Emerging Technologies

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Internet of Things

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Internet of Things

- The term Internet of Things refers to the collective network of connected devices and the technology that facilitates communication between devices and the cloud, as well as between the devices themselves
- Basically, IoT integrates everyday “things” with the internet

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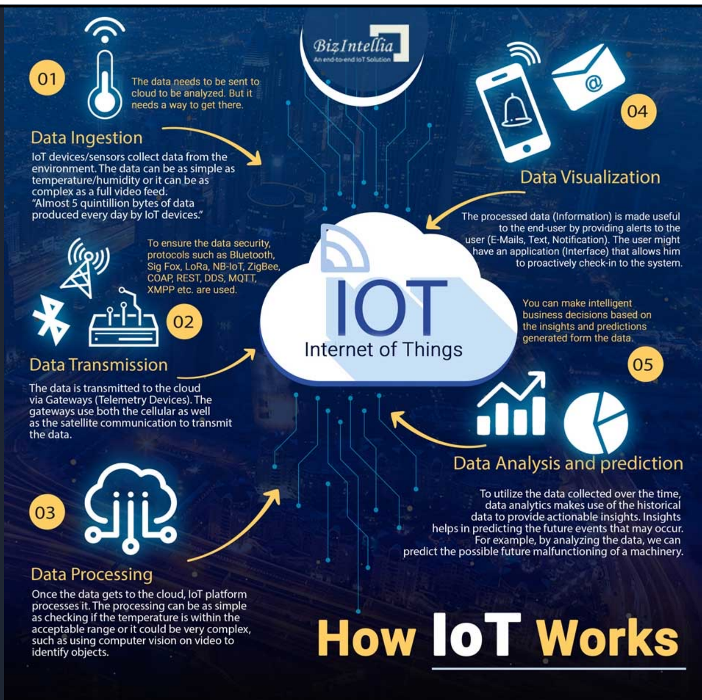

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1.1. Working of IoT

- Data Ingestion: IoT devices and sensors collect diverse environmental data. This can include basic metrics such as temperature and humidity, with devices generating substantial data volumes daily.
- Data Transmission: Data is securely transmitted to cloud platforms via gateways, which may use various communication protocols like Bluetooth, LoRa, Zigbee, and others to ensure security and integrity.
- Data Processing: Upon reaching the cloud, data undergoes processing, which could range from simple validations to complex operations like video analysis for object identification.

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1.1. Working of IoT

- Data Visualization: Processed data is made accessible to end-users through applications, providing actionable insights via notifications such as emails and texts, which also enable user interaction with the system.
- Data Analysis and Prediction: Historical data is analyzed for patterns, providing insights and predictions. This predictive analysis helps anticipate events such as equipment malfunctions.
- Execution Command sent to connected devices

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1.2. Examples of IoT devices

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Connected cars

- There are many ways vehicles, such as cars, can be connected to the internet
- They collect data from the accelerator, brakes, speedometer, odometer, wheels, and fuel tanks to monitor both driver performance and vehicle health
- The data gets shared with:
  - Service Centre
  - Owner
  - Insurer
  - Manufacturer

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Connected homes

- Smart home devices are mainly focused on improving the efficiency and safety of the house, as well as improving home networking
- Devices like smart outlets monitor electricity usage and smart thermostats provide better temperature control
- Hydroponic systems can use IoT sensors to manage the garden while IoT smoke detectors can detect tobacco smoke
- Home security systems like door locks, security cameras, and water leak detectors can detect and prevent threats, and send alerts to homeowners

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Smart cities

- IoT applications have made urban planning and infrastructure maintenance more efficient
- IoT applications can be used for measuring air quality and radiation levels, reducing energy bills with smart lighting systems, detecting maintenance needs for critical infrastructures and increasing profits through efficient parking management

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Manufacturing

- IoT applications can predict machine failure before it happens, reducing production downtime
- Wearables in helmets and wristbands, as well as computer vision cameras, are used to warn workers about potential hazards

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Logistics and transport

- Commercial and Industrial IoT devices can help with supply chain management, including inventory management, vendor relationships, fleet management, and scheduled maintenance
- Shipping companies use Industrial IoT applications to keep track of assets and optimize fuel consumption on shipping routes

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Smart Stores

- Smart stores, also known as connected stores, are brick-and-mortar stores that incorporate various technologies to enhance the shopping experience, optimize operations, and improve customer engagement and lifetime value
- Smart stores offer features such as personalized product recommendations, frictionless checkout experiences, real-time inventory tracking, and targeted marketing messages
- They often incorporate IoT technologies in the form of smart devices and sensors, and artificial intelligence technologies such as computer vision to power cashierless checkout

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1.3. Benefits of IoT

- Real-time resource visibility
- Efficient Homes
- Reduced costs
- Improved operational efficiency and productivity
- More business opportunities
- Data-driven insights for quick decision-making
- End-to-end, remote monitoring and management of assets/resources
- Real-time, predictive and prescriptive insights
- Improve end-customer experience
- Increased mobility and agility

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Hyperloop

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2.1. What is Hyperloop?

- Hyperloop is a mode of ultra-fast mass transportation solution that transports people and cargo through a pod in a vacuum environment
- It was proposed as a concept by Elon Musk
- In 2020, the US-based company “Virgin Hyperloop” tested the Hyperloop system with passengers for the first time

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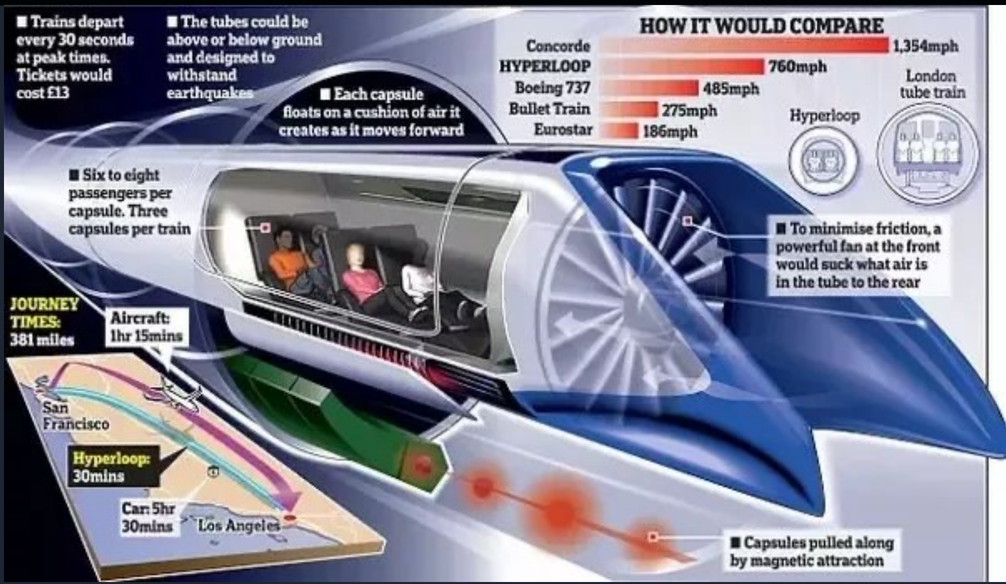
2.2. Working of a Hyperloop Train



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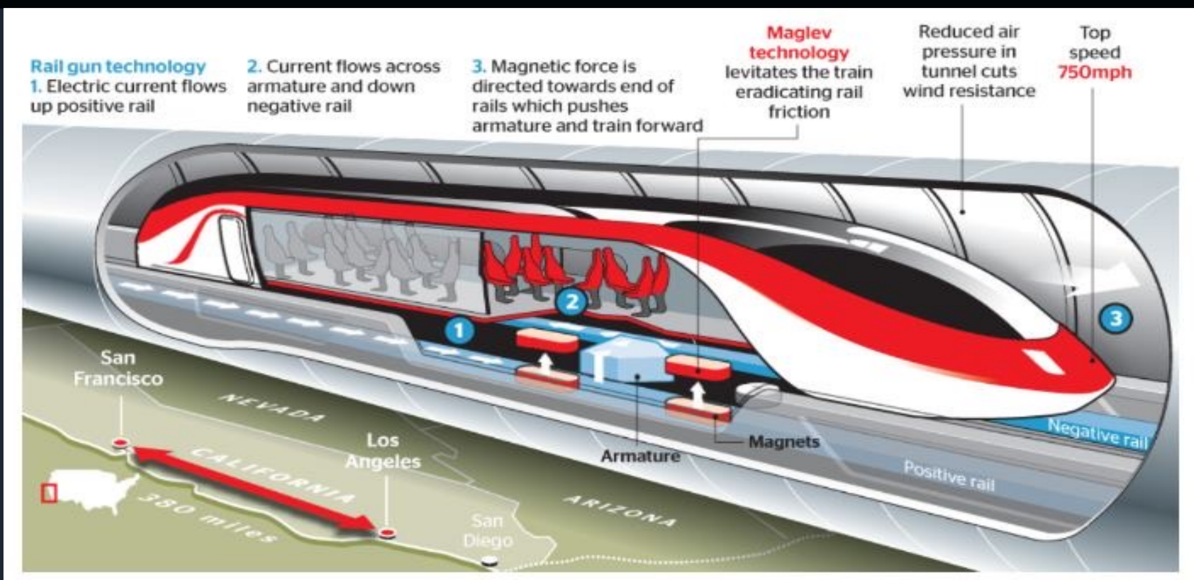

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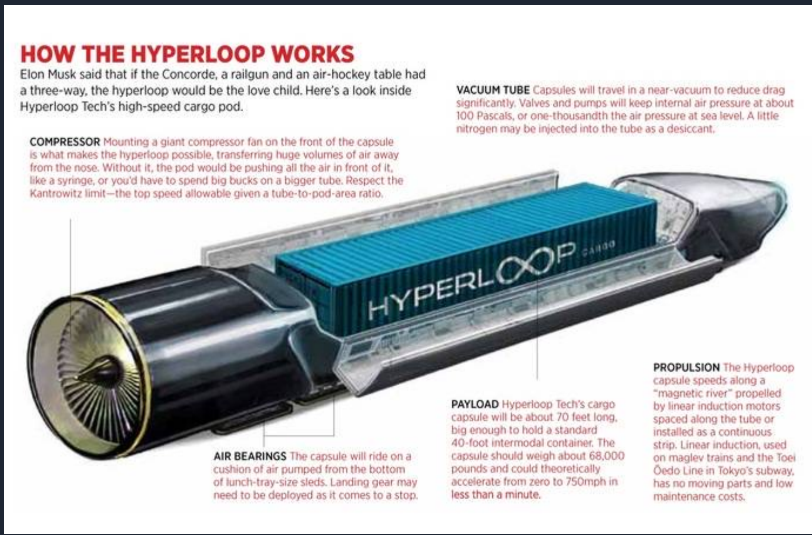

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2.2. Working of a Hyperloop Train

- A hyperloop train is based on the concept of a vactrain, which is a train that travels in a vacuum tube, using magnetic levitation to float above the tracks and reduce friction
- It uses a powerful fan to suck the air out of the tube
- It uses superconducting magnets to create a powerful magnetic field that propels the train forward
- It also uses a linear motor to accelerate and decelerate the train
- The result is a train that can travel at hypersonic speeds, with minimal energy consumption and environmental impact
- A hyperloop train could potentially transport passengers and cargo across continents in minutes, revolutionizing the transportation industry

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2.3. Advantages of Hyperloop

- Speed: The technology aims to propel passenger or cargo pods at speeds of over 1000 km/h
- Lower carbon emissions: The hyperloop offers low-energy long-distance travel, running on electricity and solar energy
- Weatherproof: The hyperloop is less vulnerable to bad weather such as rain, snow, wind, and earthquakes
- Less invasive: It’s easier to add layers of tunnels than a lane to a road

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2.4. Limitations of Hyperloop

- **Costs:** It’s hard to price the construction and infrastructure costs. They will also require regular maintenance.
- **Fire Safety:** While the low-pressure environment prevents fire from breaking out in the tubes, a fire inside a pod is a real threat.
- **Communication system challenges:** The steel tube prevents wireless signals from reaching the pod. Further, due to the high speeds, pods often switch between communication cells, increasing the chance of handover failure, and temporary communication loss.
- **Emergency evacuation:** Evacuating a hyperloop is difficult as the tubes are designed to have a limited number of exits.

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2.5. Hyperloop Projects in India

- In **July 2017, NITI Aayog has approved 6 proposals** of the Ministry of Transport for improving public transport through high-tech mass rapid transportation techs such as hyperloop, metrino, pod taxis, Stadler buses, hybrid buses, and freight railroad.
- In **September 2017, Andhra Pradesh** signed a Memorandum of Understanding (MoU) with Hyperloop Transportation Technologies (HIT) for developing the project. The proposed Hyperloop will cover 35 km distance between **Vijayawada and Amaravati** within 5 minutes.

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2.5. Hyperloop Projects in India

- **Quintrans Hyperloop**: Pune-based startup developing India's first Hyperloop system, aiming for a **cargo-carrying prototype** in 12-14 months, focusing on **cost-effectiveness**.
- **Government Support**: Maharashtra → agreements signed with **Virgin Hyperloop One** for Mumbai-Pune connection.
- **Academic Initiatives**: **IIT Madras** and Avishkar Hyperloop advancing in indigenous systems, prototype testing, and planning **global competitions**.

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2.5. Hyperloop Projects in India

- **Proposed projects in India**
  1. Mumbai-Pune Hyperloop: This project will link central Pune to Mumbai in under 35 minutes.
  2. Amaravati-Vijayawada Hyperloop: A hyperloop transportation system in India was first proposed in Andhra Pradesh state to connect Vijayawada with the state capital Amaravati.
  3. New Delhi-Mumbai Hyperloop
  4. Amritsar-Ludhiana-Chandigarh-Delhi Hyperloop
  5. Bengaluru City to Airport Hyperloop

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2.5. Hyperloop Projects in India

- **Global Competition**: India competes in Hyperloop development with countries like **Saudi Arabia, the US, Canada, Mexico, and the UAE**, leveraging its **economy, young workforce, and engineering skills**.

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Autonomous Vehicles

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3.1. What is an Autonomous Vehicle?

- An autonomous vehicle is one that is able to operate itself in varying degrees and perform necessary functions without any human intervention, through the ability to sense its surroundings and take driving decisions.
- An autonomous vehicle utilizes a fully automated driving system to allow the vehicle to respond to external conditions that a human driver would manage

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3.2. Levels of Autonomous Vehicles

- 0 Level : Car has no control over its operation
- 1st Level : Vehicle's Advanced Driver-Assistance Systems (ADAS) has the ability to support the driver with either steering or accelerating and braking
- 2nd Level : ADAS can oversee steering, accelerating and braking in some conditions
- 3rd Level : Advanced driving systems can perform all parts of the driving task in some conditions, but the human driver is required to be able to regain control when required
- 4th Level : Advanced driving systems perform all driving tasks independently in certain conditions where human attention is not required
- 5th Level : Full automation

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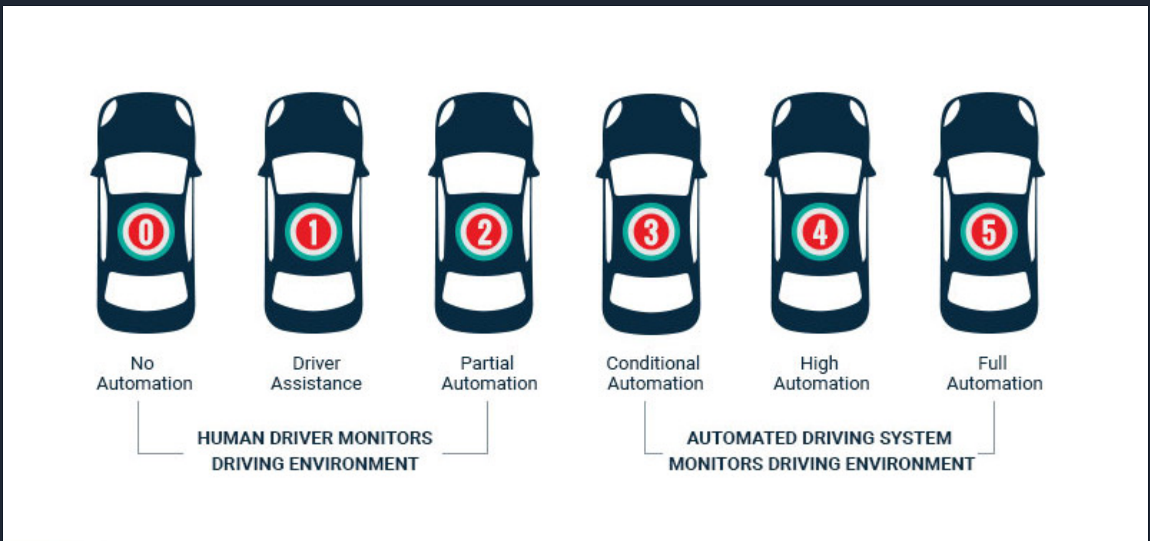

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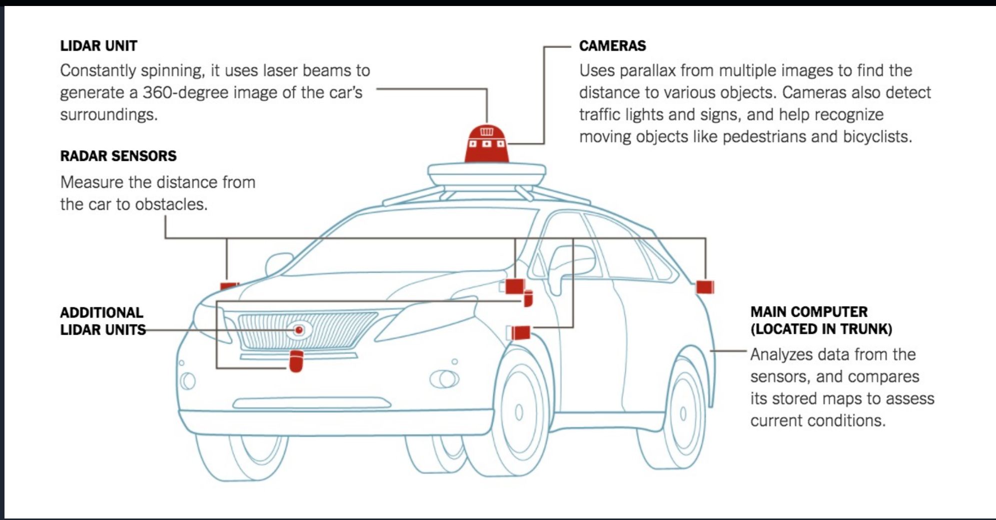
Working of Driverless Cars



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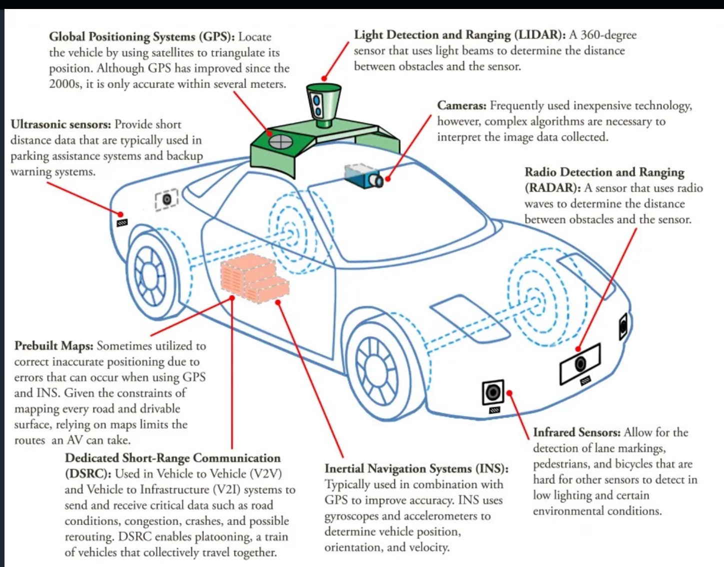

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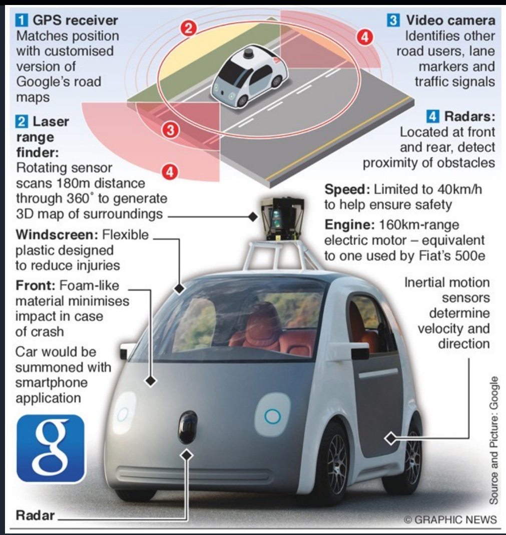

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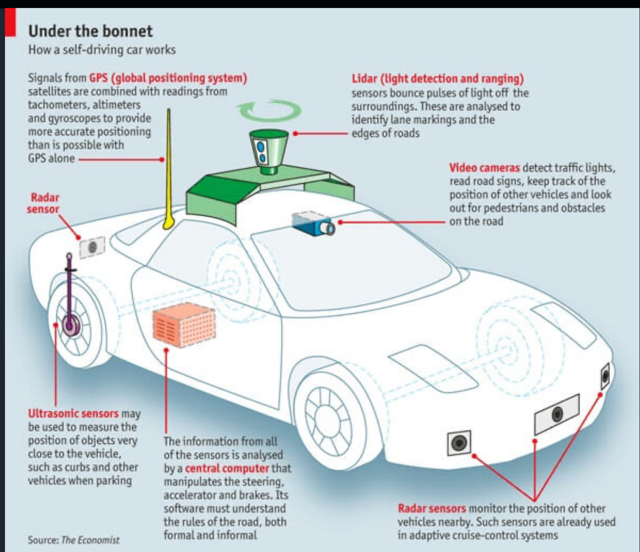

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3.3. Advantages of Autonomous Vehicles

- Decreased Casualties: Vehicle crashes cause many deaths every year, and automated vehicles could potentially decrease the number of casualties as the software used in them is likely to make fewer errors in comparison to humans
- Reduce traffic congestion: A decrease in the number of accidents could also reduce traffic congestion, which is a further potential advantage posed by autonomous vehicles
- Benefit for old and disabled people: People who are not able to drive – due to factors like age and disabilities – could be able to use automated cars as more convenient transport systems
- Less fatigue: Additional advantages that come with an autonomous car are elimination of driving fatigue

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Limitations of Autonomous Vehicles

- Security issues
- High Cost of Vehicles
- Who Will Be Guilty
- Misunderstanding
- Rise In Unemployment
- Weather issues

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3.4. Limitations of Autonomous Vehicles

- Security issues: To communicate and coordinate with one another, automated vehicles must use the same network protocol
- High Cost of Vehicles: Although significant progress has been made in lowering the cost of producing their implements, these reductions are not significant enough to make them a financially viable option for the average family
- Who Will Be Guilty: Who is to blame if a car crashes without a driver: the software designer or the vehicle owner?
- Misunderstanding: Human behavior is complex and unpredictable
- Rise In Unemployment: Another disadvantage of self-driving cars will be increased unemployment in the transportation sector, as many cab drivers will no longer be needed

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UAVs

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4.1. What are Unmanned Aerial Vehicles?

- Unmanned aerial vehicles are aircraft with no on-board crew or passengers
- UAVs are a component of an unmanned aircraft system , which include additionally a ground-based controller and a system of communications with the UAV
- UAV uses aerodynamic forces to provide vehicle lift

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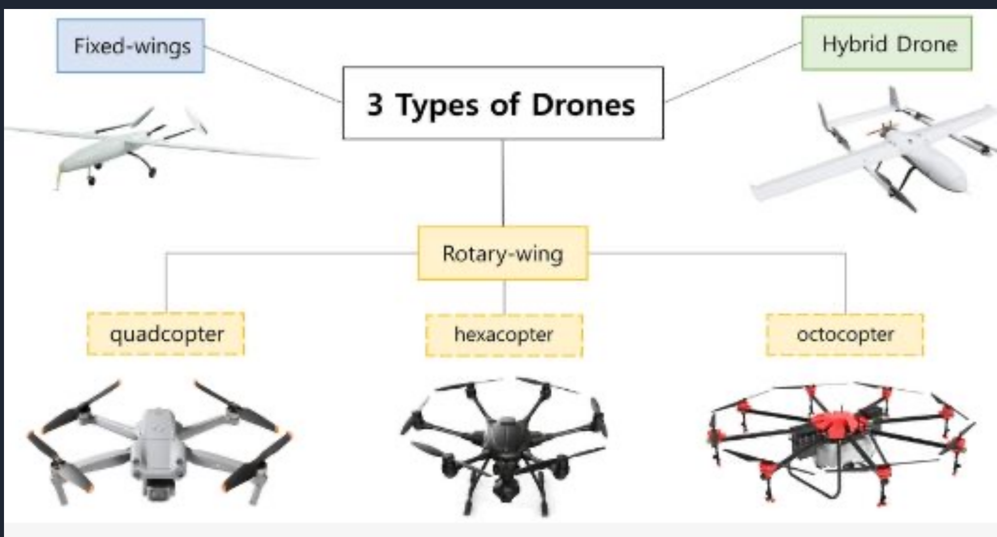

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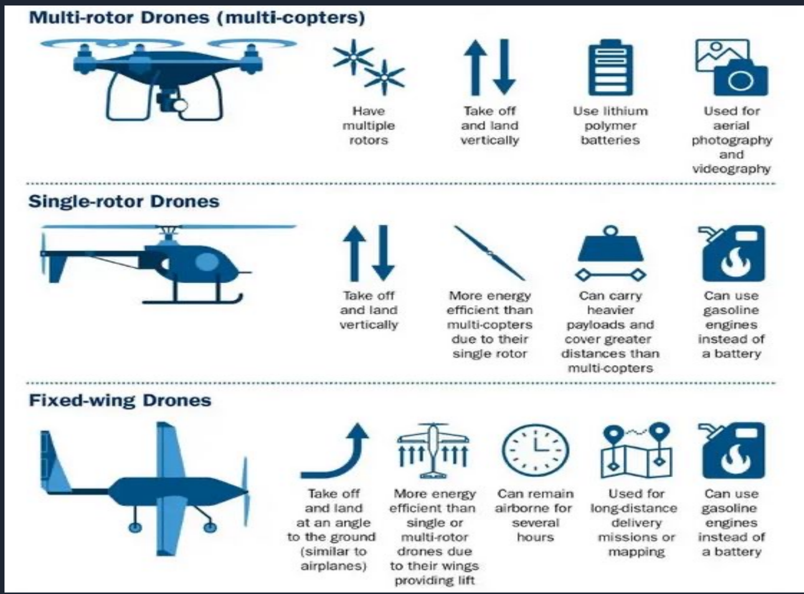

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Types of Drones

- Single-Rotor Drones
  - Basic drones with a single rotor
  - Efficient thrust for longer flight times
  - Stability issues and higher costs
  - Suitable for longer flights
  - Safety risks due to the single rotor design

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- Multi-Rotor Drones
  - Most commonly used drones
  - Known for their stability
  - Used in military reconnaissance and commercial applications
  - Limited in carrying heavy loads or traveling long distances
- Fixed-Wing Drones
  - Resemble airplanes with fixed wings
  - Energy-efficient forward movement
  - Ideal for covering longer distances, mapping large areas, and flying at higher altitudes
  - Not capable of vertical take-off and landing

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- Fixed-Wing Hybrid Drones
  - Hybrid design combining fixed-wing and rotor-based features
  - Suitable for hovering and forward flight
  - Examples include Amazon’s Prime Air delivery drone
- Large Combat Drones
  - Used for military strikes with air-to-surface missiles and laser-guided bombs
  - Operate for extended periods with a range of over 1000 miles
  - Utilized by various countries for military operations

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- Non-Combat Large Drones
  - Designed for reconnaissance and surveillance missions
  - Larger than small commercial drones
  - Used primarily for surveillance purposes
- Target and Decoy Drones
  - Serve as decoys during military operations

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- Other Significant Drone Types
  - Small Drones: Used for recreational purposes
  - Micro Drones: Equipped with micro cameras for intelligence gathering
  - Tactical Drones: Large drones equipped with GPS technology and infrared cameras for surveillance work
  - Reconnaissance Drones: Used for data collection and mapping, linking to satellites via GPS technology

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HAPS, or high-altitude pseudo-satellite vehicles

- HAPS UAV
  - New-generation unmanned aerial vehicle tested in late February 2024
  - Can fly at great heights, about 20 km from ground
  - Runs entirely on solar power
  - Can remain in the air for months on end
  - Belongs to a class of flying objects called HAPS, or high-altitude pseudo-satellite vehicles, or HALE, that is high-altitude long-endurance vehicles
- HAPS Technology
  - Still under development
  - Several countries and companies have developed and flown such vehicles
  - World record for a vehicle of this class is held by the Airbus-manufactured Zephyr, which flew continuously for 64 days

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Why HAPS

- Normal UAVs are mostly battery-powered and cannot remain in the air beyond a few hours
- Satellites can observe much larger areas, but the ones in low-earth orbits are continuously moving with respect to Earth
- Geostationary satellites can keep a constant gaze over one area but are fairly expensive, and once deployed, cannot be repurposed or reoriented
- HAPS are designed to overcome these shortcomings

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Engineering Challenges of HAPS

- Developing an autonomous flying machine fuelled entirely by solar power and capable of remaining in the air for months faces major technological hurdles
- Primary challenge is to generate enough solar power to keep the aircraft flying, the payloads operating, and the batteries charging
- Design-related challenges include the aircraft needing to be extremely lightweight to minimise the power requirement, but it also has to be stable
- Temperatures at the height HAPS fly can drop to -50 degree Celsius or lower
- Air density is just about 7 per cent of what it is at sea level

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India and HAPS

- India is entering the HAPS technology development at a relatively early stage
- Emphasis on promoting research in emerging technologies
- Joining technology development at an early stage results in capacity building, early adoption of technologies, control over patents, business opportunities and spin-off technologies
- India has moved into HAPS technology development at the right time
- Successful test flight showed that India had capabilities similar to some of the other countries trying to develop this technology

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4.2. UAV Application Areas

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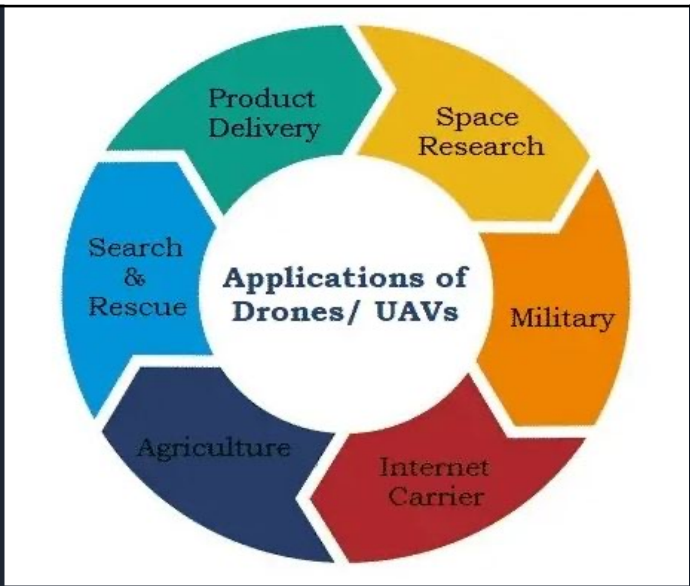

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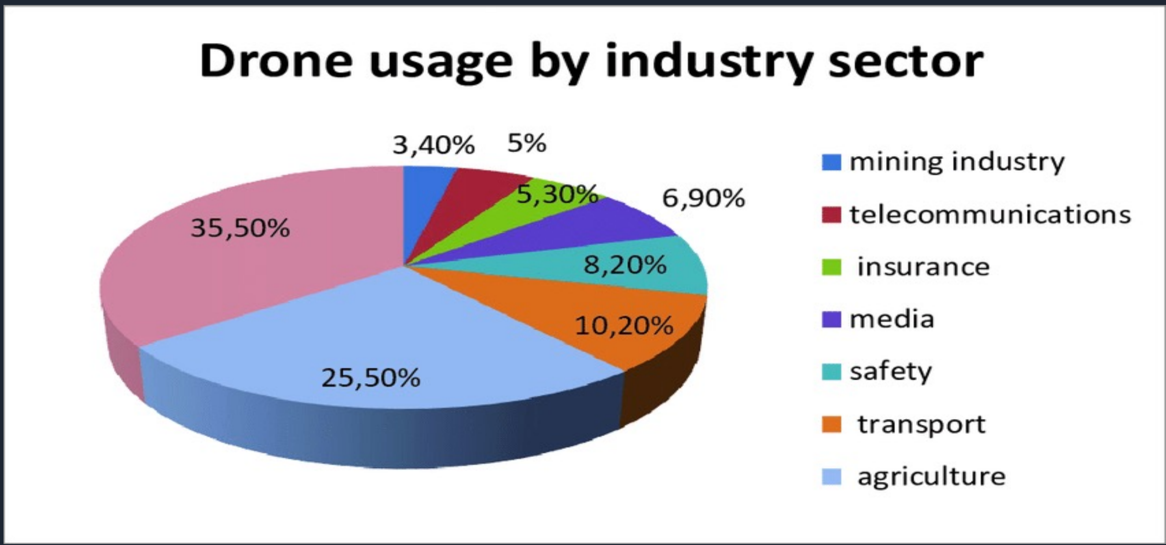

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Disaster Management

- UAVs can visit disaster regions that are unsafe for manned action in the event of a man-made or environmental catastrophe, such as terrorist strikes, tsunamis, and flooding
- UAVs can assist in the collection of data, the need for quick answers, and the navigation of debris
- UAVs equipped with sensors, radars, and high-resolution cameras can aid rescue teams in identifying damage, launching urgent recovery efforts, and dispatching supplies including first-aid manned helicopters and medical kits
- A swarm of drones equipped with firefighting equipment can watch, analyze, and track any region in the event of a wildfire without jeopardizing human life

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Remote Sensing

- The usage of UAVs serves as a link between aerial, ground-based and space-borne remotely sensed data
- Disease diagnosis, water quality inspection, famine monitoring, gas and oil yield estimations, conservation of natural resources, geological calamity survey, topographical survey, woodland mapping, hydrological modeling, and crop management are all possible applications of UAV remotely sensed

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Infrastructure and Construction Inspection

- Tracking the development of the building project from start to finish ensures that the work on the site is of high quality
- It may deliver reports to prospective stakeholders that include pictures, video, and 3D mapping
- UAVs are gaining high popularity for evaluating the global system for mobile communication towers, keeping an eye on gas pipelines, inspecting power cables, and keeping an eye on building projects

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Precision Agriculture

- UAVs could be installed in smart agriculture to obtain specific information through ground sensors , spray pesticides, diagnose illness, schedule irrigation, detect weeds, and monitor and manage crops
- The applicability of UAVs in precision agriculture is a cost-effective and time-saving strategy that can improve agricultural systems' revenue, performance, and agricultural production
- UAVs combined with remote sensing have the potential to revolutionize smart farming

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Real-time Monitoring of Road Traffic

- UAVs can accomplish 100% automation of the transportation industry in road traffic monitoring
- Local police can use drones to gain a clear picture of road accidents or to conduct a large security crackdown on illegal activities along the highway, including car theft
- Some of the other implications include vehicle recognition; raids on suspect cars; pursuing hijackers and armed robbers, or anybody who breaches traffic regulations

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Forest Inspection and Restoration

- UAVs could be used to aid in the accomplishment of re-vegetation activities e.g., site infrastructure, site inspection, restoration plan, seedling supply, site maintenance, and biodiversity survey after restoring interventions
- Existing technology, such as GPS and image sensors, assists UAVs in performing specific tasks, such as fundamental pre-restoration site inspections and monitoring various aspects of biodiversity revival
- UAVs could evaluate any alterations in temperature, forest functions, and ecological composition, hence assisting in the surveillance of replanting
- High-resolution cameras mounted on UAVs can give useful data on natural forests to aid in forest restoration initiatives

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Space Exploration

- UAVs offer tremendous potential to carry our space missions such as study about the moon surface and atmosphere
- Although several planetary exploration techniques are available to perform these missions including rovers, landers, orbiters, flying balloons, flying spacecraft, etc. these techniques are restricted by resolution, limited information and versatility
- Several government bodies and space agencies including National Aeronautics and Space Administration have started using UAVs for other solar bodies
- UAVs offer a wide coverage area as compared to existing orbiters and rovers

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Maritime Communication and Surveillance

- Some UAVs can be installed and remotely operated from small boats, while larger systems rely on onshore architectures to launch and operate
- This technology is complementary to surface and underwater vehicles since it can be easily controlled in the air at some distance and altitude, and thus communicate at a different speed and position
- Due to the enormous benefits of UAVs in maritime communication, UAV-to-ship wireless channels must be developed

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4.3. Challenges and Limitations

- One of the critical challenges is to ensure the security of sensitive data such as position, location etc., from drones or UAVs
- In military operations, UAVs are vulnerable to potential threats of data leakage
- Despite the extensive emergence of UAVs, there is a dire need to devise standardizations from regulatory bodies for the operations of UAVs in geographic areas of different countries
- UAVs can also affect the navigation of commercial airplanes
- Limited transmission range, processing capability and slower speed are also some major concerns in UAVs which need more research contributions and investigations to mature this technology
- Another major concern of privacy arises with the use of UAVs

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4.4. Drone Rules, 2021

- The Ministry of Civil Aviation has notified the Drone Rules, 2021 in August
- These Rules were published under the Aircraft Act, 1934 and replaced the Unmanned Aircraft System Rules
- The Drone Rules 2021 remove the requirement of any certificate for operating or importing drones
- The Rules mandated seeking approval from the Director-General for the transfer of drones to another person in India
- The digital sky platform shall be developed as a business-friendly single-window online system
- No flight permission is required up to 400 feet in green zones and up to 200 feet in the area between 8 and 12 km from the airport perimeter
- No pilot license is required for micro drones , nano drones and R&D organizations

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4.4. Drone Rules, 2021

- Coverage of drones under Drone Rules, 2021 increased from 300 kg to 500 kg

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Drone Rules, 2022

- Drone Rules, 2022 has been notified on 11th February 2022, abolishing the requirement of a drone pilot license
- No remote pilot certificate will be required for operating a drone up to two-kilogram for non-commercial purposes
- The Remote Pilot Certificate issued by a Directorate General of Civil Aviation approved drone school through the single window Digital Sky platform will be sufficient for operating drones in the country
- An individual owning any unmanned aircraft system manufactured in India or imported into India on or before 30th of November, 2021 must make an application to register and obtain a unique identification number and state the required details in form D-2 and the stipulated fee under Rule

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Drone Rules, 2022

- To promote Made in India drones, the import of foreign drones has been prohibited in the country

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Drone Rules, 2023

- The Ministry of Civil Aviation has notified the Drone Rules, 2023 for drone pilots, effective from the 27th of September
- The move aims to liberalize, promote and facilitate drone operations across the country and make India a global drone hub by
- The most significant change in the new rules is the removal of the requirement for drone pilots to possess a passport for obtaining a Remote Pilot Certificate
- Instead, individuals can now use government-issued proof of identity and proof of address, such as Voter ID, Ration Card, or Driving License, to apply for the certificate
- This change is particularly beneficial for aspiring drone pilots in rural areas, especially those in the agricultural sector, who may not have passports

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