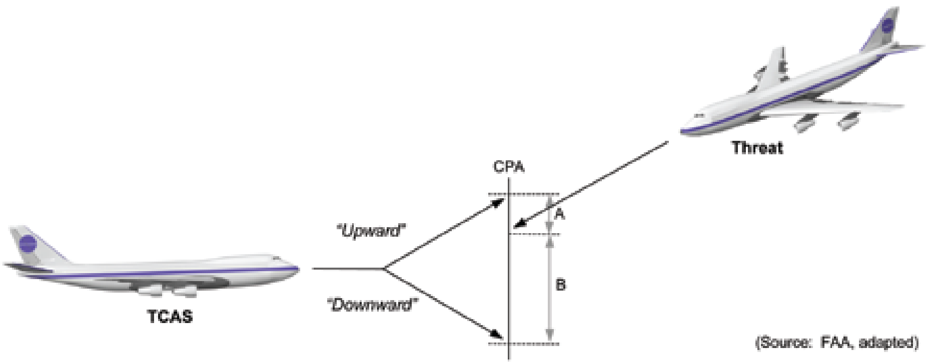
Automated Collision Avoidance Systems

CTAS provides automation tools for air traffic controllers to use in planning and controlling arrival traffic. It includes methods for achieving acceptable aircraft sequencing and separation as well as improved airport capacity. This photo shows CTAS' Traffic Management Advisor (TMA) in operation in the Denver airport facility. FAA operates TMA at all of its centers and says it has fundamentally changed National Airspace System (NAS) operations.

Control theory to date has achieved tremendous success in the analysis and synthesis of automatic guidance systems in aerospace. Aircraft and spacecraft autopilots are elegant schemes that employ a hierarchical structure. For example, pilots can fly today's commercial jets by programming into their onboard flight management system a set of waypoints describing the desired flight path over time. These waypoints are automatically translated into a sequence of guidance commands for the aircraft, and these in turn into the actuator commands for the aircraft throttle and control surfaces. In recent years, this success of guiding single aircraft has been extended to the relative control of two or more vehicles in the design of airborne collision avoidance systems and tactical separation assurance tools in air traffic control (ATC). Although many of these systems have been developed as prototypes within the research community, several have been tested and are now operational in NASA's Center TRACON Automation System (CTAS).

Collision avoidance and separation assurance tools can be classified into three groups according to the time horizons over which they operate. The Traffic Alert and Collision Avoidance System (TCAS) operates over a time horizon of less than a minute and is called an immediate collision avoidance scheme. New automated methods for both ground-based and airborne collision avoidance, known as midterm collision avoidance schemes, are being designed for a time horizon of a few minutes. Tactical air traffic control schemes provide separation to aircraft and generally operate over a longer time horizon of about 30 minutes. These are denoted as separation assurance schemes. Separation assurance is an air traffic control responsibility for aircraft to maintain a separation of 5 nautical miles (lateral) and 1000 feet (vertical).

In the TCAS protocol, when an intruder aircraft is declared to be a "Threat" to the "TCAS" aircraft, the Resolution Advisory (direction and rate) is designed, based on range and altitude tracks, to give the most separation at the closest point of approach (CPA).



Today, TCAS is installed on all commercial aircraft with at least 30 passenger seats operating in the U.S. It receives and displays bearing and relative altitude information about all other aircraft within a 40-mile radius and provides alerts and its Resolution Advisory with respect to the aircraft that poses the greatest potential threat.

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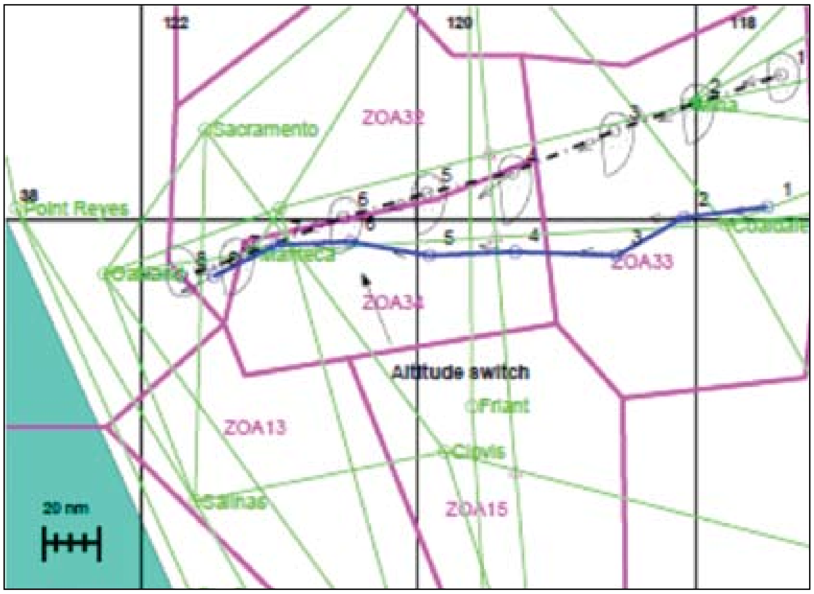
For the ground-based system, automated tools such as the midterm collision avoidance scheme called Tactical Separation Assisted Flight Environment (TSAFE) are being developed to provide conflict alert and resolution advisories to the air traffic controller or to the pilot directly via data link. Separation assurance functionality, operating over a time horizon of about 30 minutes, consists of a tactical ATC function that handles the coordination of traffic in a local area (for example, the maneuvers for efficiently spacing and sequencing traffic to a metering fix or to a runway). Fast optimization schemes for routing aircraft in the presence of metering and capacity constraints have also been developed with the goals of providing advisories or automated functionality to tactical-level control.

The horizontal resolution method used in TSAFE generates a set of maneuvers to ensure achieving the specified minimum separation between aircraft. These maneuvers consist of a turn to a specified heading followed by straight-line flight. TSAFE also uses vertical maneuvers when required. The solution is generated analytically and is thus computationally efficient and suitable for real-time implementations. The resolutions could be implemented by the air traffic controller or could be uplinked directly to the aircraft using existing data link technologies.

The figure on the left shows a highlight of a predicted conflict between two aircraft, with the red lines indicating the flight paths that lead to a predicted loss of separation in 9 minutes from the current positions of the two aircraft in conflict. The resolution trajectory is generated automatically and is shown in yellow for one of the two conflict aircraft. The small white, blue and green diamonds show the locations of neighboring traffic that was accounted for in the generation of the resolution trajectory.

Methods for analyzing the safety of collision avoidance systems have also been developed. One such method uses reachable set technology to determine the unsafe configurations of one aircraft with respect to another. As an aircraft approaches the boundary of the unsafe region, corrective action must be applied. This control action is computed automatically as part of the reachable set calculation. The figure on the left shows two aircraft arriving at Oakland airport. At the position labeled 6, both aircraft are inside the reachable set, indicating an unsafe configuration (loss of separation in 3 minutes). In the actual scenario, the controller performed an altitude change to resolve the conflict.



For further information: http://www.aviationsystemsdivision.arc.nasa.gov/index.shtml; Introduction to TCAS II, Version 7, U.S. Dept. of Transportation, FAA, November 2000; Erzberger and Heere, DOI:10.1234/09544100JAERO546; Mitchell, Bayen, and Tomlin, DOI:10.1109/TAC.2005.851439.