Air traffic control

Air Traffic Control Towers (ATCTs) at Schiphol Airport

Air Traffic Control (**ATC**) is a service provided by ground based controllers who direct aircraft on the ground and in the air to ensure safe, orderly and expeditious traffic flow. In the United States, the Federal Aviation Administration (FAA) provides this service to all aircraft in the National Airspace System (NAS). The FAA is responsible for all aspects of U.S. Air Traffic Control including hiring and training controllers, who are employees of the Federal Government.

In many countries, ATC services are provided throughout the majority of airspace, and its services are available to all users (private, military, and commercial). Such airspace is called "controlled airspace" in contrast to "uncontrolled airspace." By law, pilots must follow the instructions of air traffic controllers when they are in controlled airspace, however, the pilot always retains the final responsibility for the aircraft.

Air traffic control services can be divided into two major subspecialties, **terminal control** and **en-route control**.

Terminal control includes the control of traffic (aircraft and vehicles) on the airport proper and airborne aircraft within the immediate airport environment. Generally, this is approximately a 30 to 50 nautical mile (56 to 93 km) radius of the airport, from the surface to about 10,000 ft (about 3,050 m). Terminal controllers work in facilities called control towers and Terminal Radar Approach Control (TRACON). At some locations, staffs are shared between Tower Control and the TRACON, while at others the tower and the TRACON are completely separate entities. For example, Philadelphia International Airport is served by a combined ("up/down") facility, while Chicago's O'Hare Airport is served by a control tower at the airport, and a remote TRACON located at Elgin, Illinois.

En-route controllers control the traffic between the terminals. They can also control traffic in and out of airports where the traffic volume does not warrant the establishment of a terminal ATC operation. En-route controllers work at facilities called Area Control Centers or Air Route Traffic Control Centers.

Terminal Control


Controllers survey the field at Misawa Air Base, Japan.

The primary method of controlling the immediate airport environment is visual observation from the control tower. The tower is a tall, windowed structure located on the airport grounds. Tower controllers are responsible for the separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself, and aircraft in the air near the airport, generally 2 to 5 nautical miles (4 to 9 km) depending on the airport procedures.

Radar displays are also available to controllers at some airports. Controllers may use a radar system called Secondary Surveillance Radar also known as Airport Surveillance Radar for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, heading, and other information described in local procedures.

The areas of responsibility for tower controllers fall into three general operational disciplines; **Ground Control**, **Local Control**, and **Clearance Delivery**. While each tower's procedures will vary and while there may be multiple teams in larger towers that control multiple runways, the following provides a general concept of the delegation of responsibilities within the tower environment.

Ground Control

Ground Control is responsible for the airport "movement" areas, or areas not released to the airlines or other users. This generally includes all taxiways, holding areas, and some transitional aprons or intersections where aircraft arrive having vacated the runway and departure gates. Exact areas and control responsibilities are clearly defined in local documents and agreements at each airport. Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from the ground controller. This is normally done via VHF radio, but there may be special cases where other processes are used. Most aircraft and airside vehicles have radios. Aircraft or vehicles without radios will communicate with the tower via aviation light signals or will be led by vehicles with radios. People working on the airport surface normally have a communications link through which they can reach or be reached by ground control, commonly either by handheld radio or even cell phone. Ground control is vital to the smooth operation of the airport because this position might constrain the order in which the aircraft will be sequenced to depart, which can affect the safety and efficiency of the airport's operation.

Some busier airports have systems, such as the ASDE-X, designed to display aircraft and vehicles on the ground. These are used by the ground controller as an additional tool to control ground traffic, particularly at night or in poor visibility. There are a wide range of capabilities on these systems as they are being modernized. Older systems will display a map of the airport and the target. Newer systems include the capability to display higher quality mapping, radar target, data blocks, and safety alerts.

Local Control

Local Control (most often referred to as the generic "Tower" control, although Tower control can also refer to a combination of the local, ground and clearance delivery positions) is responsible for the active runway surfaces. Local control clears aircraft for take off or landing and ensures the runway is clear for these aircraft. To accomplish this, local control controllers are normally given 2 to 5 nautical miles (4 to 9 km) of airspace around the airport, allowing them to give the clearances necessary for airport safety. If the local controller detects any unsafe condition, a landing aircraft will be told to "go around" and will be re-sequenced into the landing pattern by the TRACON controller.

Within the tower, a highly disciplined communications process between local and ground control is an absolute necessity. Ground control must request and gain approval from local control to cross any runway with any aircraft or vehicle. Likewise, local control must ensure ground control is aware of any operations that impact the taxiways and must work with the arrival radar controllers to ensure "holes" in the arrival traffic are created (where necessary) to allow taxiing traffic to cross runways and to allow departures aircraft to take off. Crew resource management procedures are often used to ensure this communication process is efficient and clear.

Clearance Delivery

Clearance delivery is the position that coordinates with the national command center and the en-route center to obtain releases for aircraft. Under normal conditions, this is more or less automatic. When weather or extremely high demand for a certain airport become a factor, there may be ground "stops" (or delays), or re-routes to ensure the system does not get overloaded. The primary responsibility of the clearance delivery position is to ensure that the aircraft have the proper route and release time. This information is also coordinated with the en-route center and the ground controller in order to ensure the aircraft reaches the runway in time to meet the release time provided by the command center.

TRACON Control

Inside the Potomac TRACON

Larger airports have a radar control facility that is associated with the control tower. In the U.S., this is referred to as a TRACON or **T**erminal **R**adar **A**pproach **CON**trol facility (sometimes referred to as Approach or Departure control). While every airport varies, TRACONs usually control traffic in a 30 to 50 nautical mile (56 to 93 km) radius from the airport and from the surface up to 10,000 feet. The actual airspace boundaries and altitudes assigned to a TRACON are based on factors such as traffic flows and terrain, and vary widely from airport to airport.

TRACONs are responsible for providing all ATC services within their airspace. Traffic flow is broadly divided into departures, arrivals, overflights, and VFR aircraft. As aircraft move in and out of the TRACON airspace, they are handed off to the next appropriate control facility (a control tower, an en-route control facility, or a bordering TRACON). TRACON is responsible for ensuring that aircraft are at an appropriate altitude when they are handed off, and that aircraft arrive at a slow enough rate to permit safe landing times.

Not all airports have a TRACON available. In this case, the en-route center will coordinate directly with the tower and provide this type of service where radar coverage permits. Under these circumstances, the separation minimums are usually increased.

En-route Control


Controllers at work at the Jacksonville Air Route Traffic Control Center.

ATC provides services to aircraft in flight between airports as well. The level of service is dependant on the type of flight the aircraft falls under (IFR or VFR), the type of airspace the aircraft is in and the services requested by the pilots.

En-route Air Traffic Controllers issue clearances and instructions for airborne aircraft, and pilots are required to comply with these instructions. Controllers adhere to a set of separation standards that define the minimum distance allowed between aircraft. These distances vary depending on the equipment and procedures used in providing ATC services.

Pilots fly under one of two sets of rules for separation; Visual flight rules (VFR) or Instrument flight rules (IFR). Air Traffic Controllers have different responsibilities to aircraft operating under the different sets of rules.

Visual flight rules (VFR)

Pilots flying under VFR assume responsibility for their separation from all other aircraft and are not assigned routes or altitudes by ATC (outside of positive control airspace). They fly on their own using a "see and be seen" separation criteria. In busier controlled airspace, VFR aircraft are required to have a transponder. This amplifies the radar signal (as well broadcasting altitude level and a transponder code), and is used to allow controllers to warn IFR aircraft of any potential conflict. Governing agencies establish strict VFR "weather minima" for visibility, distance from clouds, and altitude to ensure that VFR pilots can see far enough.

VFR pilots can request, and ATC can elect to provide "VFR Advisory Services," if the controllers' workload permits. This is also referred to as "Flight following." Under this environment, the controllers will radar identify the VFR aircraft and provide traffic information and weather advisory services for the VFR pilot. Controllers do not provide any instructions concerning direction of flight, altitude, or speed to the VFR pilot receiving advisory services, and they do not provide separation services. This is an optional service and may be discontinued by ATC or the pilot at any time.

Instrument Flight Rules (IFR)

Pilots flying under IFR must file a flight plan with ATC and accept any revisions ATC requests to their route or altitude. In return, controllers will ensure that pilots flying IFR are separated from all other IFR aircraft and terrain by the appropriate minimum separation. The IFR pilot, however, must maintain a close watch for VFR aircraft since ATC has no control over these aircraft. For this reason, VFR aircraft are restricted to altitudes below 18,000 ft and must have an operating transponder in congested airspace. Once IFR aircraft are above 18,000 ft (Flight Level 180) the aircraft is considered in "Positive Control Airspace," meaning that ATC controls all aircraft in the airspace.

General Characteristics

En-route air traffic controllers work in facilities called Area Control Centers, each of which is commonly referred to as a "Center". The United States uses the equivalent term Air Route Traffic Control Center (ARTCC). Each center is responsible for many thousands of square miles of airspace (known as a Flight Information Region) and for the airports within that airspace. Centers control IFR aircraft from the time the aircraft departs an airport or leaves the TRACON's airspace or until the aircraft approaches the airspace controlled by a TRACON or if the airport does not have a TRACON, until the aircraft lands. Centers may also "pick up" aircraft that are airborne and integrate them into the IFR system. These aircraft must, however, remain VFR until the Center provides a clearance.

Center controllers are responsible for climbing the aircraft to their requested altitude while, at the same time, ensuring that the aircraft is properly separated from all other aircraft in the immediate area. Additionally, the aircraft must be placed in a flow consistent with the aircraft's route of flight. This effort is complicated by cross traffic, severe weather, special missions that require large airspace allocations, and traffic density.

As an aircraft reaches the boundary of a Center's control area it is "handed off" to the next Area Control Center. This "hand-off" process is simply a transfer of identification between controllers so that air traffic control services can be provided in a seamless manner. Once the hand-off is complete, the aircraft is given a frequency change and begins talking to the next controller. This process continues until the aircraft is handed off to a TRACON.

Radar Coverage

Since centers control a large airspace area, they will typically use long range radar that has the capability to see aircraft within 200 nautical miles (370 km) of the radar antenna. They may also use TRACON radar data to control when it provides a better "picture" of the traffic or when it can fill in a portion of the area not covered by the long range radar.

In the U.S. system, over 90% of the U.S. airspace is covered by radar and often by multiple radar systems. A center may require numerous radar systems to cover the airspace assigned to them. This results in a large amount of data being available to the controller. To address this, automation systems have been designed that consolidate the radar data for the controller. This consolidation includes eliminating duplicate radar returns, ensuring the best radar for each geographical area is providing the data, and displaying the data in an effective format.

Centers also exercise control over traffic travelling over the world's ocean areas. These areas are also FIRs. Due to the fact that there are no radar systems available for oceanic control, oceanic controllers provide ATC services using "non-radar" procedures. These procedures use aircraft position reports, time, altitude, distance, and speed to ensure separation. Controllers record information on flight progress strips and in specially developed oceanic computer systems as aircraft report positions. This process requires that aircraft be separated by greater distances, which reduces the overall capacity for any given route.

Some Air Navigation Service Providers (e.g Airservices Australia, Alaska Center, etc.) are implementing Automatic Dependant Surveillance - Broadcast (ADS-B) as part of their surveillance capability. This new technology reverses the radar concept. Instead of radar "finding" a target by interrogating the transponder, ADS transmits the aircraft's position several times a second. ADS also has other modes such as the "contract" mode where the aircraft reports a position based on a pre-determined time interval. This is significant because it can be used where it is not possible to locate the infrastructure for a radar system (e.g. over water). Computerised radar displays are now being designed to accept ADS inputs as part of the display. As this technology develops, oceanic ATC procedures will be modernised to take advantage of the benefits this technology provides.

Problems

Traffic

The day-to-day problems faced by the air traffic control system are primarily related to the volume of air traffic demand placed on the system, and weather. Several factors dictate the amount of traffic that can land at an airport in a given amount of time. Each landing aircraft must touch down, slow, and exit the runway before the next crosses the end of the runway. This process requires between one and up to four minutes for each aircraft. Allowing for departures between arrivals, each runway can thus handle about 30 arrivals per hour. A typical large airport with two arrival runways can thus handle about 60 arrivals per hour in good weather. Problems begin when airlines schedule more arrivals into an airport than can be physically handled, or when delays elsewhere cause groups of aircraft that would otherwise be separated in time to arrive simultaneously. Aircraft must then be delayed in the air by holding over specified locations until they may be safely sequenced to the runway. Up until the 1990s, holding was a common occurrence at airports. Advances in computers now allow controllers to predict transit times and sequence planes hours in advance. Thus, planes may be delayed before they even take off, or may reduce power in flight and proceed more slowly in order to fit perfectly into a landing sequence without holding.

Weather

Beyond runway capacity issues, weather is a major factor in traffic capacity. Rain or ice and snow on the runway cause landing aircraft to take longer to slow and exit, thus reducing the safe arrival rate and requiring more space between landing aircraft. This, in turn, increases airborne delay for holding aircraft. If more aircraft are scheduled than can be safely and efficiently held in the air, a ground delay program may be established, delaying aircraft on the ground before departure due to conditions at the arrival airport.

In ACCs, a major weather problem is thunderstorms, which present a variety of hazards to aircraft. Aircraft will deviate around storms, reducing the capacity of the en-route system by requiring more space per aircraft, or causing congestion as many aircraft try to move through a single hole in a line of thunderstorms. Occasionally weather considerations cause delays to aircraft prior to their departure as routes are closed by thunderstorms.

Much money has been spent on creating software to streamline this process. However, at some Area Control Centers, air traffic controllers still record data for each flight on strips of paper and personally coordinate their paths. In newer sites, these flight progress strips have been replaced by electronic data presented on computer screens. As new equipment is brought in, more and more sites are upgrading away from paper flight strips.

Call signs

A prerequisite to safe air traffic separation is the assignment and use of distinctive airline call signs that usually include up to four digits (the flight number) prefaced by a company-specific airline call sign. In this arrangement, an identical call sign might well be used for the same scheduled journey each day it is operated, even if the departure time varies a little across different days of the week. The call sign of the return flight often differs only by the final digit, from the outbound flight. Generally, airline flight numbers are even if eastbound, and odd if westbound. In air traffic control terminology, a block of airspace of predetermined size assigned to a radar air traffic controller is called a "sector". Depending on various factors (traffic density, etc.), a controller may be responsible for one or more sectors at any given time.

Technology

Many technologies are used in air traffic control systems. Primary and secondary radar are used to enhance a controller's "situational awareness" within his assigned airspace — all types of aircraft send back primary echoes of varying sizes to controllers' screens as radar energy is bounced off their skins, and transponder-equipped aircraft reply to secondary radar interrogations by giving an ID (Mode A), an altitude (Mode C) and/or a unique callsign (Mode S). Certain types of weather may also register on the radar screen.

These inputs, added to data from other radars, are correlated to build the air situation. Some basic processing occurs on the radar tracks, such as calculating ground speed and magnetic headings.

Other correlations with electronic flight plans are also available to controllers on modern operational display systems.

Some tools are available in different domains to help the controller further:

- Conflict Alert (CA): a tool that checks possible conflicting trajectories and alerts the controller.
- Minimum Safe Altitude Warning (MSAW): a tool that alerts the controller if an aircraft appears to be flying too low to the ground or will impact terrain based on its current altitude and heading.
- System Coordination (SYSCO) to enable controller to negotiate the release of flights from one sector to another.
- Area Penetration Warning (APW) to inform a controller that a flight will penetrate a restricted area.
- Arrival and Departure manager to help sequence the takeoff and landing of aircraft.
- Converging Runway Display Aid (CRDA) enables Approach controllers to run two final approaches that intersect and make sure that go arounds are minimized
- Final Approach Spacing Tool (FAST) gives aircraft a runway assignment that the Approach Controller will give to the aircraft. FAST can also suggest vectors for downwind and base with the correct timing.
- User Request Evaluation Tool (URET) takes paper strips out of the equation for En Route controllers at ARTCC's. By providing a display that shows all aircraft in or entering the sector. Provides conflict resolution up to 30 minutes in advance.

Major Accidents

Failures in the system have caused delays or even, in rare cases, crashes. On July 1, 2002 a Tupolev Tu-154 and Boeing 757 collided above Überlingen near the boundary between German and Swiss-controlled airspace when a Skyguide-employed controller apparently gave instructions to the southbound Tupolev to descend despite an instruction from the on-board automatic Traffic Collision Avoidance System software to climb. The northbound Boeing, equipped with similar avionics, was already descending due to a software prompt. All passengers and crew died in the resultant collision. Skyguide company publicity had previously acknowledged that the relatively small size of Swiss airspace makes real-time cross-boundary liaison with adjoining authorities particularly important. See *Bashkirian Airlines Flight 2937* for more on this accident. It is worth noting, that currently air traffic controllers have no way of knowing if or when the TCAS system is issuing resolution advisories to pilots. They also do not know what the advisory is telling the pilots. Therefore, pilots are supposed to immediately report TCAS resolution advisories and follow them as soon as possible. Consequently, they should ignore ATC instructions until they have reported to the ground that they are clear of the conflict.

Other fatal collisions between airliners have occurred over India and Zagreb in Croatia. When a risk of collision is identified by aircrew or ground controllers an "air miss" or "air prox" report can be filed with the air traffic control authority concerned. The worst fatal collision between airliners actually took place on the ground, on March 27, 1977, in what is known as the Tenerife Disaster.

The FAA has spent over USD$3 billion on software, but a fully-automated system is still over the horizon. The UK has recently brought a new control centre into service at Swanwick, in Hampshire, relieving a busy suburban centre at West Drayton in Middlesex, north of London Heathrow Airport. Software from Lockheed-Martin predominates at Swanwick. The Swanwick facility, however, has been troubled by software and communications problems causing delays and occasional shutdowns, paralyzing air traffic in the area.

Air Traffic Control Internationally

This article is based upon Air Traffic Control in the US. Although there is much common ground between Air Traffic Control in various countries around the world (since ICAO has many Standards and Recommended Practices in this Area), there are some significant differences in airspace, procedures and terminology.

In the UK, Clearance Delivery is referred to as 'Planner', Ground Control is referred to as 'Ground Movement Control' or 'GMC' and Local Control is referred to as 'Air Control'. It is common for airports to have an Approach Radar Control based upon the airport to provide radar services to arriving and departing aircraft. For five London-area airports approach radar control is provided from the London Terminal Control Centre in West Drayton, Middlesex.

Air Navigation Service Providers (ANSPs)

- Australia - Airservices Australia (State Owned Corporation)
- Canada - NAV CANADA
- Europe - Eurocontrol (European Organisation for the Safety of Air Navigation)
- France - DGAC (French ATC)
- Germany - Deutsche Flugsicherung (German ATC)
- Italy - ENAV (Italian ATC)
- Mexico - Servicios a la Navegación en el Espacio Aéreo Mexicano
- Netherlands - LVNL (Dutch ATC)
- New Zealand - Airways Corporation (State Owned Enterprise)
- Spain - AENA (Spanish ATC and Airports)
- Sweden - LFV (Swedish ATC)
- United Kingdom - National Air Traffic Services (49% State Owned Public-Private Partnership)
- United States of America - Federal Aviation Administration (Government Body)
- India - Airports Authority Of India (AAI) (Under Ministry Of Civil Aviation , Government Of India)
- South Africa - Air Traffic and Navigation Services , [[1]]

Related Topics

- Air Safety
- Airspace
- Automatic Dependent Surveillance-Broadcast (ADS-B)
- Aviation light signals
- Flight Level (FL)
- Flight Progress Strip
- Free Flight
- Global Air Traffic Management
- IFATCA (International Federation of ATC Associations)
- Tenerife Disaster

External links

Official Air Traffic Control Organizations and Research Institutes

- AENA - Spanish ATC and Airports (Madrid)
- Airservices Australia
- ATC Guild India
- DGAC - French ATC (Paris)
- Deutsche Flugsicherung - German ATC (Frankfurt/Langen)
- Deutsches Zentrum für Luft- und Raumfahrt - German Aerospace Centre (Cologne)
- EASA - European Aviation Safety Agency (Cologne)
- EGATS - **Eurocontrol** Guild of Air Traffic Services
- ENAV - Italian ATC (Rome)
- Eurocontrol - European Organisation for the Safety of Air Navigation (Brussels)
- Eurocontrol Experimental Centre - EEC (Paris/Brétigny)
- Eurocontrol Maastricht Upper Area Control Center - MUAC
- FAA - Federal Aviation Administration (Washington, D.C.)
- Air Traffic Control Manual
- LFV - Swedish ATC (Stockholm)
- Luchtverkeersleiding Nederland - Dutch ATC (Amsterdam)
- NATCA - National Air Traffic Controllers Association (Washington, D.C.)
- NATS - National Air Traffic Services of the UK (London)
- NAV CANADA - Canadian Air Navigation Services
- Nationaal Lucht- en Ruimtevaartlaboratorium - National Aerospace Lab of the Netherlands (Amsterdam)

Next Generation ATC - Research

- Communication Navigation Surveillance / Air Traffic Management
- Global Air and Ground Collaboration in Air Traffic Separation Assurance
- Next Generation Air Transportation System Joint Planning and Development Office
- NASA Aeronautics Research Mission Directorate

Internet Services

- Listen to Air Traffic Control radio with live audio
- Live audio Air Traffic Control from over 100 airports worldwide
- Live Air Traffic Control & Live Airport Webcams
- Map of airborne flights controlled by US ATC