INFLUENCE OF AUTOMATION OF AIRSPACE ACTIVITIES ON AIR TRAFFIC SAFETY

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Abstract: *The Traffic Avoidance and Collision Alert System is a system that reduces the risk of airplane crashes in the air. The system operates independently of the Air Traffic Service and has the role of informing and recommending maneuvers when approaching another aircraft. It monitors airspace around an aircraft for other aircraft equipped with an active transponder independent of air traffic control, and alerts pilots to the presence of other transponder-equipped aircraft that may present an air collision hazard.*

Keywords: *flight safety, TCAS, UAV, sensors*

Acronyms

TCAS	Traffic Avoidance and Collision Avoidance System	TA	Traffic Advisory
GCS	Ground Control System/Station	RA	Resolution Advisory
ADS-B	Automatic Dependent Surveillance-Broadcast	RPA	Remotely Piloted Aircraft

1.THEORETICAL CONSIDERATIONS

Increasing flight safety is based on the automation of the flight with the modernization of the instrument instruments and their correlation with a secondary radar-based system that allows the determination of the future positions of the aircraft, Fig.1.

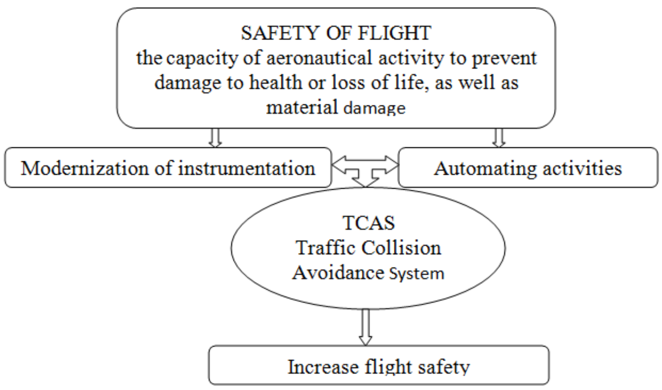

FIG. 1. A flight safety chart

The problem of detecting and avoiding fixed and mobile obstacles involves two distinct approaches: avoiding increased air traffic and avoiding collisions [1].

These aspects involve the use of in-flight technology technologies with acquisition, integration, processing and execution functions. The Traffic Avoidance and Collision Avoidance System (TCAS) is a system that reduces the risk of aircraft crashing in the air [2, 3].

TCAS operates independently from the Air Traffic Service and has the role of informing and recommending crew maneuvers in the event of another airline approaching. It should be noted that the system can not provide any protection against an aircraft that does not have an integrated transponder. After the presented models the TCAS has the components, (Fig.2).

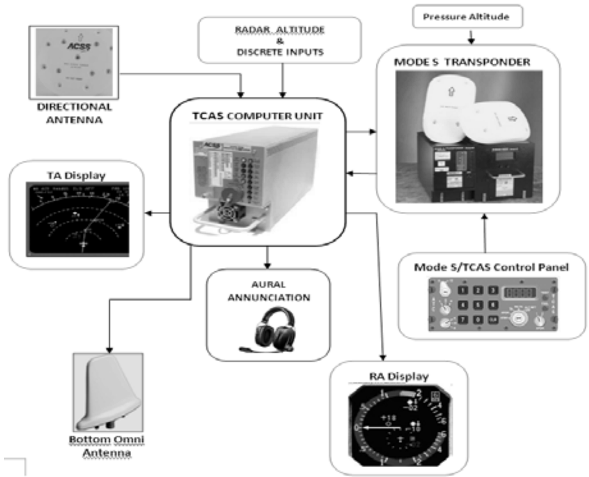

FIG.2. Simplified block scheme of the TCAS system [1].

To determine the distance and altitude, the air vectors identifies itself in a Cartesian coordinate system.

$$(D_n)_t=\left[(D_n)_{x,t};(D_n)_{y,t};(D)_{a,t}\right]^T \tag{1}$$

3D position equation for the airship n and

$$(J_n)_t=\left[(J_n)_{x,t};(J_n)_{y,t};(J_n)_{a,t}\right]^T \tag{2}$$

The 3D express of the speeds, where *x*, *y* represent the horizontal system of the axes and a represents the altitude.

The notion of perpendicularity of two air vectors in the plane.

Two functions α_1 and α_2, defined on an interval (u,v) into r are said to be orthogonal if :

$$\int_u^v \alpha 1(x) \bullet \alpha_2(x)\,dx = 0,\ \alpha_1 \neq \alpha_2 \tag{3}$$

$$\int_u^v \alpha 1(x) \bullet \alpha_2(x)\,dx \neq 0,\ \alpha_1 = \alpha_2 \tag{3'}$$

A set of real, valued functions – $\{\alpha_1(x), \alpha_2(x) \ldots \alpha_n(x)\}$ is said to be orthonormal if:

$$\int_u^v \alpha_m(x) \bullet \alpha_n(x)\,dx = 0,\ m \neq n \tag{4}$$

$$\int_u^v \alpha_m(x) \bullet \alpha_n(x)\,dx \neq 0,\ m = n \tag{4'}$$

We have two types of alerts:

Traffic Advisory (TA), which is designed to assist the pilot in identifying the intrusive aircraft, and in announcing it to be ready for a potential Resolution Advisory (RA). Resolution Advisory (RA), which are maneuvers recommended to the pilot. When the intruder is also equipped with a warning system, both warning systems coordinate their RAs via the transponder Mode S data link to select complementary solutions, (fig.3), [2, 3, 4].

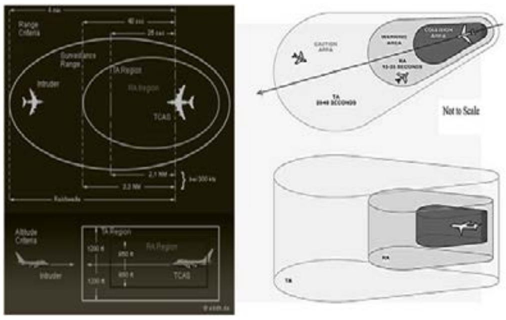

FIG.3. Protection zones between 5,000 and 10,000 feet [3, 4].

We have a fairly rapid growth lately, regarding the use of aerial vectors without flying on board by human factor (UAV). At present, UAVs are equipped with sens and avoid systems for detecting and resolving air traffic conflicts, see figure 4, [4, 5].

FIG.4. UAV with sense and avoid detection system, [6, 7]

For the speed and accuracy of the detection process, these systems are equipped with a series of sensors that can retrieve information from both the proximity of the air vector and the area of interest, such as minimum values for: EO sensors (Opto Electronics) with 5 -8 miles; radar at 5 miles; ADS-B (Air Data System) for air traffic surveillance over a 15-mile radius, see Figure 5, [6].

The conflict resolution procedure includes both maneuvers of command and control from the GCS (Ground Control System) initiated by the human operator (based on maneuvers indicated by the system) and on automatic emergency mode when the direct link has interruptions or delays.

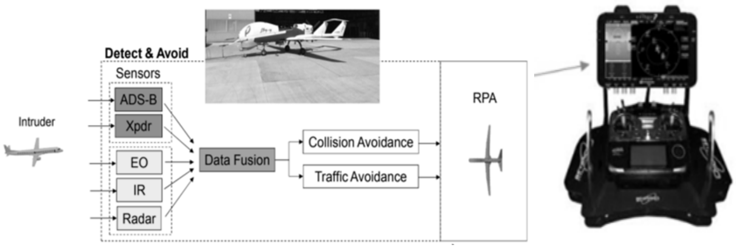

FIG.5. Sense and avoid system operating diagram [7].

2. AVOIDANCE SENSOR SYSTEM

Radar is a sensor used to detect aircraft; it can be a reasonable choice for detecting intruders [10, 11] with the ability to detect all objects. Although new technologies have caused radar size reduction, gauge, mass and power consumption constraints require a number of hardware performance restrictions that lead to significant compromises on antenna precision and field of view available, so this type of detection is suitable for UAS with dimensions similar to those piloted, [12].

Optical sensors (EO) can be used on UASs, they do not require cooperative communication from intruder aircraft, and however the tests have revealed a low detection accuracy (bad weather conditions) that does not provide time for avoidance manoeuvres speed, [13].

IR sensors have the advantage of night-time use but, as with EO sensors, the level of detection is compromised by signal degradation due to weather conditions and LIDAR sensors provide accurate system size data that does not offer the ability to use on small UAVs.

Automatic Dependent Surveillance-Broadcast (ADS-B) is a co-operation sensor that can be an option for small UASs, the information of this system is not affected by weather conditions and the on-directional antennas used have low power requirements. The disadvantage of ADS-B is dependence on the degree of airspace GPS coverage (compromised information in valleys and urban areas), see Figure 6.

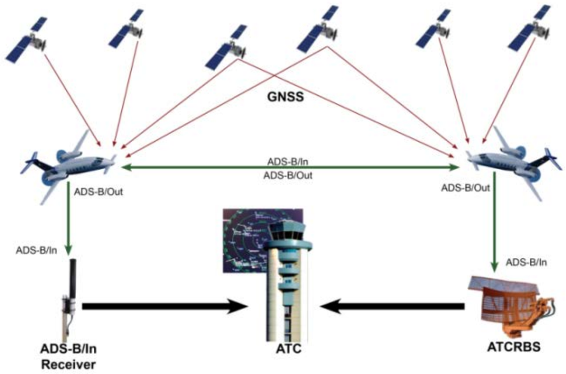

FIG.6. ADS-B transmission, [14]

A series of ADS-B-based collision avoidance studies have demonstrated its capacity to transmit up to 20nm to small-scale, commercial-grade systems [15, 16, 17].

TCAS and ACAS X are aircraft collision avoidance systems based on secondary surveillance radar transponders to provide proximity traffic pilot information and potential conflicts by querying aircraft equipped with transponders (aircraft identification and altitude data).

3.COLLISION AVOIDANCE SYSTEM

Our proposal is that: the air vector equipped with such a system monitors the air traffic within the sensing range of the sensors in order to prevent collisions, so that in order to have time for the avoidance process a threshold of avoidance is defined, the avoidance process contains a series of actions that allow acquisition of surveillance data, estimation of current and future status, detection of possible risks and finding an optimal avoidance maneuver, see Figure 6, [8].

Traffic detection and tracking involves activating detection, tracking, monitoring and fusing functions and verifying data from sensors.

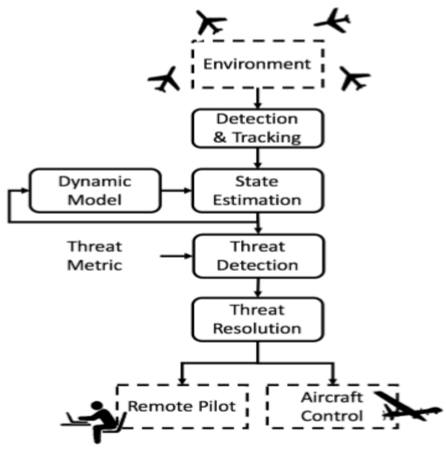

FIG.6. Steps of operation of the collision avoidance system

Current status evaluation consists of a process of estimating a set of variables describing the current situation in terms of the presence of an intruder or group of intruders in their own volume of maneuver. For example, TCAS is based on an estimate of time to the closest approach point and relative altitude up to vector to threat.

Future status evaluation allows estimation of own kinetics and intruder by response patterns that include optimal avoidance trajectories.

The threat assessment may depend on the value of the vector-intrusive distance, the maneuvering speed, the time to the closest approach point, and the time until the collision volume is violated (horizontal or horizontal and vertical values can be considered), so assessing the threat of and TCAS includes a series of actions in time and space under multiple conditions that must be met before an intruder is declared a threat. Threat detection includes assigned processes for each monitored aircraft that reveals a collision risk estimate based on present status, design status, and collision avoidance threshold.

Threat solving is carried out after an intruder has been flagged as a threat to threat resolution. It calculates an optimal avoidance maneuver that can affect your own speed, horizontal direction, and vertical direction. Avoidance can be materialized by a large avoidance maneuver or even a complete trajectory.

CONCLUSIONS

In the UAS field, it is desirable to implement non-transponder traffic detection methods based on a single sensor or sensor network with a series of limitations determined by relative data and varying degrees of accuracy.

The sensor systems contain design elements that compete at the overall performance level, determined by optimal sensor selection or by creating a series of sensors that can cover the control volumes in the vicinity of the aircraft.

The situation of sensor systems involves fusion data from the same type of sensors or from different sensors. Merged data is processed using fusion algorithms that cover detection and undetectability in the presence of single targets or multiple targets.

The use of TCAS warning systems does not alter the responsibilities of pilots, UAV ground operators, air traffic controllers for the safe operation of aircraft.

A technological challenge is the optimal use of sensors according to airframe characteristics and performances, the correct alignment of the sensors is made according to the airplane-related information acquisition resolution so that it has an optimal area of data sampling.

The system's sense and avoid system operation chart, which we propose, eliminates uncertainty areas and offers viable protection solutions.

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