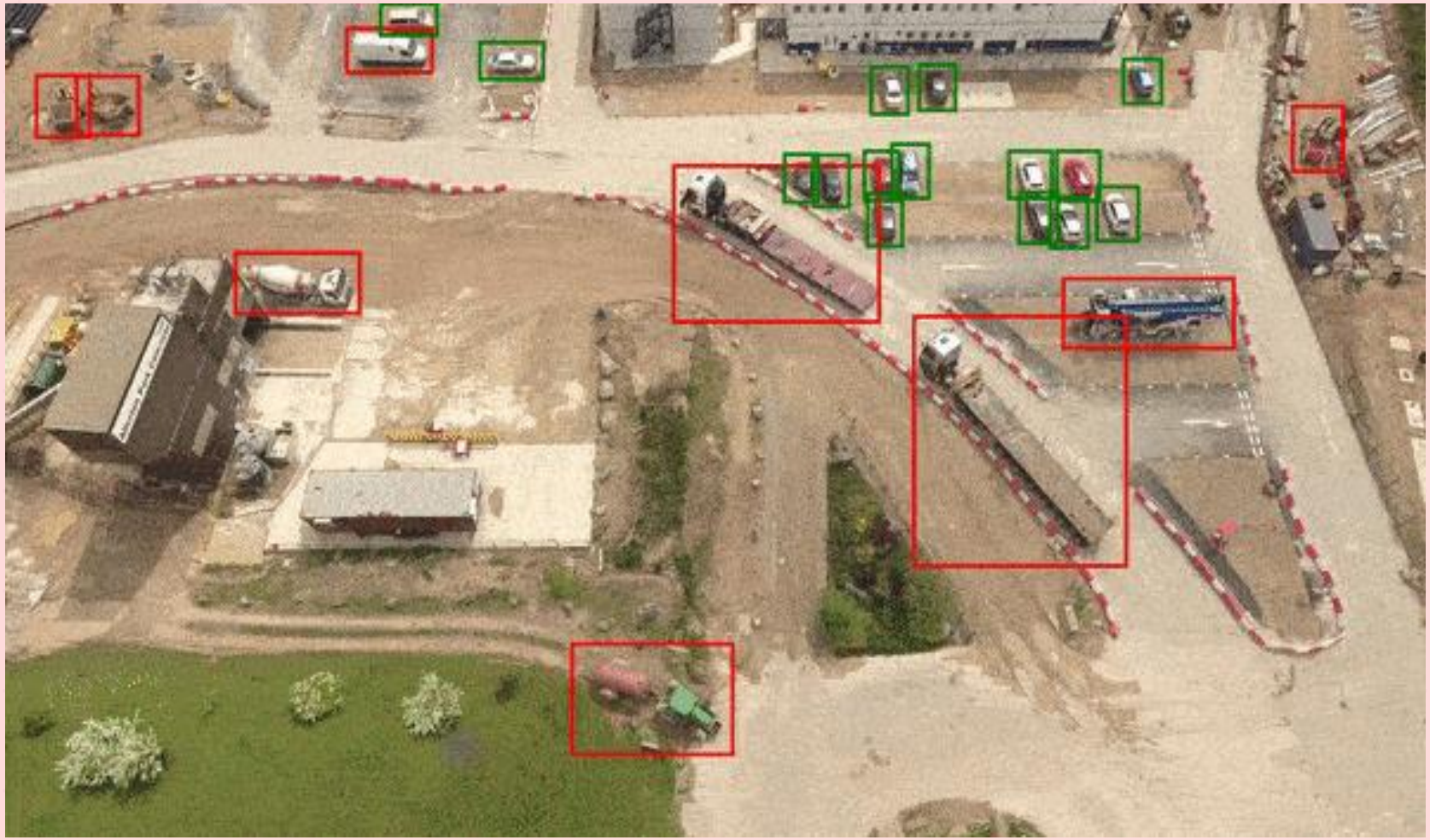
Optical Satellite based Object Detection – RarePlanes Dataset

SAR Imagery - Object Detection



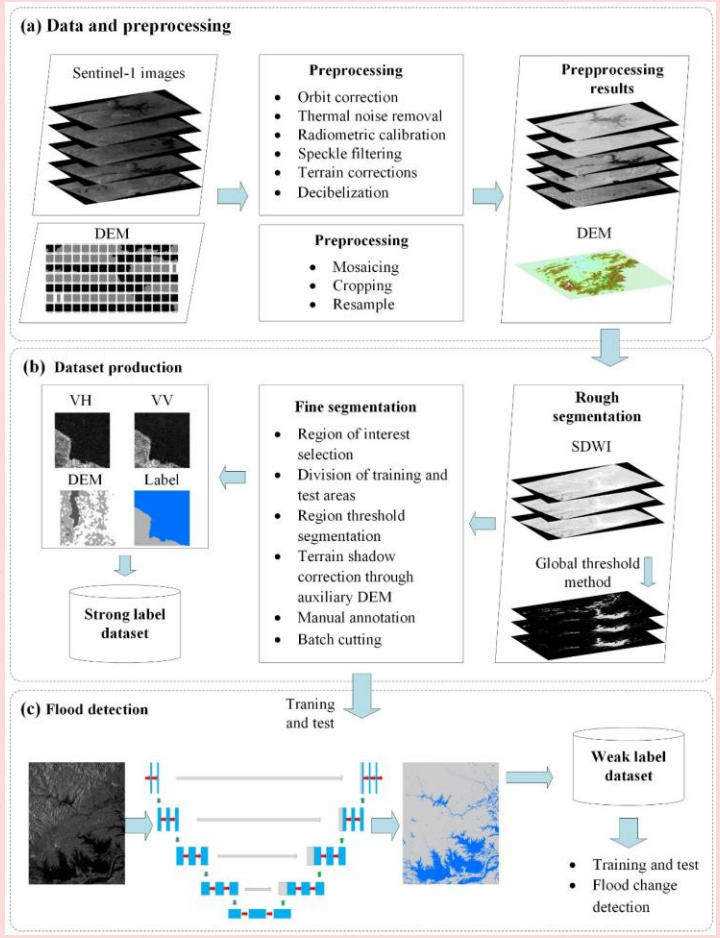
Vessel Detection - SAR Imagery

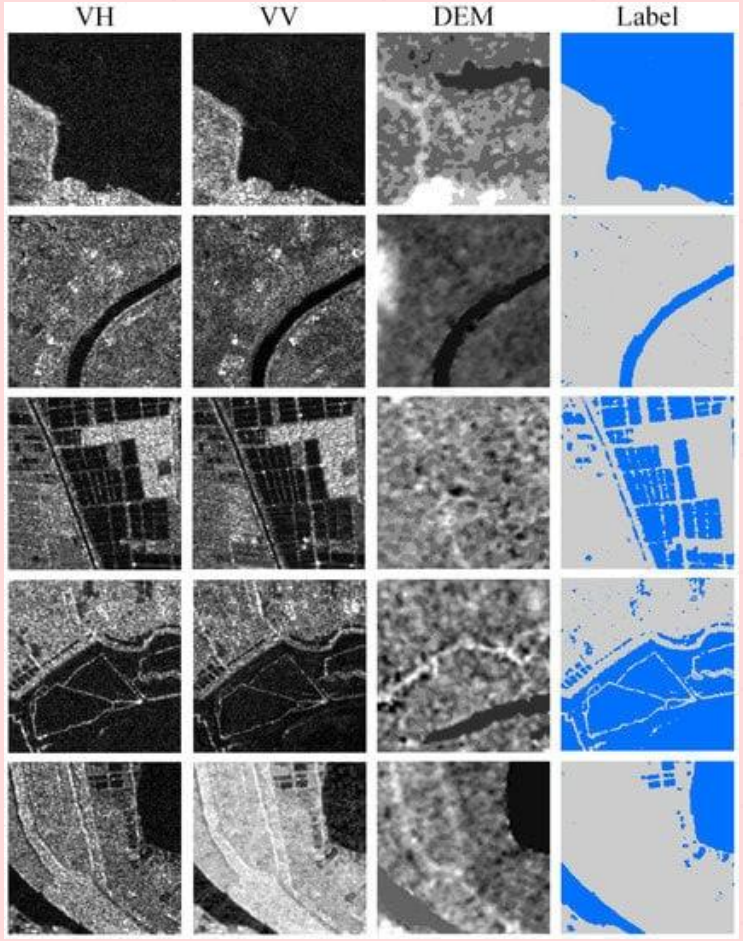
UAV Based Object Detection

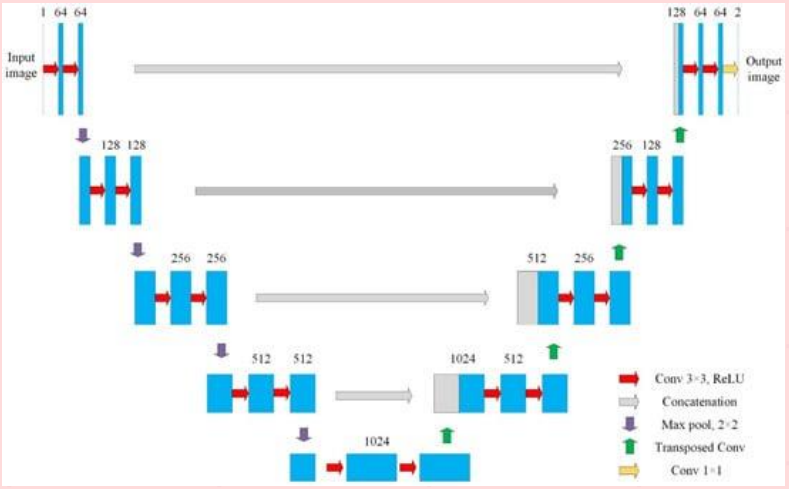


Drone based object detection

Flood Detection

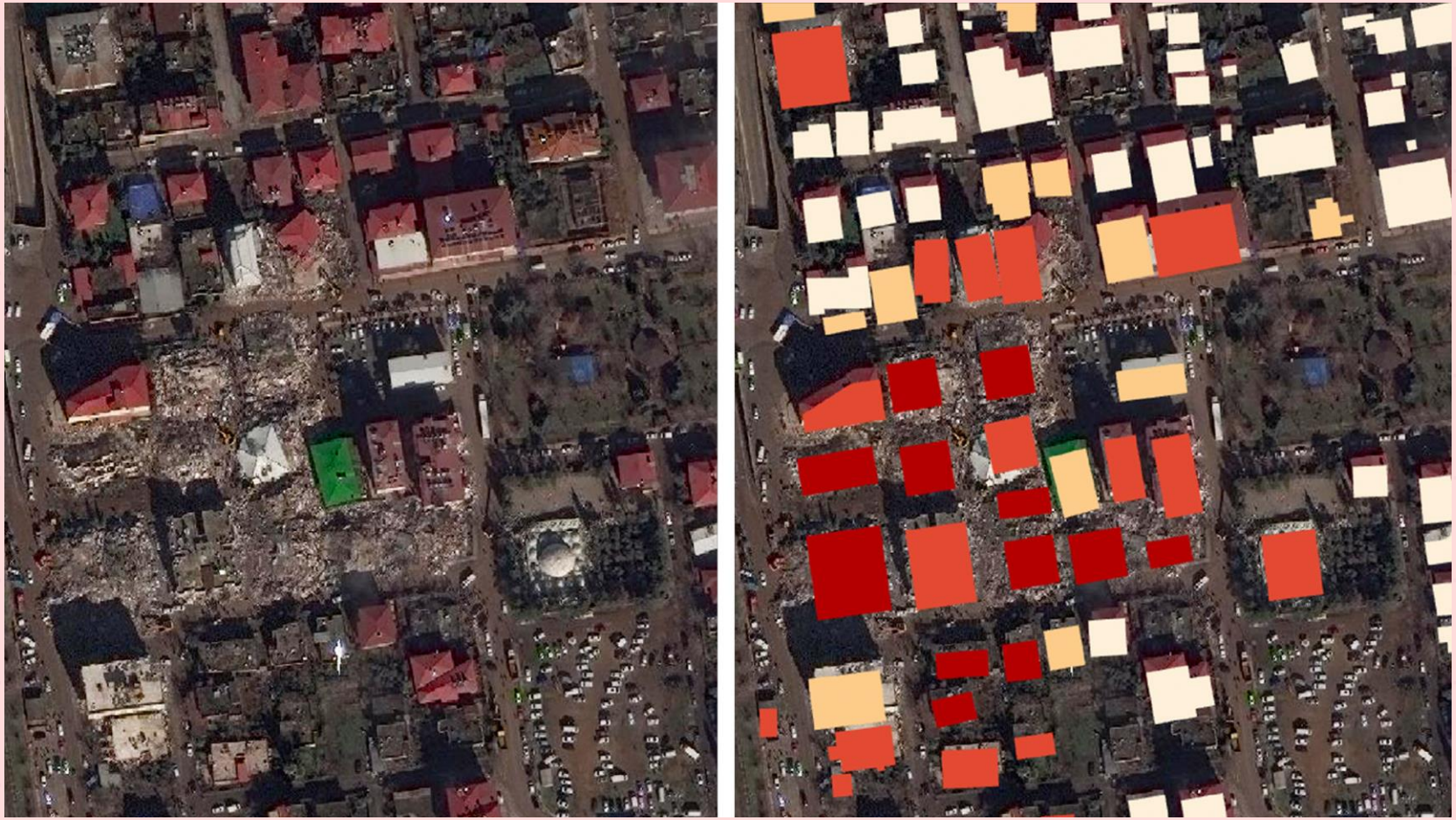






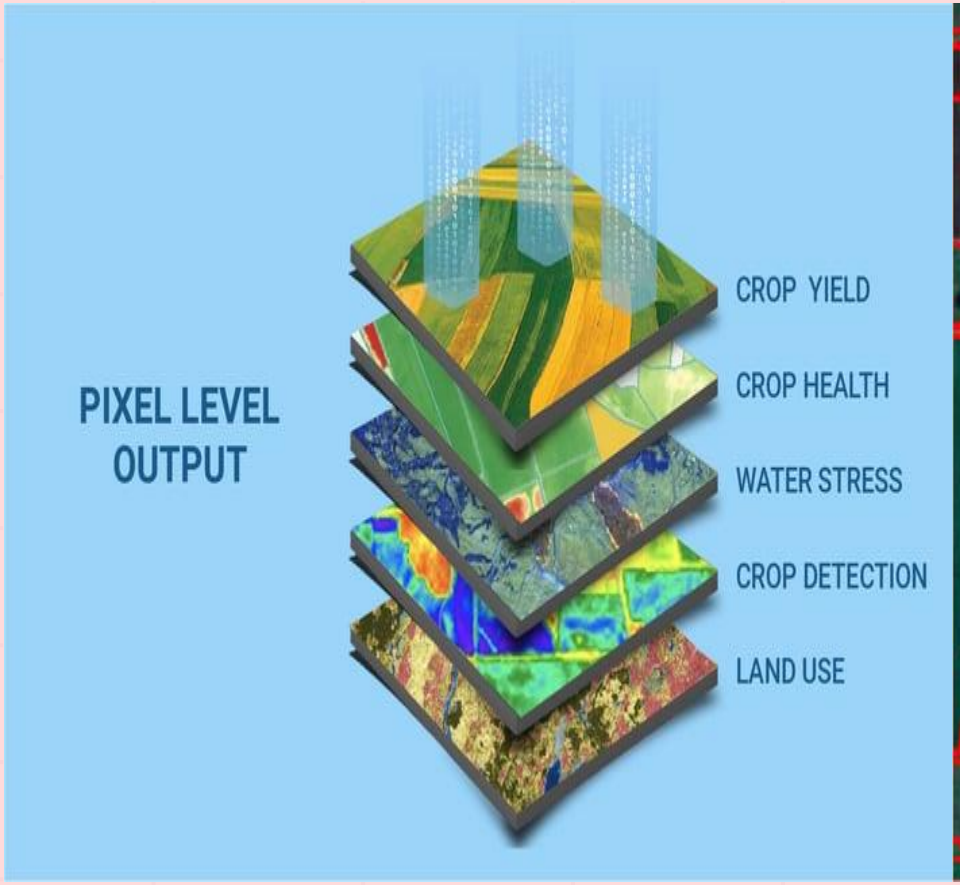
U-Net architecture for flood detection: SAR Imagery

Disaster Response



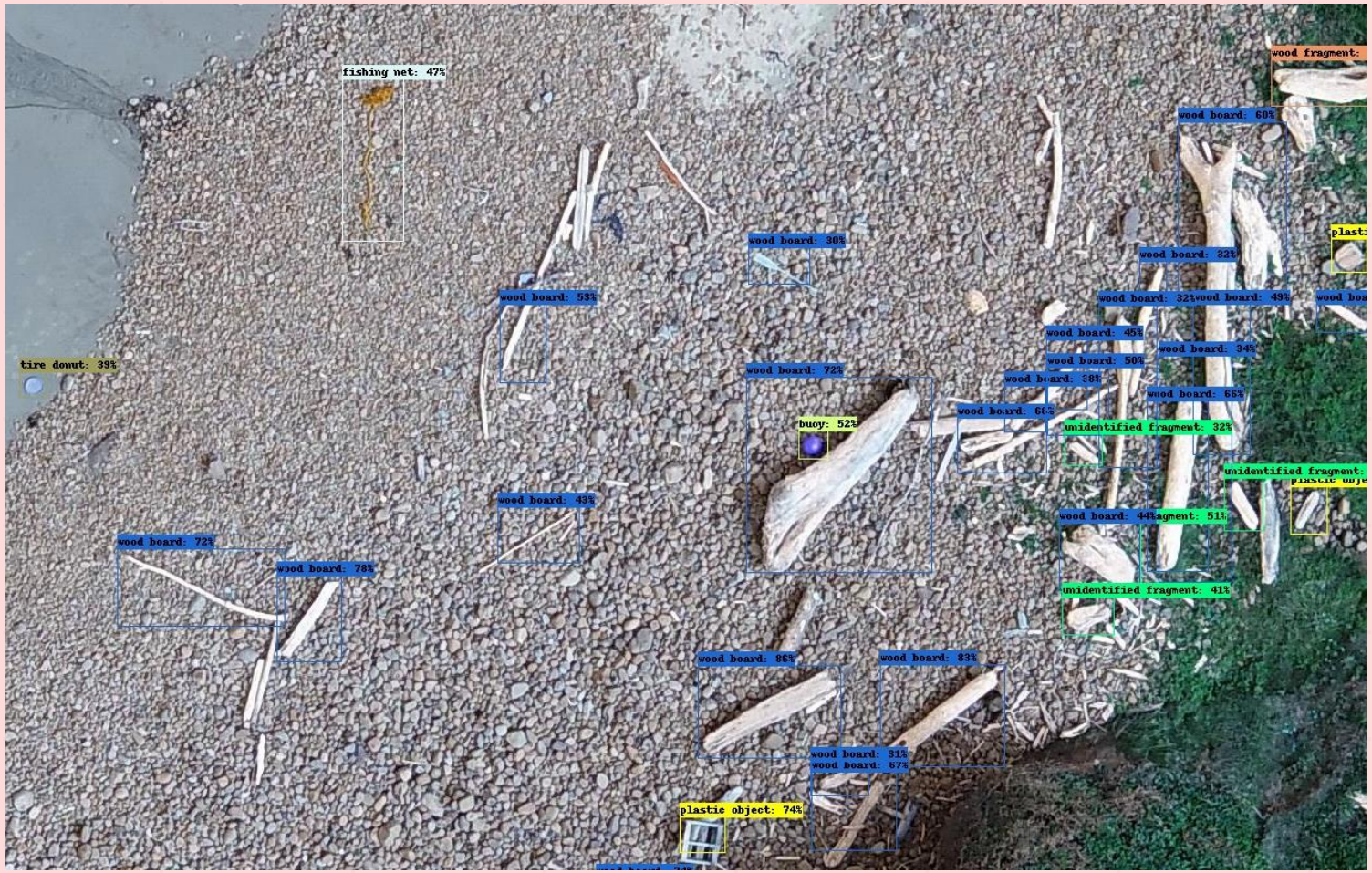
2023 Earthquake in Turkey: Humanitarian teams using AI/ML to plan disaster response

Crop Field Boundary Detection



Cropin

Monitoring Shoreline & Marine Debris

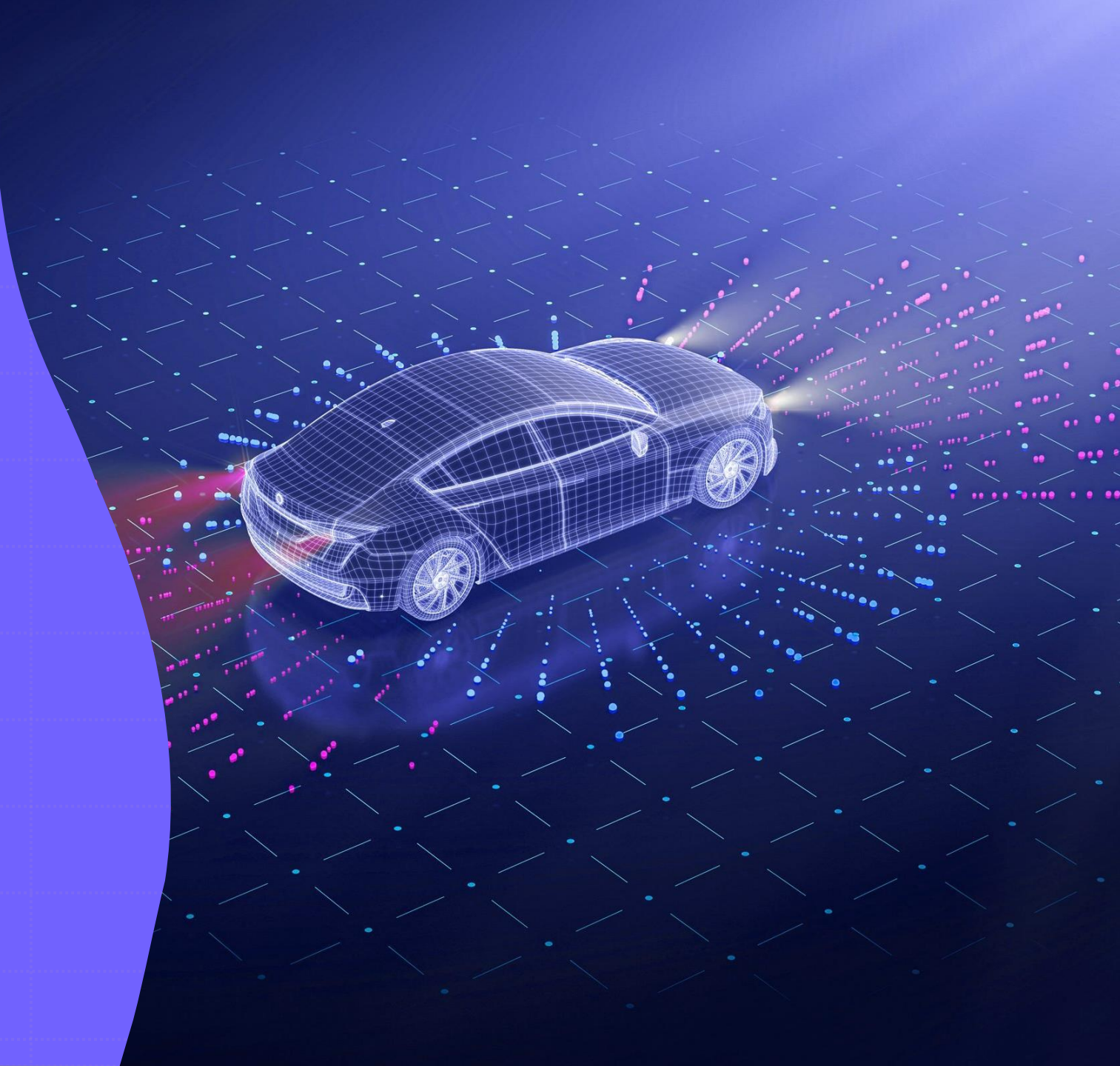


NCCOS: Monitoring shoreline and marine debris using AI/ML

Mini Q&A

Autonomous Driving

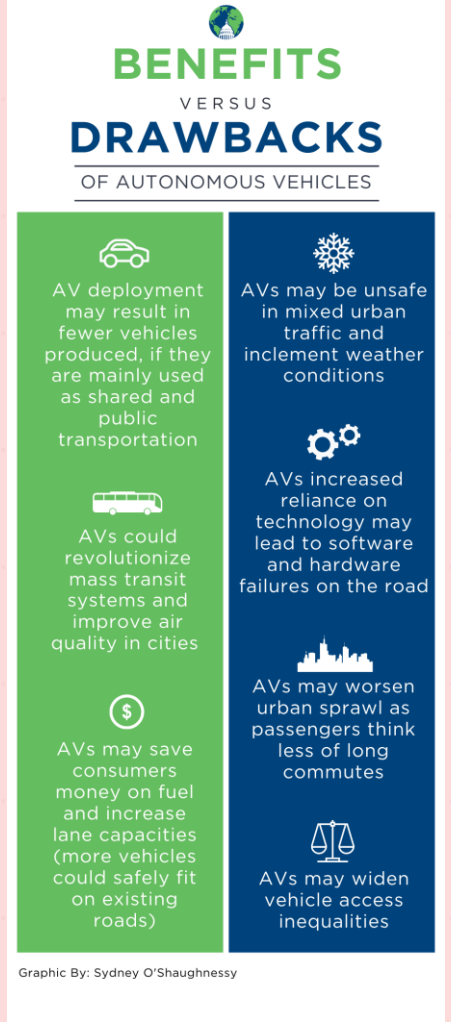
Autonomous Revolution



Autonomous driving and its societal impact

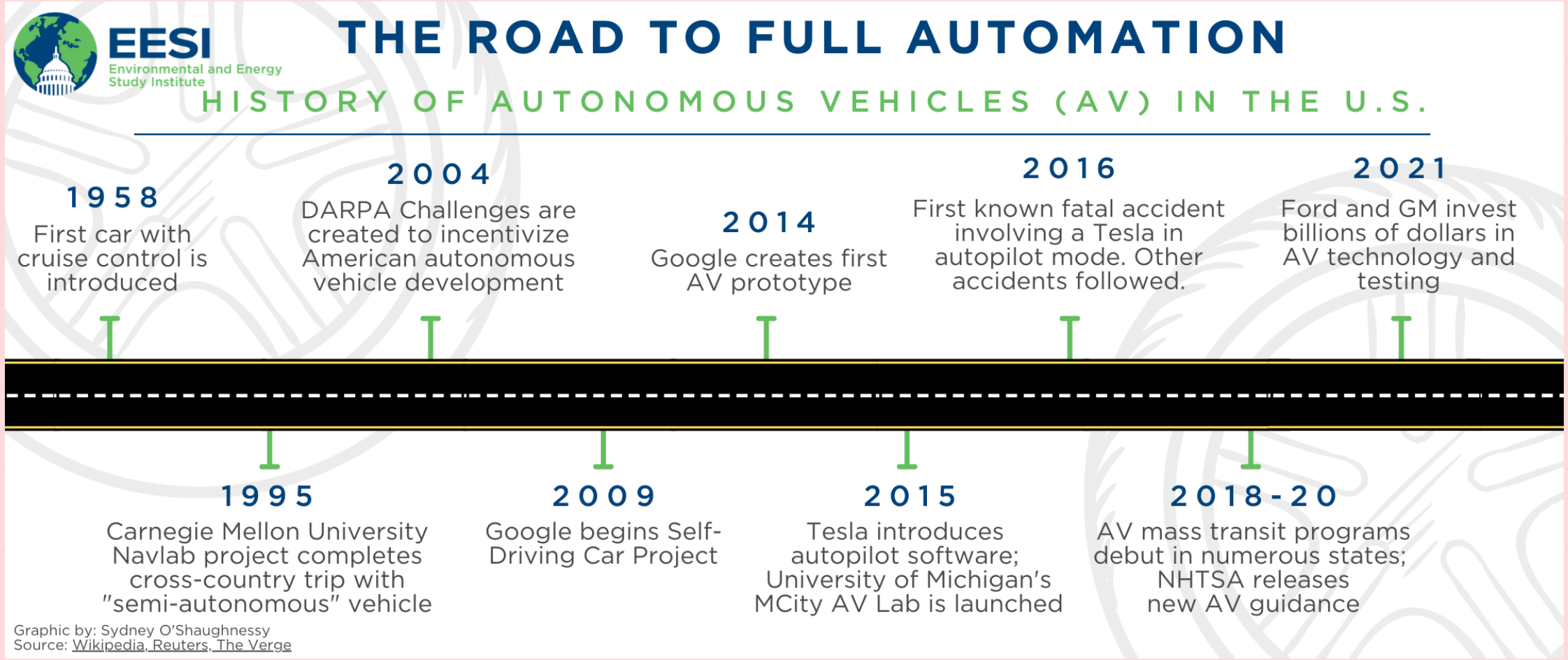
According to *Alliance for Automotive Innovation*:

- **Greater Road Safety**
  - Higher levels of autonomy have the potential to reduce risky and dangerous driver behaviors.
- **Reduced Congestion**
  - Fewer crashes or fender benders mean fewer roadway backups.
- **Environmental Gains**
  - Fewer traffic jams save fuel and reduce greenhouse gases from needless idling.
- **More Productivity**
  - Get time back as less time is spent on commuting.
- **Greater Independence**
  - People with disabilities are capable of self-sufficiency, and automated vehicles can help them live the life they want.
- **Better Land Use**
  - Need less road space so highway capacity could be increased – without construction.



Source: EESI

Evolution of autonomous vehicles

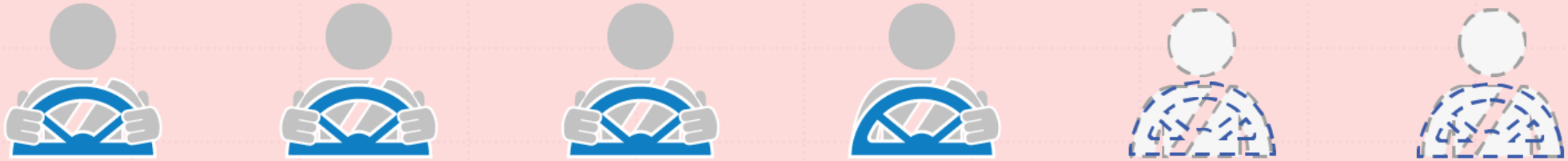


Source: EESI

Levels of Autonomy

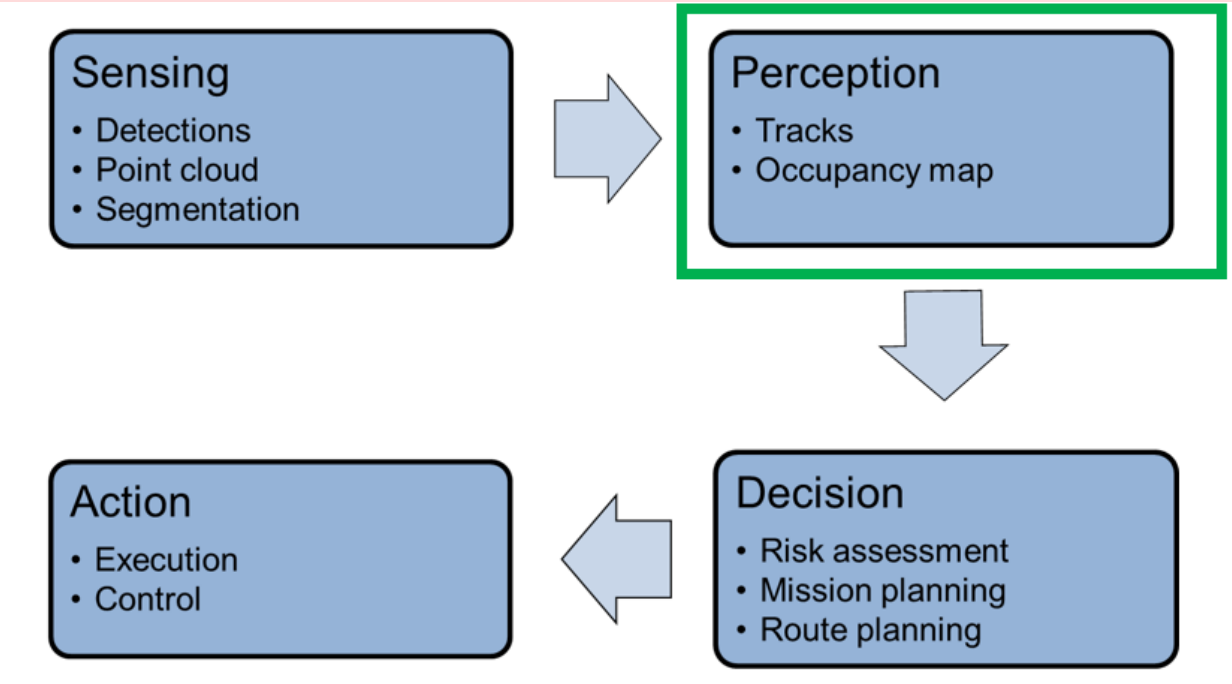
SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

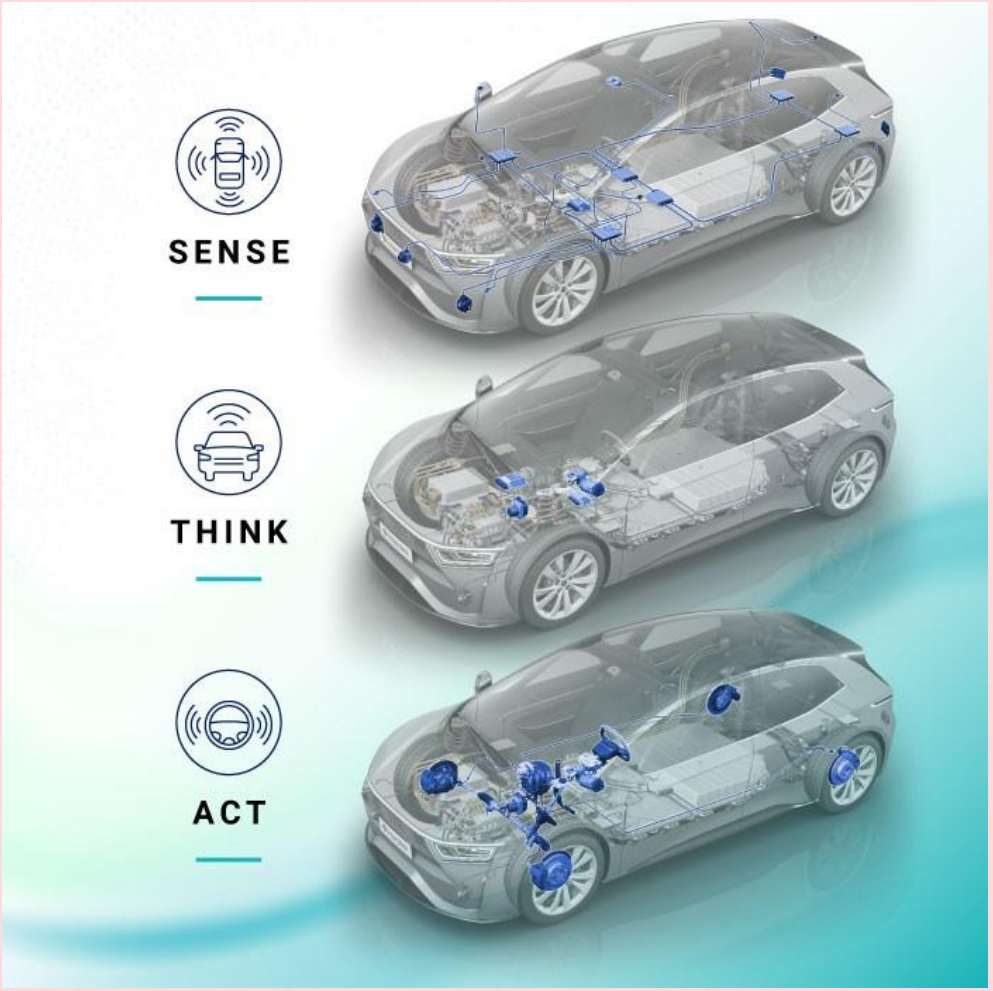
Full Automation



0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Sense, Think, Act





The Three Keys to Enabling Autonomous Driving

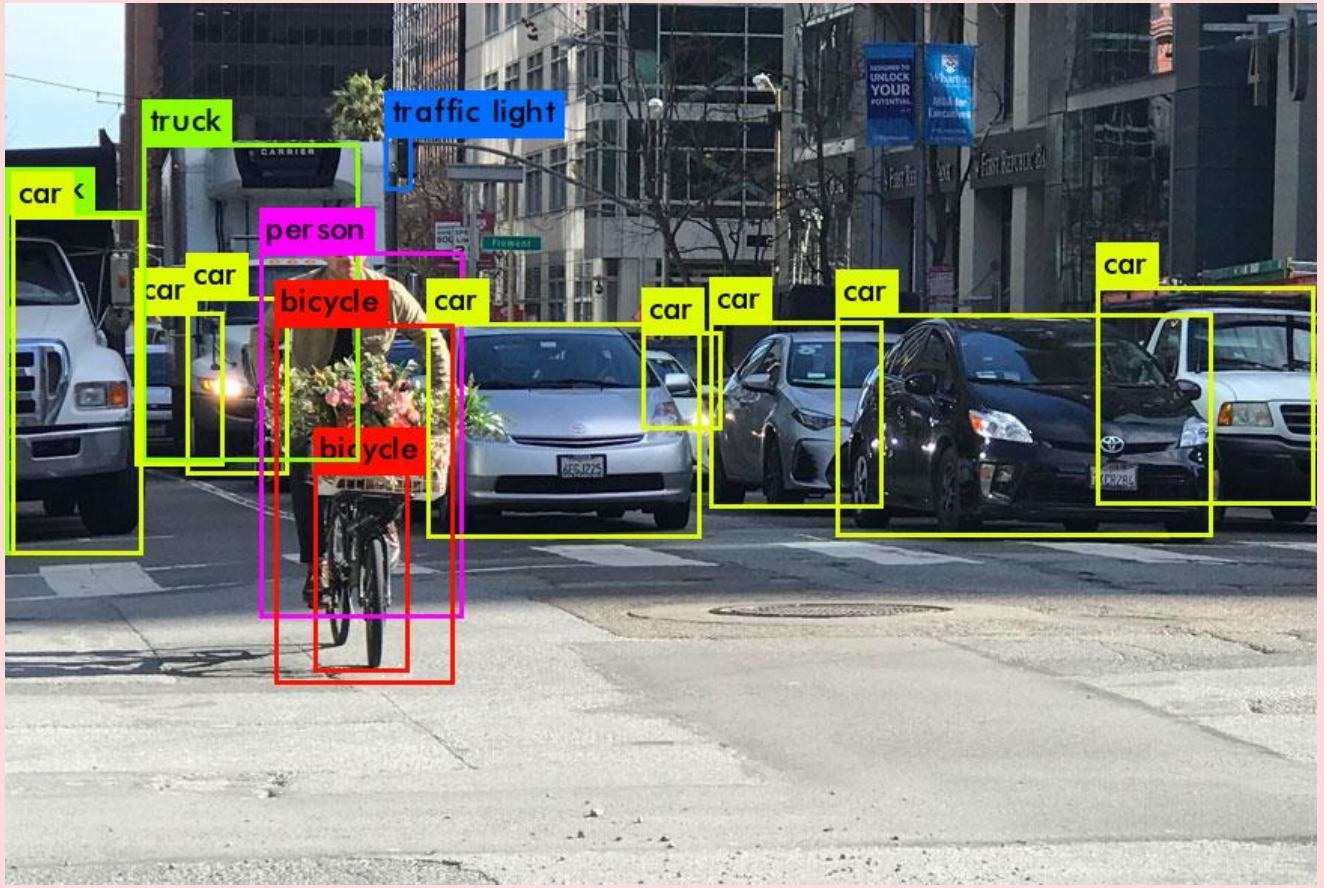
AI/ML in Autonomous Driving

AI and ML at the Wheel

AI/ML technologies driving autonomous vehicles

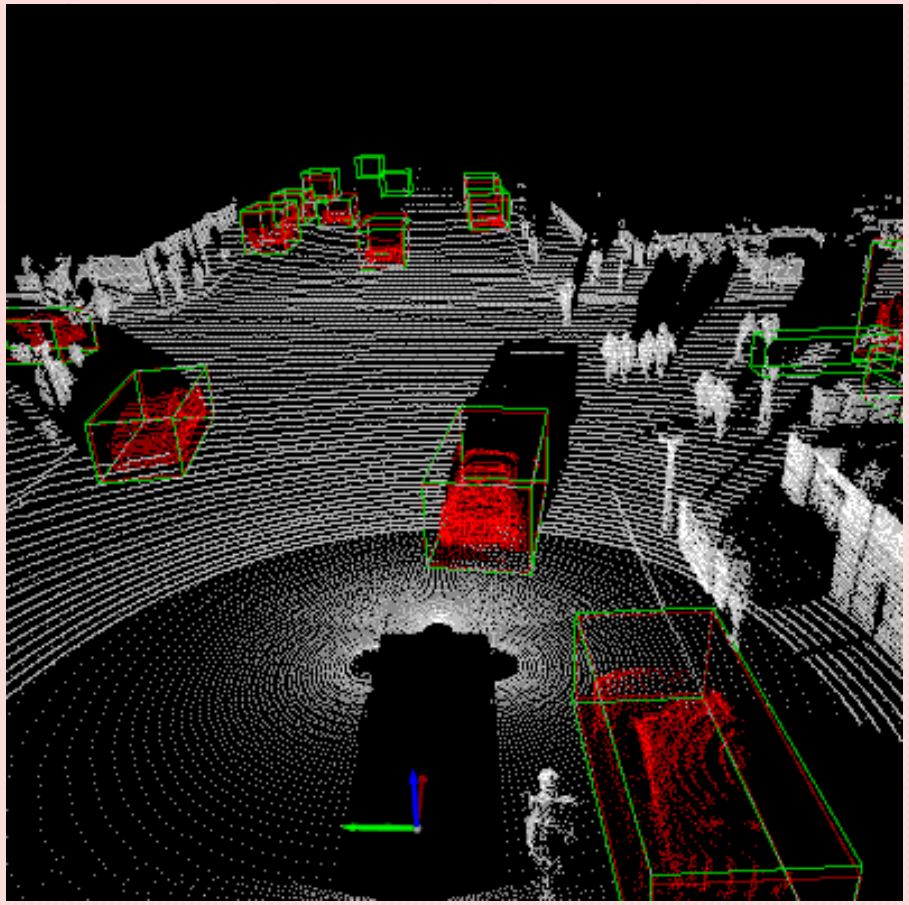
- **Perception**
  - Object Detection
    - based on data from the sensors (cameras, LiDARs, RADARs, USS).
  - Object Recognition
    - Example: Emergency Vehicles, Traffic Signs
  - Semantic Segmentation
    - Driveable Road Area Detection
  - Instance Segmentation
    - Object detection finds bounding boxes around objects and classifies them. Instance segmentation adds, for every detected object, a pixel mask that gives the shape of the object
- **Sensor Fusion**
  - Low, Mid, High-level fusion
- **Path Planning**
  - Reinforcement Learning

Perception – Object Detection/Recognition (camera)



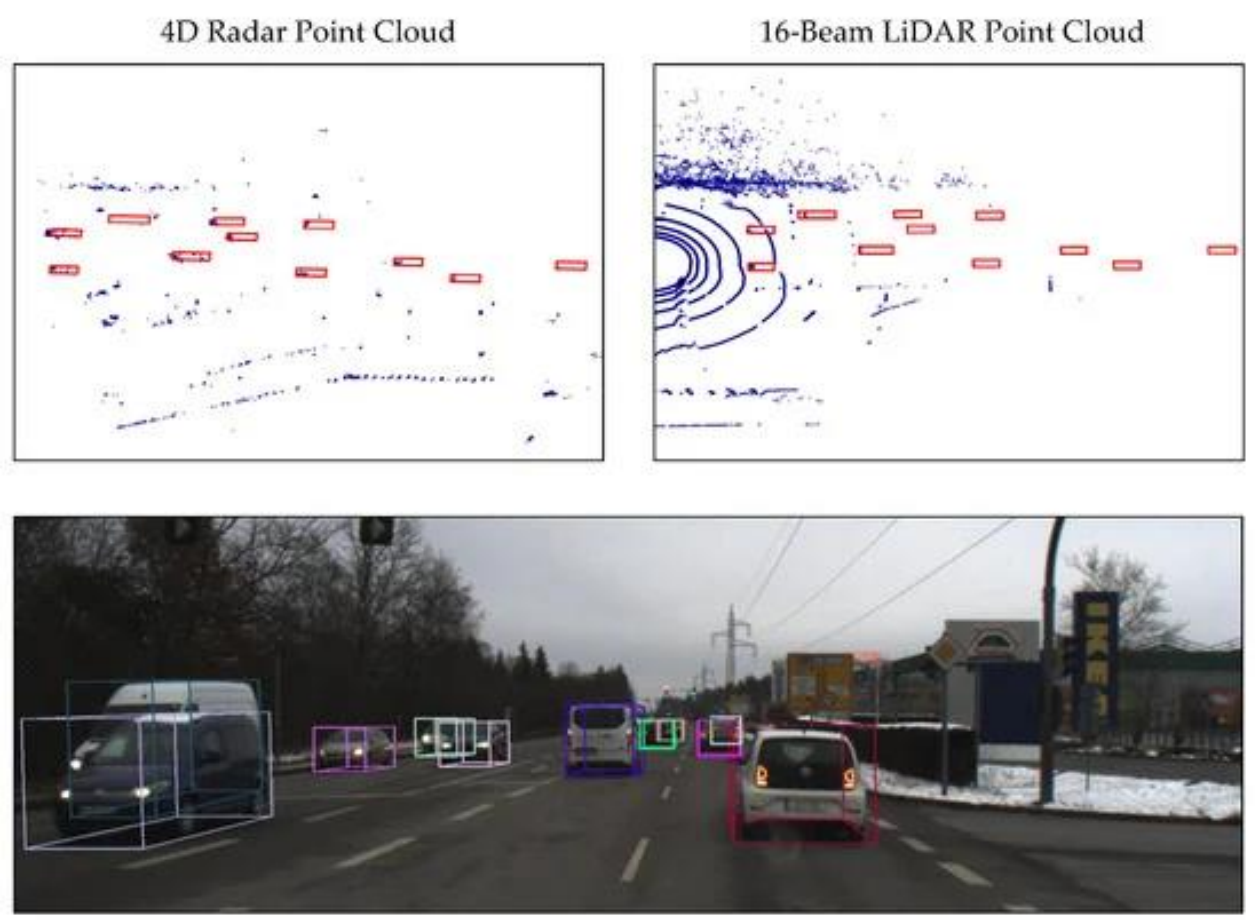
Using YOLOv7 model

Perception – Object Detection/Tracking (LiDAR)



Source: https://www.thinkautonomous.ai/blog/3d-object-tracking/

Perception – Object Detection/Tracking (RADAR)



Towards Deep Radar Perception for Autonomous Driving: Datasets, Methods, and Challenges

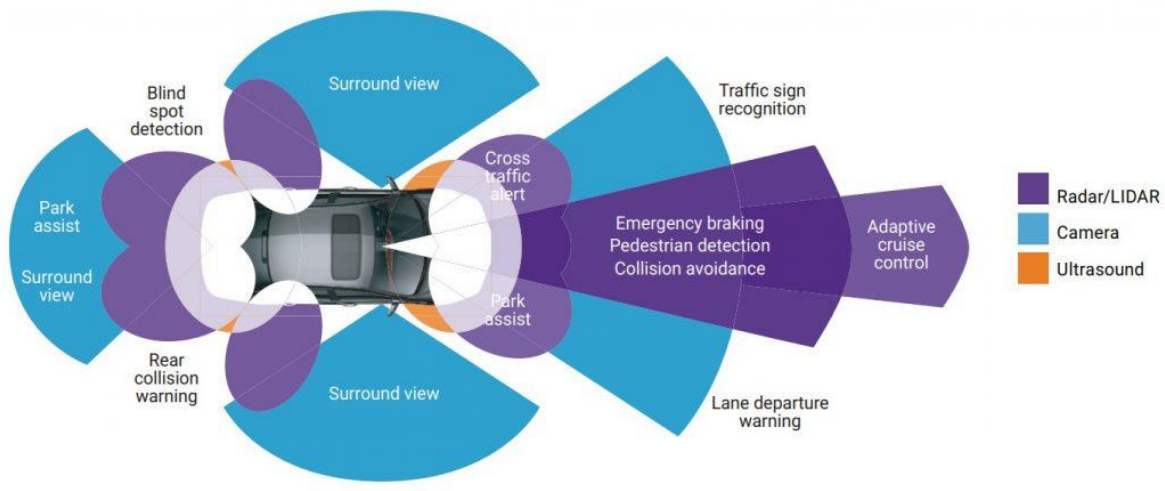
Perception – Semantic Segmenation (camera)

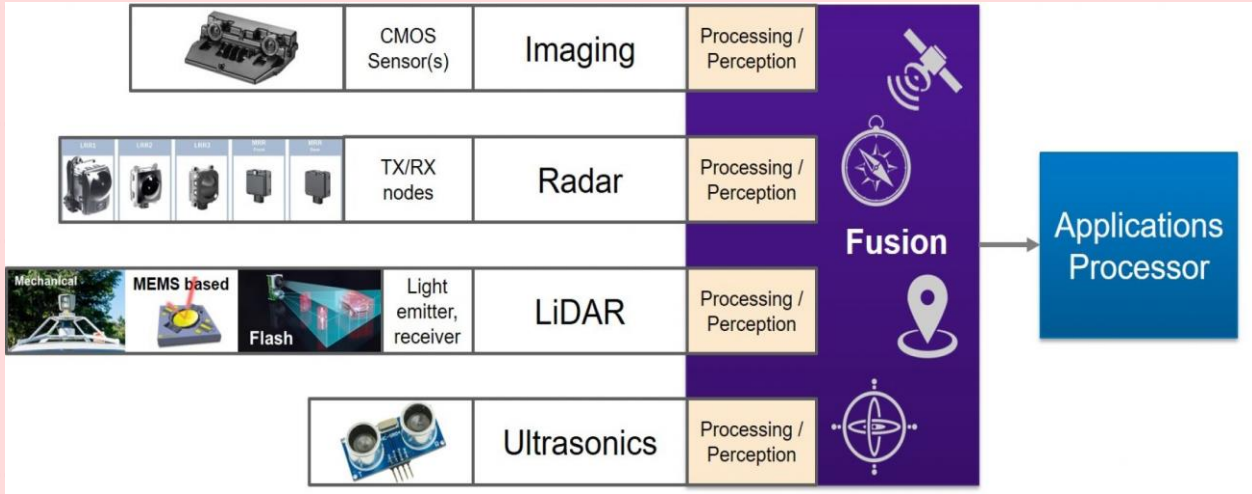
Model:

- **S**egment **E**verything **E**verywhere with **M**ulti-modal prompts (SEEM) :
  https://github.com/UX-Decoder/Segment-Everything-Everywhere-All-At-Once

Using Indian Driving Dataset

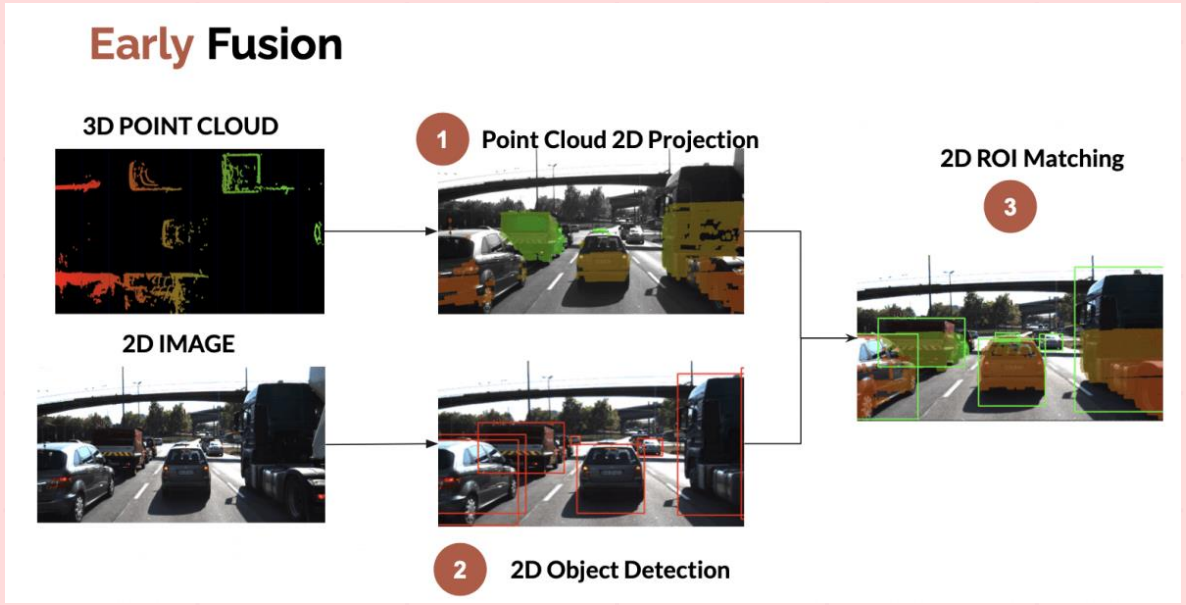
Sensor Fusion

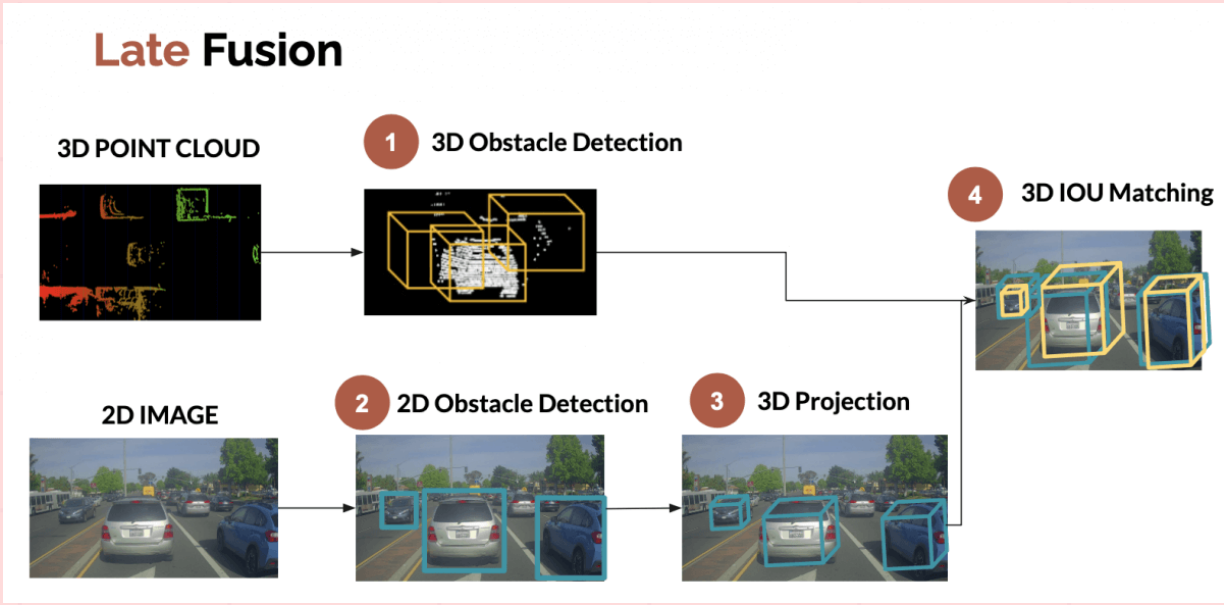




Source: [Edge AI and Vision Alliance]

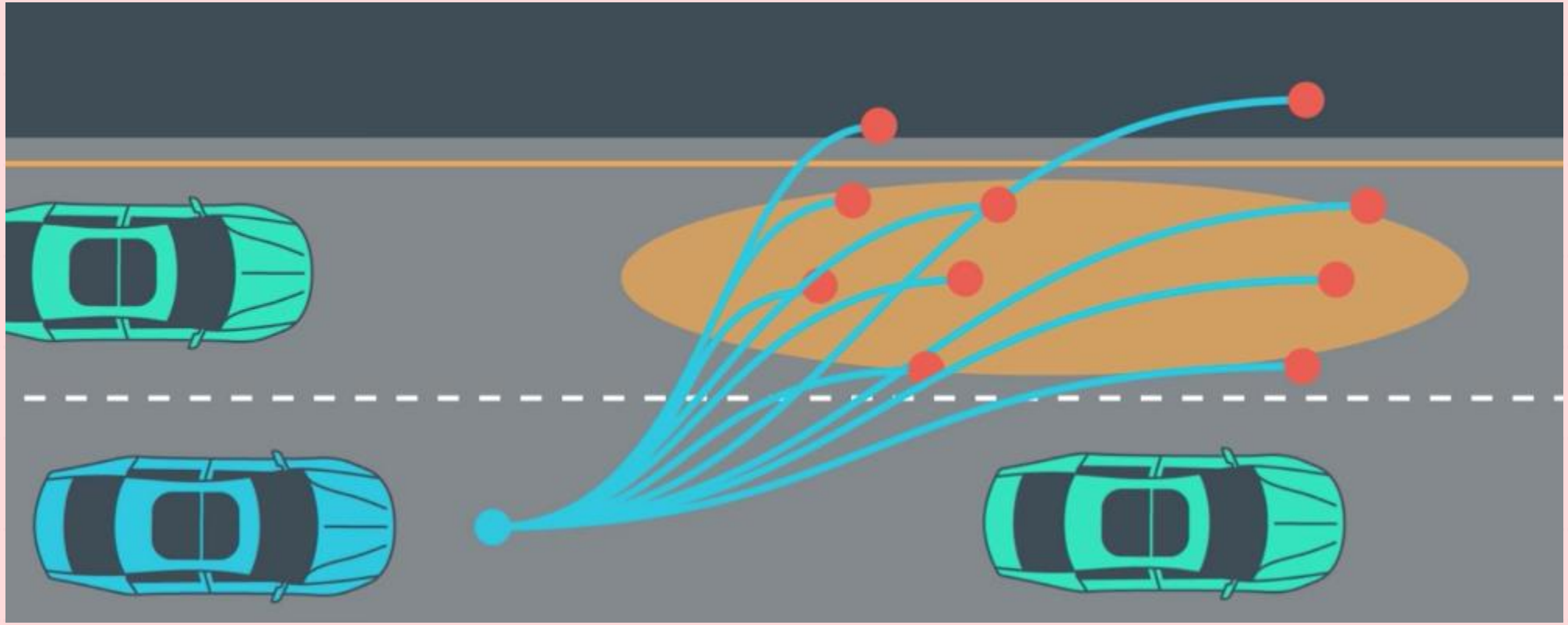
Sensor Fusion - Types





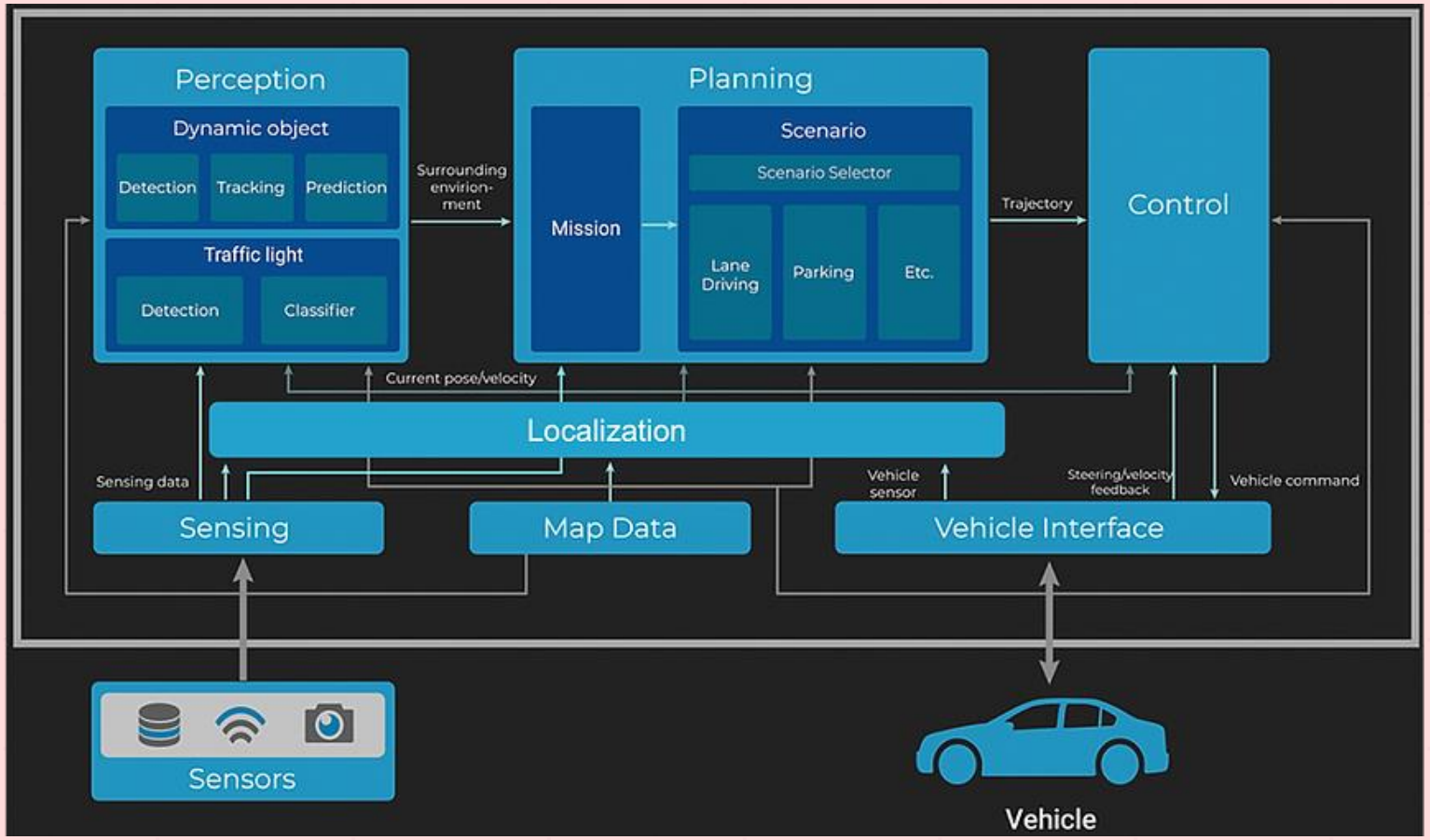
Source: https://www.thinkautonomous.ai/blog/9-types-of-sensor-fusion-algorithms/

Path Planning



Using AI to plan the vehicle trajectories

AD Full Stack

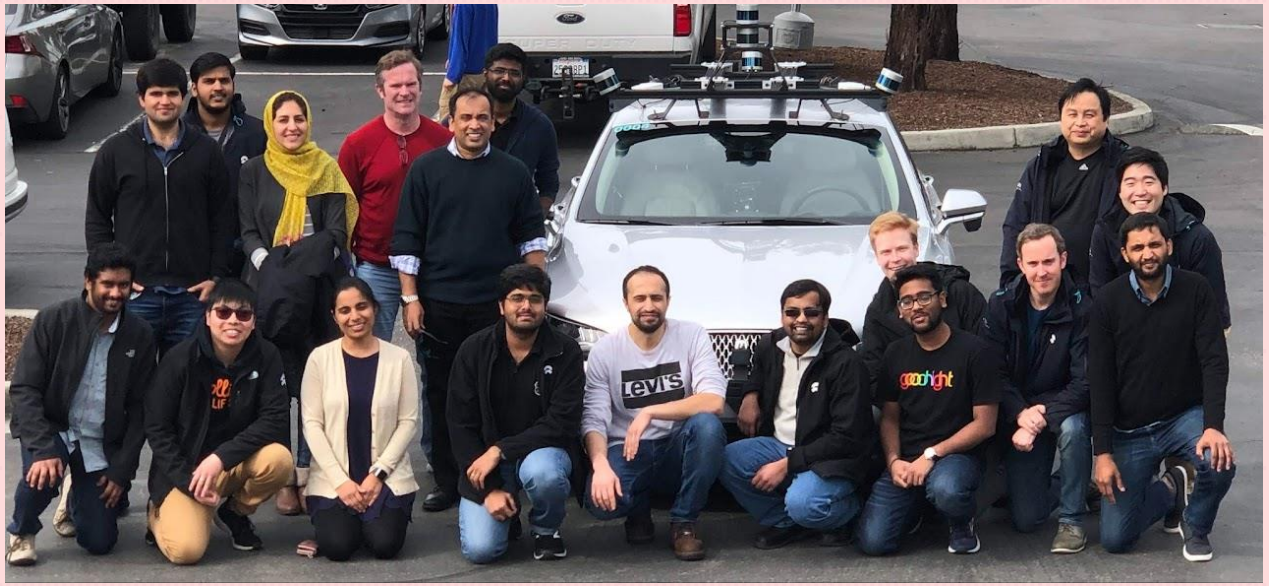


AD Full Stack

Demos

NIO EP9 at Circuit of the Americas - Fastest Autonomous Car, 2017

Demos



L4 Autonomous Driving: Perception Team at NIO USA, 2018

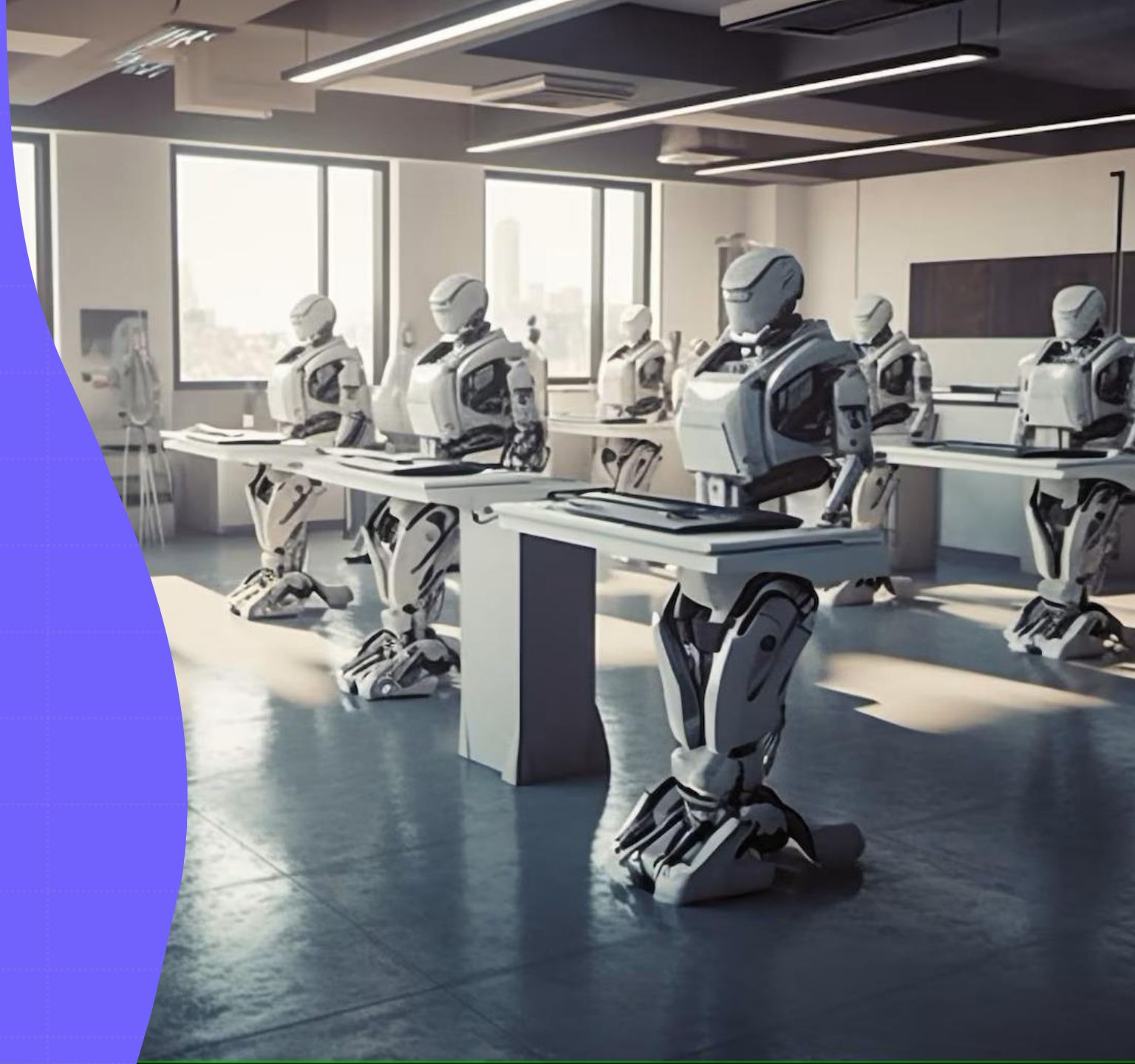
NIO ET5 NOP+
(Level-2+)

Demos

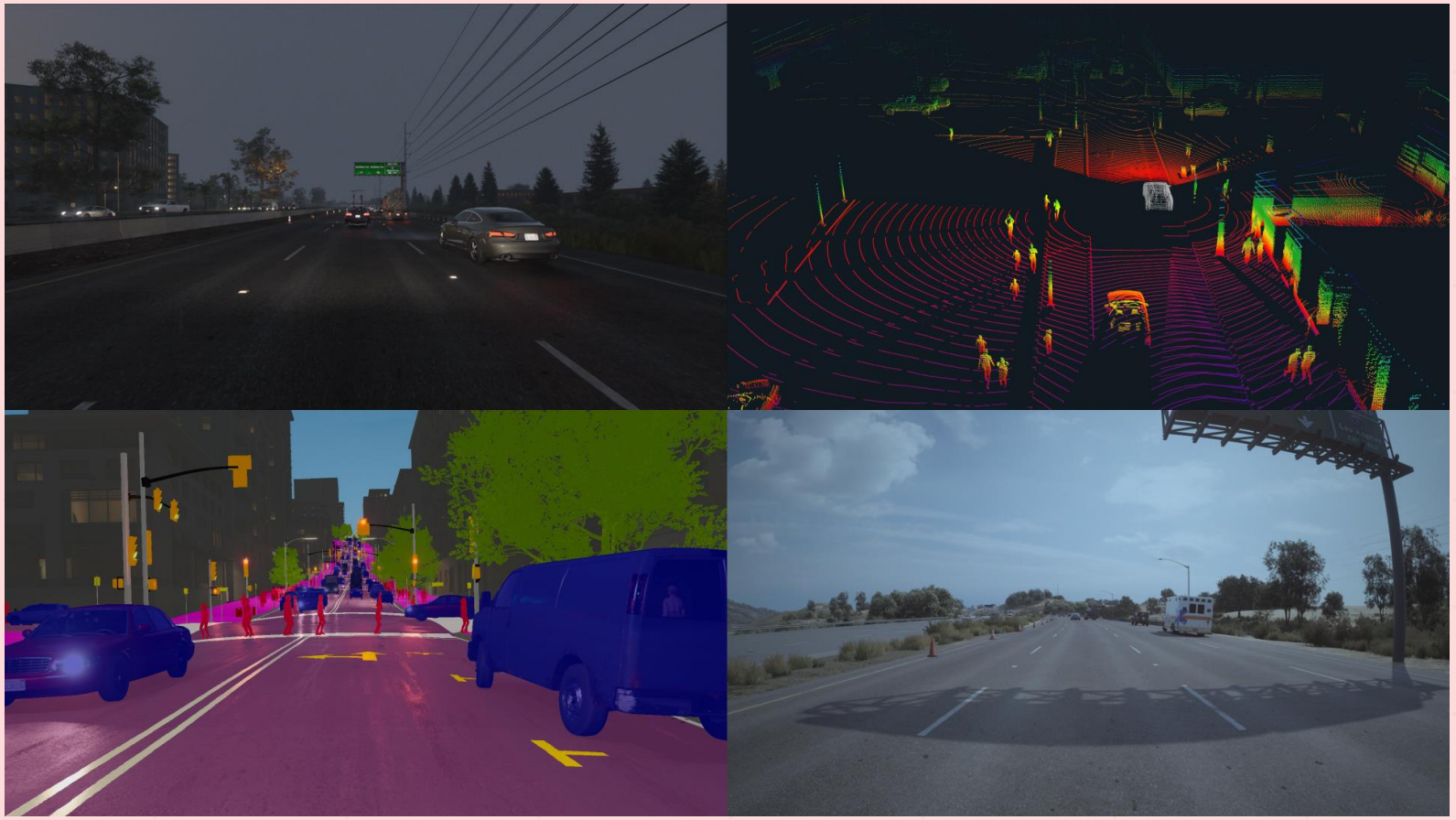
Waymo

Nuro

Emerging Frontiers

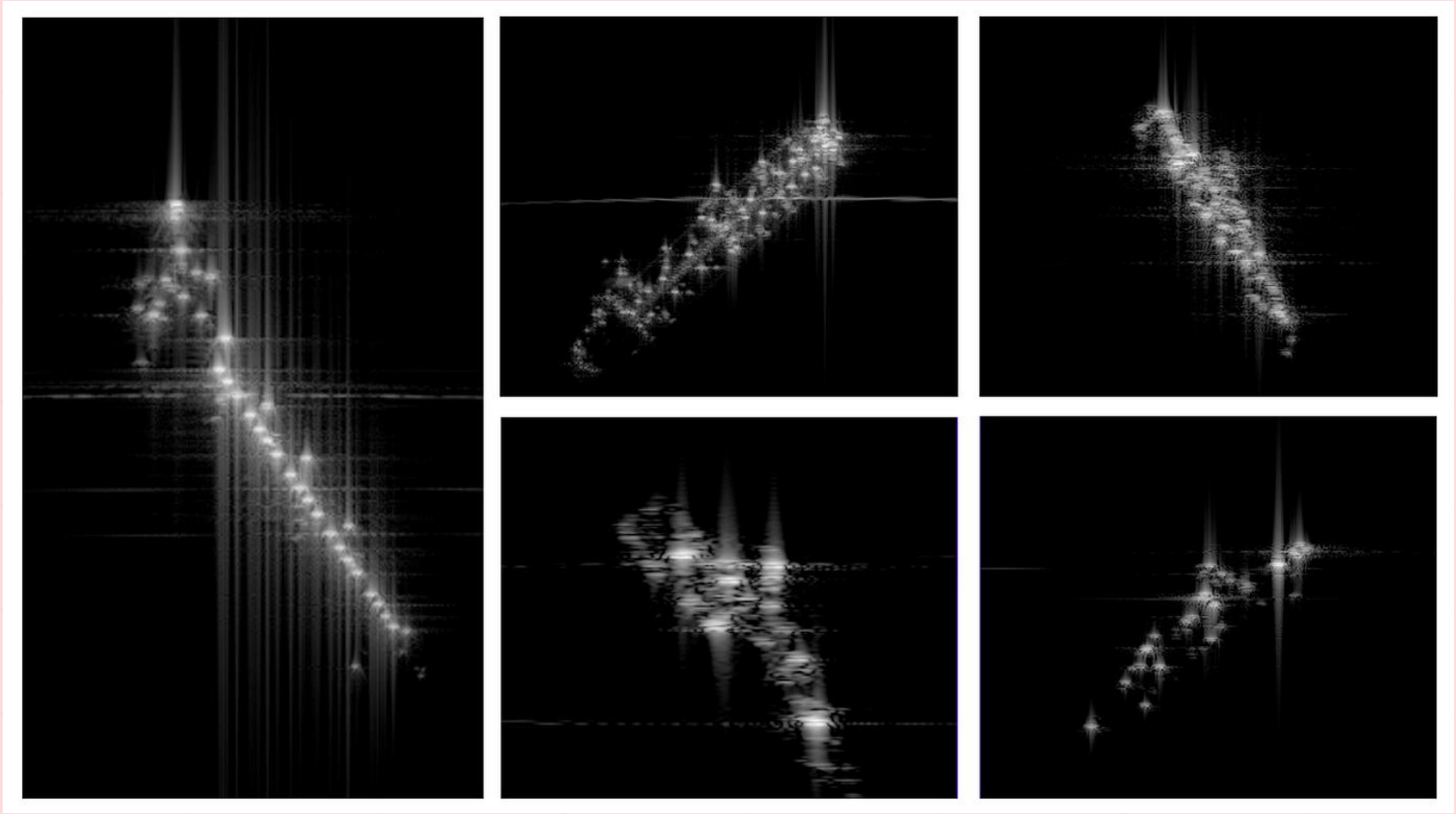


Generative AI



Synthetic Data for Autonomous Driving (illustration)
image courtesy: https://paralleldomain.com/

Generative AI

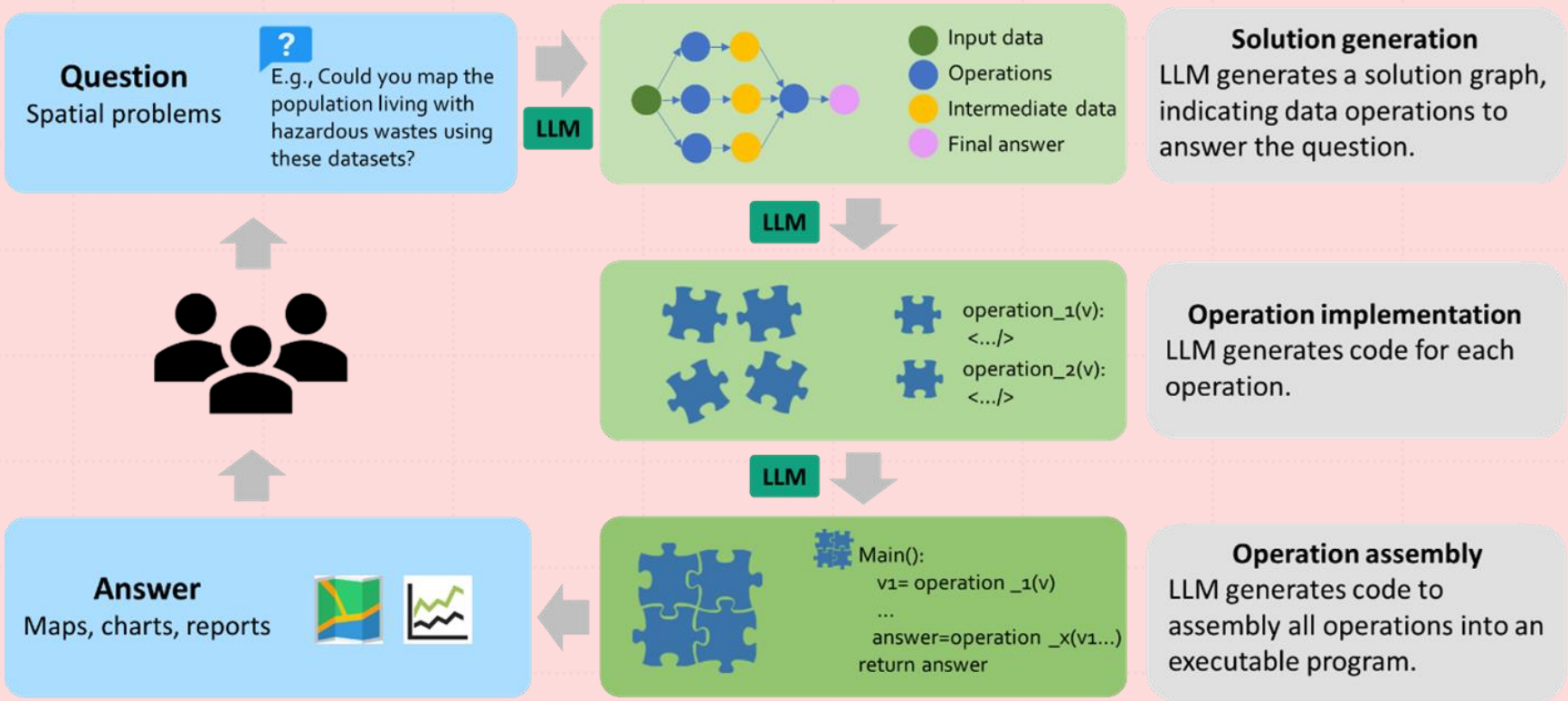


Synthetic Data for Remote Sensing, SAR images (illustration)
image courtesy: https://rendered.ai/

Large Language Models (LLMs)

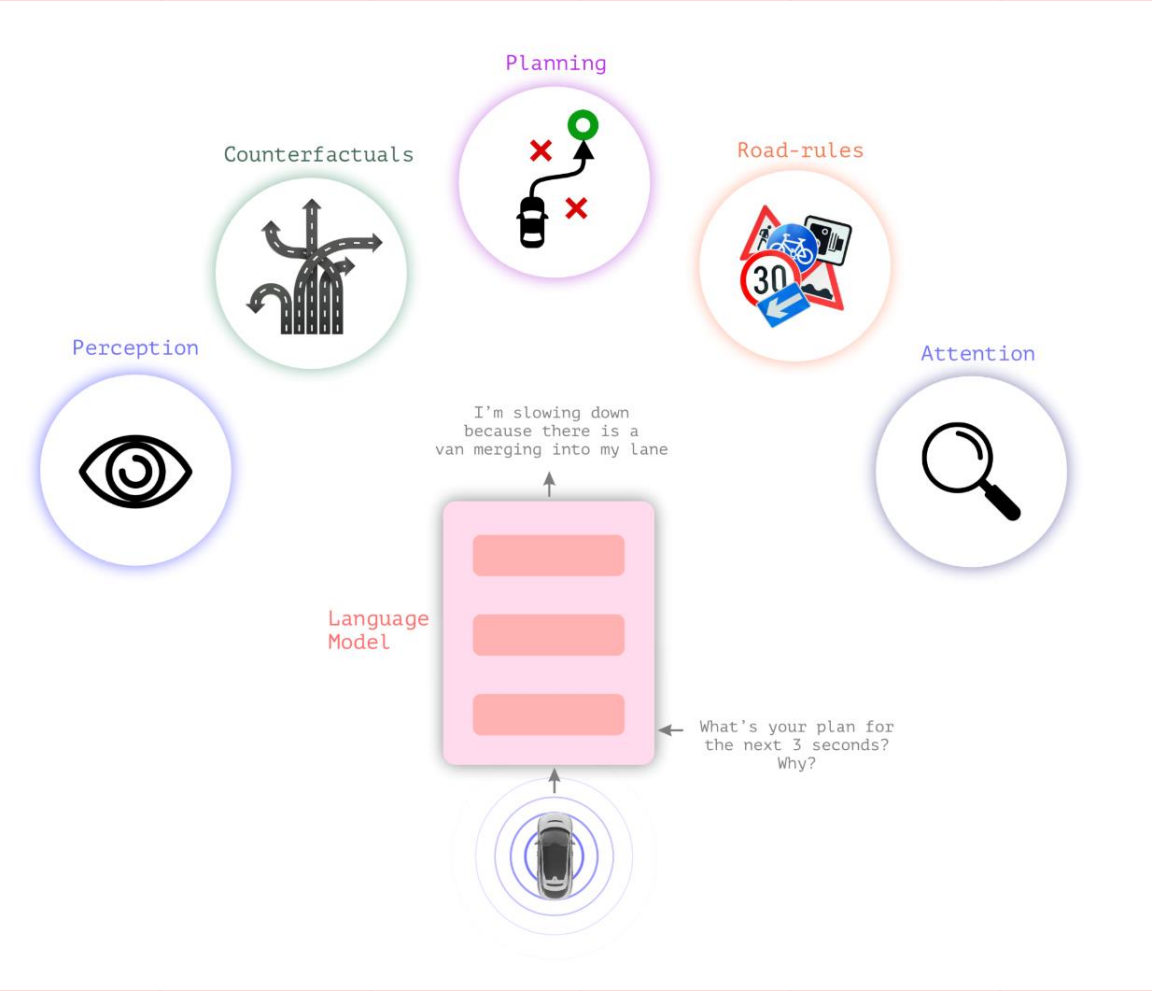
What are LLMs?

LLMs in Remote Sensing/GIS ?



[Autonomous GIS (AutoGIS): the next-generation AI-powered GIS]

LLMs in Autonomous Driving ?



LINGO-1 Architecture

What's next in AI/ML?

- **Generative AI Revolution:** Emerging generative AI technologies, like Generative Adversarial Networks (GANs), have the potential to enhance perception systems in autonomous vehicles. GANs can create realistic synthetic data, improving training and testing of AI algorithms for safer and more robust autonomous driving.
- **LLMs for Data Interpretation:** Large Language Models (LLMs), such as GPT-4, can assist in interpreting and understanding complex data collected through remote sensing. They offer advanced data analysis and decision support capabilities, enabling more precise insights from remote sensing data.
- **Human-AI Collaboration:** The integration of LLMs in remote sensing can facilitate human-AI collaboration. LLMs can assist analysts in interpreting vast amounts of remote sensing data, making it more accessible and actionable.
- **Predictive Modeling:** Generative AI models can be used for predictive modeling in both fields. In autonomous driving, they can simulate various scenarios and optimize vehicle behavior. In remote sensing, they can generate predictive models for environmental changes, aiding in early detection and response.
- **Ethical and Regulatory Considerations:** As these advanced AI technologies are integrated, addressing ethical concerns and regulatory frameworks will be critical. Ensuring transparency, accountability, and privacy in AI-driven applications will shape the path forward.

Summary

Summary

- **Remote Sensing Empowers Insight:** Remote sensing technologies, enhanced by AI and ML, provide valuable data for diverse applications, from environmental monitoring to disaster response.
- **Remote Sensing in Action:** Explore real-world applications of AI-powered remote sensing, showcasing how it revolutionizes fields such as agriculture, urban planning, and more.
- **AI Fuels Autonomous Driving:** AI and ML are driving the transformation of autonomous vehicles, empowering them with advanced perception, decision-making, and control capabilities.
- **Autonomous Driving Advancements:** Discover the evolution of autonomous vehicles and the role AI/ML play in overcoming challenges and unlocking new possibilities.
- **Future Horizons:** The future of AI/ML in both autonomous driving and remote sensing is filled with exciting possibilities.

Q&A

Some useful references

AI/ML

- OpenAI Blog [link]
- Allen Institute for AI [link]
- Nvidia Blog [link]
- Intel Blog [link]
- Google AI Research Blog [link]
- Meta AI Blog [link]
- Apple Machine Learning Research [link]
- Stanford Artificial Intelligence Lab [link]
- MIT CSAIL [link]
- INAI [link]
- Hugging Face [link]
- Kaggle Learn [link]

Autonomous Driving

- Center for Connected and Automated Transportation [link]
- Toyota InfoTech Labs [link]
- Honda Research Institute USA Inc [link]
- Waypoint - The official Waymo Blog [link]
- Cruise Automation [link]
- Mobileye Blog [link]
- Carnegie Mellon University Robotics Institute [link]
- University of Washington [link]
- Robotics and Computer Vision Lab, KAIST [link]

Remote Sensing

- NASA Applied Remote Sensing Training Program (ARSET) [link]
- ESA Copernicus RUS Training Material [link]
- Alaska Satellite Facility [link]
- Sentinel Hub [link]

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