Sense and Avoid Systems in Commercial UAVs

Sense and Avoid (SAA), also known as Detect and Avoid (DAA), refers to onboard technologies that enable unmanned aerial vehicles (UAVs) to safely operate in shared airspace. SAA systems allow drones to autonomously fulfill the "see and avoid" obligation of pilots, by detecting potential conflicts and preventing collisions with other aircraft or obstacles. This capability is crucial for integrating UAVs into civilian airspace alongside manned aircraft and obstacles like buildings and power lines. Below we outline the core functions of SAA and the sensors, automation, and regulations that shape its use in commercial drones.

Core Functions: Detection, Assessment, and Avoidance

1. **Detection:** The UAV continuously **senses its environment** to detect other aircraft, vehicles, birds, or obstacles. Using onboard sensors (and sometimes cooperative signals from other aircraft), the drone builds situational awareness by observing its surroundings. This sensing function relies on technologies like cameras, radar, LiDAR, or transponders to **spot potential hazards in real time**.
2. **Assessment:** Once an object is detected, the UAV's flight computer **assesses whether a collision risk exists**. It tracks the object's position and trajectory relative to its own flight path to determine if they will conflict. Advanced algorithms and software calculate if the detected object poses a hazard (a **conflict detection** function). Essentially, the system predicts the likelihood and time to a potential collision, often using artificial intelligence to classify the object and estimate its motion. This decision-making step is critical to decide if avoidance is required.
3. **Avoidance:** If a collision is imminent, the UAV autonomously **executes an evasive maneuver** or adjusts its flight path to maintain safe separation. The avoidance function may involve slowing down, changing altitude, or altering course to steer clear of the object. SAA systems generate a new flight path or maneuver that ensures the drone remains "well clear" of other airspace users. These avoidance maneuvers are then fed to the drone's flight controller, which carries them out automatically to avert the collision.

Sensors and Technologies Enabling SAA

Modern SAA systems fuse data from multiple sensors to reliably detect obstacles. **Sensor fusion** and computer vision combine inputs to cover each sensor's blind spots. Key sensors and technologies include:

- **Cooperative Surveillance (ADS-B & TCAS):** Many drones use cooperative systems like **ADS-B** (Automatic Dependent Surveillance–Broadcast) to receive signals broadcast by manned aircraft. ADS-B transponders periodically transmit an aircraft's identity and GPS position; drones equipped with ADS-B *In* (such as DJI's AirSense feature) can pick up these signals to alert oncoming traffic. Similarly, UAVs can tie into **TCAS** (Traffic

Collision Avoidance System) networks. However, cooperative methods require all aircraft to be equipped and do *not* detect uncooperative objects like birds or buildings.

- **Radar: Radio Detection and Ranging** is an active sensor that emits radio waves and measures reflections to detect objects' distance and relative speed. Radar is widely used in UAV SAA due to its maturity and all-weather capability. It can track multiple objects over a broad field of view, providing robust coverage of the airspace even in rain or fog. The trade-off is that radar has lower resolution than optical sensors, but modern compact radars are light enough for drones and remain effective at collision avoidance duties.
- **LiDAR: Light Detection and Ranging** uses laser pulses to measure the range to objects with high precision. LiDAR can pinpoint obstacle distance and position very accurately, which is valuable for timely collision detection. UAV LiDAR units can detect thin obstacles (like power lines) that radar might miss. The downsides are a narrower field of view and higher cost/complexity, so LiDAR is often used in combination with other sensors to cover a drone's entire 360° environment.
- **Cameras (EO/IR): Electro-optical (EO)** visible light cameras and **infrared (IR)** cameras are passive sensors giving the drone "eyes." Vision-based SAA provides high-resolution imagery to identify and track objects. Cameras are lightweight and inexpensive, making them common on commercial drones. With multiple cameras providing a 360° view, a UAV can visually recognize aircraft or obstacles at long range. However, distance estimation from a single camera requires techniques like stereoscopic vision, and cameras depend on clear weather and lighting conditions. Despite these limits, camera-based SAA paired with onboard AI can distinguish a small airborne object against the sky and is extremely fast in detection.

Many drones use a **combination** of these sensors. For instance, a drone might use ADS-B to detect cooperative aircraft at long range, radar or LiDAR for ranging data, and cameras for object recognition. Data from all sources is fused so that the strengths of one sensor compensate for the weaknesses of another, creating a reliable all-around detection capability.

Role of AI and Automation in SAA

Artificial intelligence (AI) and automation are central to modern sense-and-avoid systems. SAA involves processing large volumes of sensor data in real time and making split-second decisions – tasks well suited for AI-driven algorithms. Computer vision techniques (often powered by machine learning) are used to interpret camera feeds, identify objects (e.g. distinguishing a bird from a manned aircraft), and estimate their trajectory. For example, Iris Automation's **Casia** system is a vision-based DAA solution that uses onboard industrial cameras for full situational awareness, and an embedded AI platform (with machine vision algorithms on hardware like NVIDIA Jetson) to rapidly decide on safe avoidance maneuvers. These intelligent algorithms perform the *detection* and *assessment* steps continuously, far faster than a human could.

Once a collision threat is assessed, the **autopilot or flight controller** takes over for avoidance. The entire loop – detect, assess, avoid – is often fully automated. The UAV's control software can autonomously change course or altitude without waiting for a remote pilot, which is vital when operating beyond visual line of sight. Advanced SAA algorithms (such as the emerging ACAS-Xu collision avoidance logic designed for UAS) ensure that avoidance maneuvers are not only effective but also compliant with aviation right-of-way rules. Automation also provides consistency: it ensures that regardless of the scenario, the drone will reliably execute the correct evasive action as programmed, reducing the chance of human error.

Current Applications and BVLOS Operations

Sense-and-avoid capabilities have moved from theory to practice in various UAV applications. High-end **military and commercial drones** (like General Atomics' MQ-9B SkyGuardian) have integrated certified DAA systems to meet regulatory requirements for flights in national airspace. On the smaller scale, popular consumer and enterprise drones are adopting simpler SAA features. DJI, for instance, equips many of its drones with the AirSense ADS-B receiver to warn pilots of nearby aircraft, improving safety for hobbyists and professionals. Skydio's autonomous drones use 360° camera vision and AI to avoid obstacles like trees and buildings during flight – a local form of sense-and-avoid for safer low-level navigation.

One of the most prominent use cases is **drone delivery and long-range inspections**. Companies like Amazon Prime Air have developed sophisticated SAA systems for their delivery UAVs, allowing them to fly *Beyond Visual Line of Sight* (BVLOS) without human observers watching the drone. Amazon's MK27-2 delivery drones, for example, use a multi-sensor approach to detect static objects (e.g. chimneys, power lines) and moving objects (like other aircraft) in real time. If an obstacle is detected on the horizon, the drone's onboard system will automatically reroute to avoid it, and only proceed with delivery when the landing area is clear of people or hazards. This level of autonomy enables safe operation at greater distances and altitudes, unlocking scalable delivery routes that would be impossible with manual line-of-sight flying.

Regulatory bodies view robust SAA as a linchpin for permitting BVLOS drone operations. Aviation authorities (FAA in the U.S., EASA in Europe, etc.) typically require drone operators to demonstrate an equivalent level of safety to a human pilot's eyes. In the U.S., **FAA Part 107 rules** mandate that operators must always yield right-of-way to other aircraft. To fly BVLOS without a visual observer, operators must obtain a waiver by showing that an adequate detect-and-avoid system is in place. In practice, this means proving the drone can reliably sense other airspace users and stay well clear. The FAA has explicitly stated that to achieve true BVLOS flight, some form of DAA – whether using cooperative means like ADS-B or non-cooperative sensors – **is required** on the drone. Regulators often demand test data and fail-safe plans (e.g. what happens if the SAA system fails) as part of the waiver process.

There have been encouraging advances: for example, Iris Automation's Casia system and others have been used in pilot programs that earned FAA waivers for long-range industrial inspections without visual observers. Similarly, regulatory pilot programs (like the FAA BEYOND initiative) are actively evaluating how ground-based or onboard SAA solutions can enable routine BVLOS flights for tasks such as infrastructure inspection, agriculture, and emergency response. Worldwide, authorities are updating standards – from RTCA DO-365/366 in the U.S. to emerging Eurocae standards – to formalize SAA performance requirements for UAVs.

In summary, sense-and-avoid technology provides the **detection, assessment, and avoidance** capabilities that let UAVs safely share the skies with other aircraft. By using a suite of sensors

(ADS-B, radar, LiDAR, cameras) and intelligent automation, SAA systems give drones an autonomous collision avoidance skill equivalent to a pilot's eyes and reflexes. This not only prevents accidents in mixed airspace but is a gateway to advanced operations like BVLOS, where drones can fly longer distances and beyond the operator's sight. As SAA technology continues to mature – bolstered by AI improvements and regulatory acceptance – we can expect UAVs to integrate even more seamlessly into the national airspace for a variety of commercial applications, all while maintaining the highest safety standards.