Center

- Conflict detection
- Conflict Solving
- Vectoring
- Speed Control
- Vertical Speed
- Level Change

Conflict detection

Definitions

Conflict. Predicted converging of aircraft in space and time which constitutes a violation of a given set of separation minima.

Conflict detection. The discovery of a conflict as a result of a conflict search.

Conflict search. Computation and comparison of the predicted flight paths of two or more aircraft for the purpose of determining conflicts.

Source: ICAO Doc 9426

Description

Detecting conflicts between aicraft is an important part of the air traffic controller job and arguably the most complex one. Once a conflict is properly identified the resolution is relatively straightforward - the controller chooses an appropriate method (e.g. level change, vectoring, speed control, etc.), implements the plan and monitors aircraft compliance. If the situation remains undetected, however, this may result in loss of separation, late (and more abrupt) manoeuvres, STCA/TCAS activation or worse.

If all aircraft are assigned different levels, and are not expected to climb or descend, then there are no conflicts. Most commercial operations however take place in the RVSM layer which means that this situation is unlikely. Therefore, normally the first thing to be done in a surveillance environment, is a "**same level scan**", i.e. looking for aircraft that are maintaining the same level. This initial step identifies aircraft that need further examination. The second phase is to discard the pairs that are "obviously" non-conflicting, e.g. flying at the same speed to the same point with long distance between them, those whose paths do not cross, etc. After that, the minimum distance of the "suspicious" pairs is determined and, if necessary, a plan for solving the conflict is created.

Climbing and descending flights present a special challenge as they require more checks to be done, e.g.:

- Does the current level cause conflicts?
- Will the final level for the sector cause a conflict (within the sector or at the exit point)?
- Will any of the intermediate levels cause a conflict within the sector?
- Will the aircraft be able to reach its planned level before the exit point? If not, will this cause a conflict in the next sector?

These checks may become more complex if the aircraft climbs or descends through a high number of flight levels (e.g. climbing from FL 140 up to FL 360). This results in significant change in groundspeed (due to wind and IAS variations) which hinders precise calculations.

Factors that help controllers detect conflicts are:

- system support (see section below)
- discipline, i.e. performing structured scan of the aircraft that are, or will be under control and evaluation of the impact of each flight profile change
- fixed-route environment. This usually means that there are fixed "hotspots" (normally where airways cross). An experienced controller can often detect a conflict by knowing that when there is an aircraft at point A then if the other one is at point B they will be in conflict at point C.
- recurrent training for non-routine situations

Factors that may cause a conflict to be missed include:

- **Strong winds** (e.g. 50-100 kt or more). These may alter aircraft speeds in such a way that a BOEING 737-300 becomes faster than a AIRBUS A-380-800 in terms of groundspeed. Also, aircraft flying at different tracks will be affected differently. As a consequence, pairs that seem to be safely separated may be in conflict.
- **Free route environment.** This means that the "standard" hotspots are no longer relevant and a situation may arise anywhere. While free route generally reduces the number of conflicts it makes them harder to identify.
- **"Irregular" aircraft**, i.e. such that form a small fraction of the traffic flow and can be overlooked due to e.g. high workload or complacency. Examples of these are **non-RVSM aircraft** in RVSM space, **slow-flying business jets**, **slow-flying aircraft** at lower levels (interfering with arriving and departing aircraft), non-routine situations (e.g. aicraft dumping fuel, military interception), etc.
- Deviation from procedures, e.g. provision of ATS outside the area of responsibility, skipping "unnecessary" coordinations, etc.
- **Aircraft avoiding weather** are a special challenge, because their behaviour is less predictable and trajectory updates cause increased controller workload. If the controller does not update these, however, system support tools may be less useful.
- **Airspace boundaries** are areas where conflicts are sometimes detected late. This can be caused e.g. by poor coordination, improper colour representation, etc.
- **Blind spots** - a controller may examine the future path of an aircraft failing to notice the conflicting one which is just above (or below)
- **Improper handover/takeover**. The relieving controller normally expects all conflicts to be solved or at least detected and having a planned solution. If this is not the case, or if the controller being relieved fails to pass the information, it is possible that the new controller focuses on the medium and long-term situations and misses a near-term conflict.

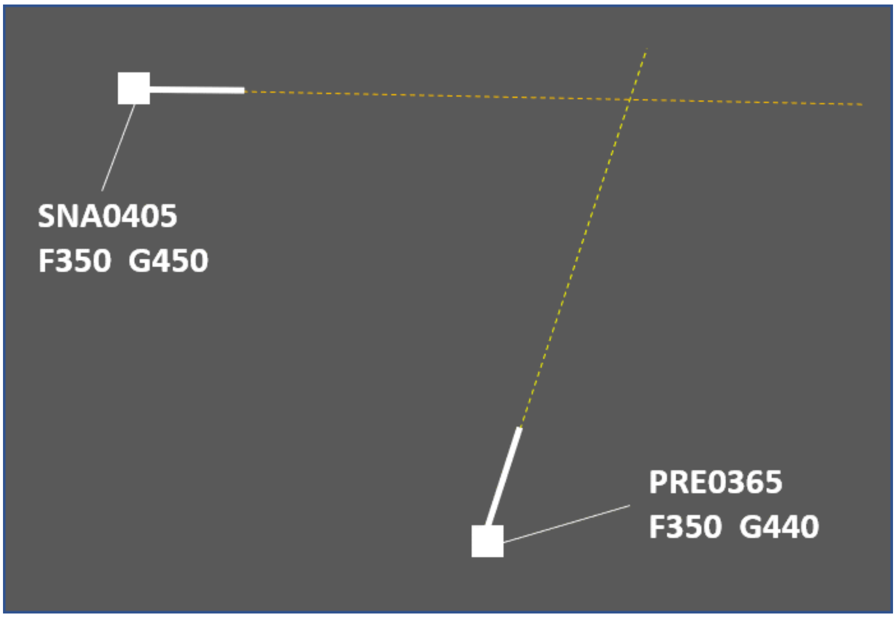
source: www.skybrary.aero

Conflict Solving

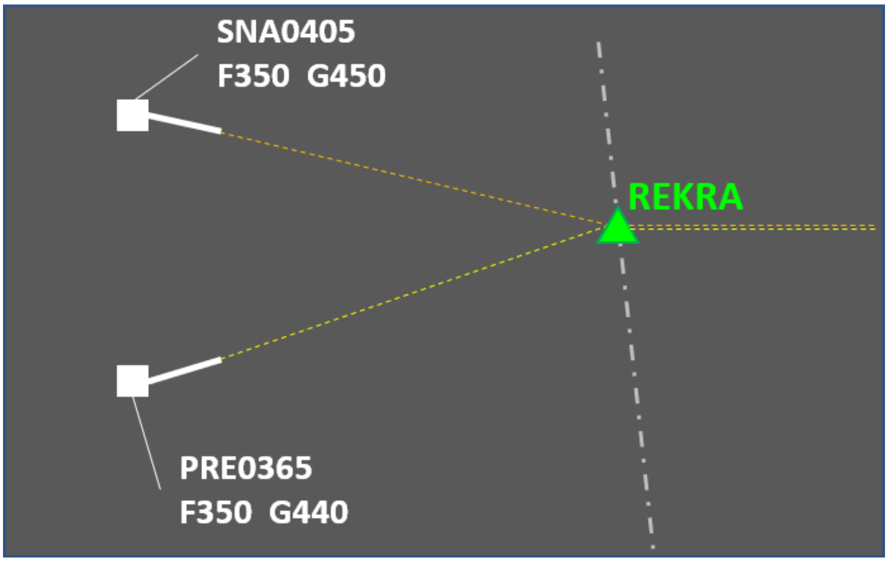
This article describes the typical methods and controller actions used to solve conflict between aircraft in a surveillance (mostly en-route) environment. Only situations with two participating aircraft are considered. Although more complex scenarios (involving three or more aircraft) do exist, they happen rarely and in most cases can be considered as multiple two-aircraft cases that happen at the same time.

In broader terms, a conflict is a situation where the separation at the closest point of approach will be less than the specified minimum and one of the following exists:

- Two aircraft are flying at the same level. In this case, doing nothing will result in a Loss of Separation. There are two sub-scenarios to this:
  - Crossing conflict - the two aircraft's paths cross at some point and diverge afterwards.



- Converging conflict - the two aircraft's paths join at some point and remain the same afterwards, at least for a portion of the flight.

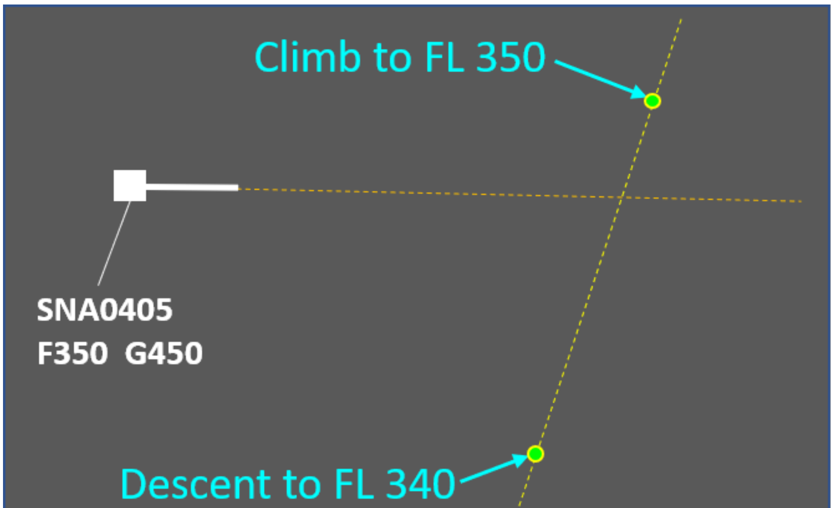


- At least one of the aircraft is climbing or descending to a level that will make it cross the other aircraft's level. In this case, doing nothing *may* lead to a loss of separation depending on the circumstances (e.g. vertical speed, distance between the aircraft, current vertical separation, etc.)
- The two aircraft are vertically separated but at least one of them needs to be cleared to a level that would cross the other's level (e.g. due to reaching the top of descent). Here, doing nothing will *not* cause loss of separation. However, improper timing of the instruction to change level may lead to this.

The second and the third situation usually happen near the transition between approach and area control. This is where departing aircraft reach their cruising level and arrivals start preparation for the final portion of the flight. The first one is more typical to the cruising part of the flight.

Action to be taken by the controller in order to eliminate the risk of separation breach depends on a number of factors such as the type of conflict, the specific circumstances, the available aircraft performance, controller workload, etc. The most common methods for solving conflicts are:

- Level change. This solution is typically used for conflicting aircraft in level flight. In the crossing case, an opposite level may be used for a short time and then the aircraft will climb again to its cruising level. This is not an option in the converging scenario, meaning that the level change needs to be at least 2000 feet. Sometimes it is possible to use opposite levels for converging conflicts but this requires coordination with the downsteam sector or unit.

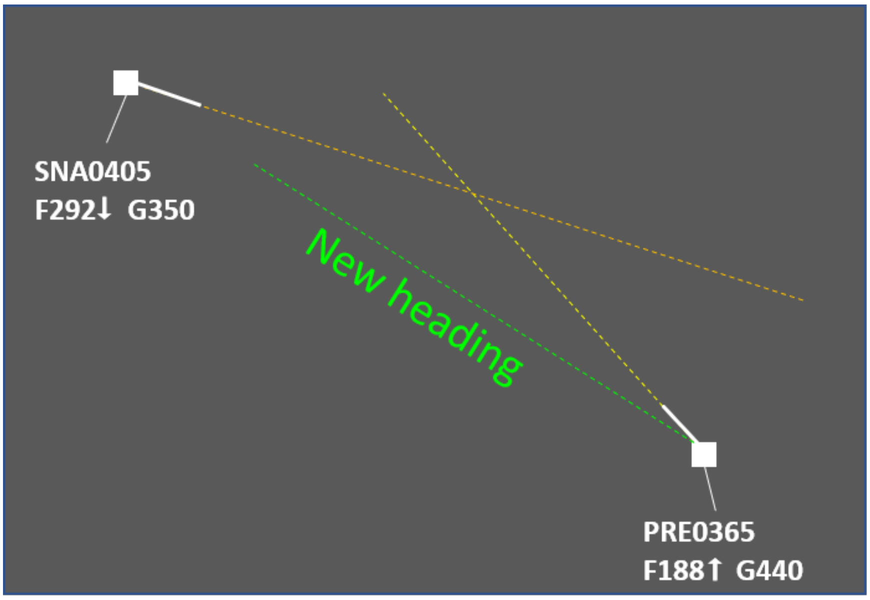


An example of using a 1000 ft level change to solve a crossing conflict

- Speed control. This method is mostly suitable for solving medium-term conflicts (as the instruction takes time to "produce" separation) and for maintaining already achieved separation. A major limiting factor is the typical cruising speed. For example, trying to sequence an AIRBUS A-380-800 behind a BOEING 737-800 would likely be impracticle (though not impossible). Additional factor to consider with speed control is that the results are not as obvious as for example with level change or vectoring. This means that the controller will need to monitor the situation more frequently to make sure that (a) the flight crews comply with the instructions and (b) the speeds are not affected by changing winds. On the other hand, this method normally results in the slighest intervention of the flight plan - the trajectory and vertical profile are not changed.
- Vectoring. This is a universal method that may solve any conflict unless additional factors (such as airspace restrictions or adverse weather) limit the available headings. This benefit comes at a cost, however - vectoring usually extends the distance flown (and hence, delays the flight). This effect may sometimes be mitigated by providing a direct routing after the conflict has been solved.
- Direct routing. This method is somewhat similar to vectoring because it relies on the aircraft track being changed to an extent where the horizontal separation will no longer be reduced below the minimum. While this method has limited applicability (the results depend mostly on the flight planned route) it often contributes to flight efficiency by reducing the distance to be flown. Other benefits are that the results from the controller intervention are immediately visible and that a single message solves the conflict altogether (unlike with most other methods that follow the instruct-monitor-resume routine). There are some downsides to this solution however, e.g.:
    - Depending on the specific circumstances, the flight may enter an area with strong headwinds (which the pilot tried to circumvent with the longer flight planned route).
    - In most cases the flight needs to be cleared to a point that is far away which in most cases means a coordination with the next sector or unit will be necessary. This increases controller workload and also adds an element of uncertainty (the next sector controller may not approve the direct routing).
    - A direct routing may solve one conflict but create another at the same time.
- Vertical speed adjustment. This technique is used in situations where an aircraft needs to safely cross another aircraft's level. If properly used, it provides safe and efficient flow of traffic. The rates of climb or descent to be assigned need to be carefully calculated to accomodate some non-compliance (e.g. if the controller assigns a rate of climb of 1500 feet per minute or greater but the aircraft actually climbs at 1300). Also, while descent rates are usually achieveable, climbing at a specified vertical speed may be outside the aircraft capability and therefore the restriction should be coordinated with the flight crew.

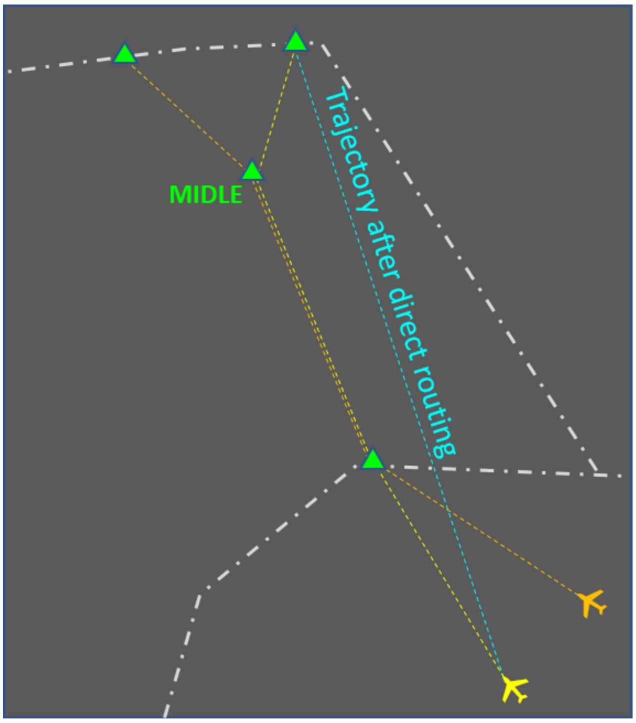
A combination of the methods above is sometimes used. Here are some examples:

- Using vectoring to ensure horizontal separation is maintained and assigning vertical speed so that vertical separation is achieved faster (and the vectoring may be terminated sooner). This is useful for separating departing and arriving aircraft.



An example of using vectoring and vertical speed control. Turning PRE0365 provides safety and assigning vertical speeds results in efficiency as the flight can be returned onto the flight planned route sooner.

- Combining vectoring and speed control may result in a smaller overall intervention as opposed to using vectoring only.
- Combining a direct routing (that makes the converging conflict a crossing one) with a level change. The benefit is that 1000 ft temporary level change may be sufficient as opposed to 2000 feet change for a longer period of time. Note that the direct routing may need to be coordinated.



An example of using a direct route and a level change. Initially, the conflict is of the converging type. By clearing the yellow aircraft to fly on a direct route, the controller does not solve the conflict but now has the option to use 1000 ft level change for a few minutes as opposed to 2000 ft until point MIDLE.

Combined solutions need to be carefully considered. These usually increase the flight crew workload. In some cases the instructions may even be incompatible. An example of this is assigning a high rate of descent to an aircraft that has already been instructed to reduce speed.

Source: www.skybrary.aero

Vectoring

This article describes the use of vectoring by air traffic controllers to manage the traffic flow and resolve conflicts. It is **focused on the en-route phase** and describes the general principles, typical uses and associated risks. The article also gives some advice about the practical use of the vectoring method. Note that the advice is based mostly on good practices and experience, and is in no way intended to replace or supersede local procedures and instructions.

Description

The goal of vectoring is to have the aircraft achieve and maintain the desired track. When an aircraft is given its initial vector diverting it from a previously assigned route, the pilot must be informed about the reason for the deviation (e.g. due to traffic, for sequencing, etc.).

General restrictions:

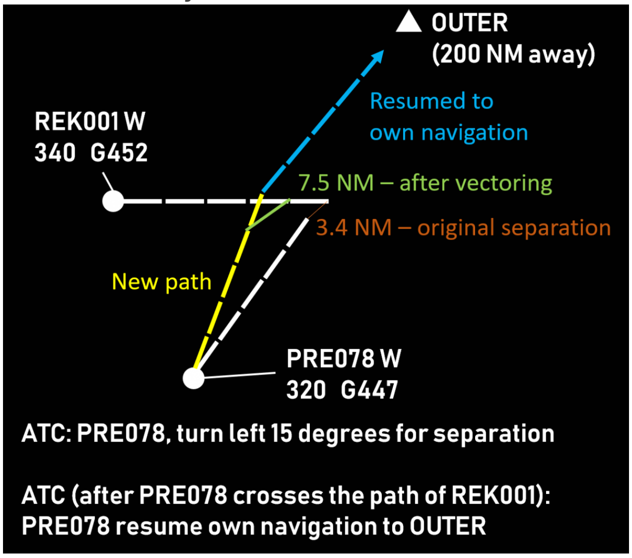
- Aircraft must not be vectored closer than a **half of the separation minimum (i.e. closer than 2.5 NM if the separation minimum is 5 NM) or 2.5NM, whichever is higher,** from the limit of the airspace which the controller is responsible for, unless otherwise specified in local arrangements.
- Controlled flights are not to be vectored into uncontrolled airspace, except in the case of emergency or in order to circumnavigate adverse weather (in which case the pilot should be informed), or at the specific request of the pilot.
- When vectoring or giving a direct route to an IFR flight takes the aircraft off an ATS route, the clearance should take into account the prescribed obstacle clearance.

After vectoring, the controller must instruct the pilot to resume own navigation, giving them the aircraft's position if necessary.

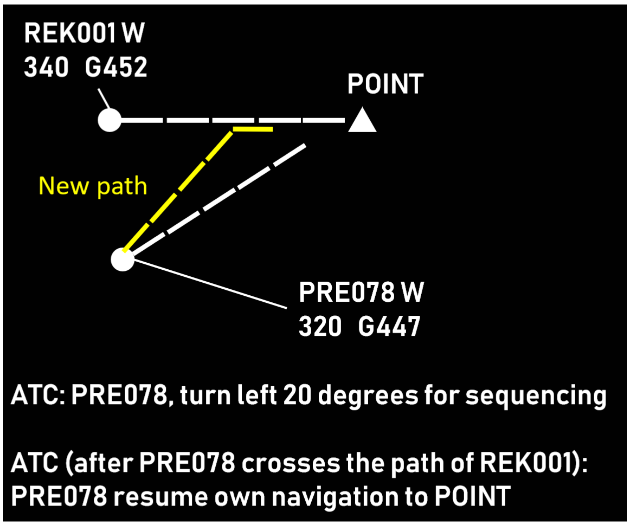
Typical uses

- **Flight Identification** - while not common in e.g. European airspace, this is one of the few methods for identification available when only primary radar is used.
- **Navigation assistance** - if due to equipment malfunction other navigation means (e.g. GNSS, INS, RNAV) are not available vectoring remains an option. This can also be useful for strayed VFR flights if the pilot has lost orientation.
- **Special use area (SUA) bypassing** - if for whatever reason a flight is approaching a SUA (prohibited, restricted, danger, temporary segregated, etc.) and flying above or below it is not feasible then vectoring may be used to guide the aircraft around it.

- **Conflict solving (opposite)** - if a level change is not possible for some reason (e.g. aircraft unable to climb, conflicting traffic at other levels, need for coordination with other sector, etc.) vectoring can be a very efficient way to solve the situation. A relatively small change of heading is often enough to achieve the desired separation.
- **Conflict solving (crossing)** - vectoring is a very effective method for solving crossing conflicts if a level change is not preferable and there is not enough time to perform speed control. In most cases, the aircraft that comes second to the intersection point of the two tracks is instructed to turn in the direction of the first one ("aiming for the other traffic"). This manoeuvre effectively puts the second (or slower) aircraft well beind the first (faster) one. After the crossing is complete, the vectored aircraft may be resumed to point that would compensate for the deviation and the extended flight path, thus gaining both safety and efficiency.



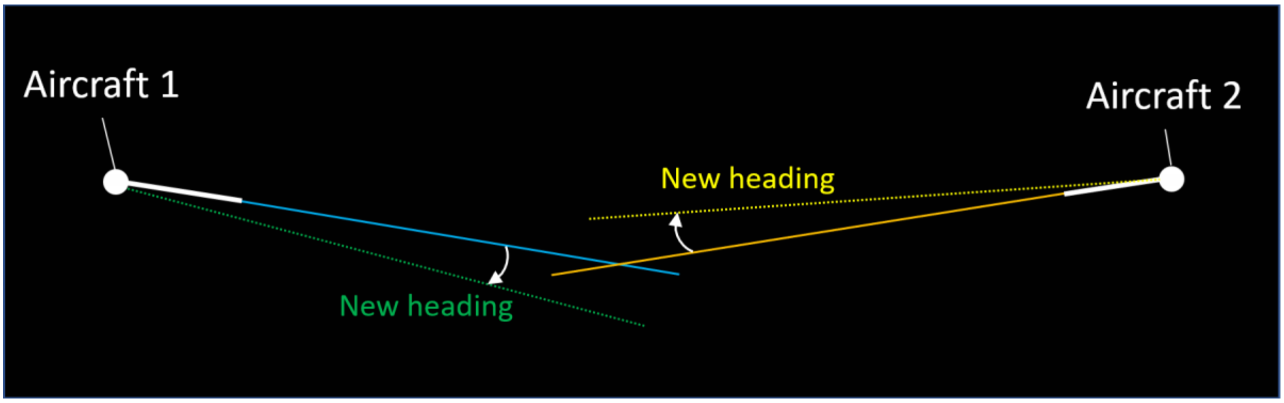
- **Sequencing** - often combined with speed control, vectoring is an effective method to achieve the desired distance before reaching the boundary with the next ATS sector or unit. The application is similar to the crossing scenario, the difference being that after the desired separation is achieved the aircraft being vectored remains behind the one that is ahead.



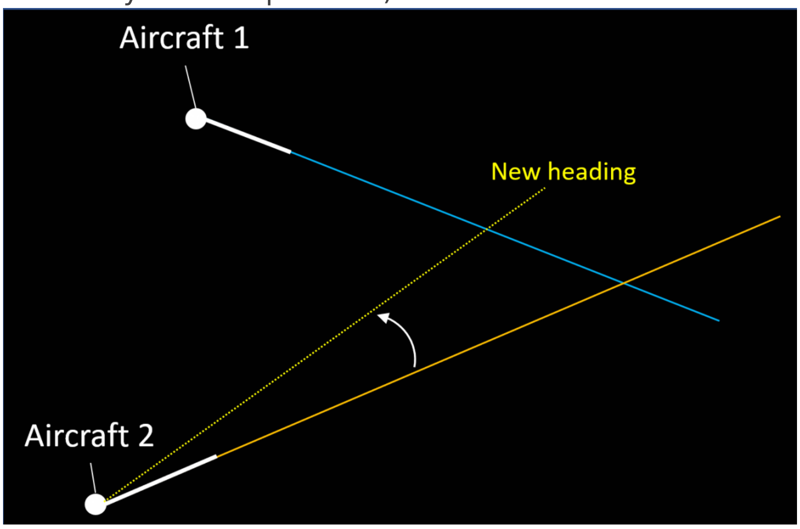
Choosing the aircraft

When vectoring is chosen as a means to solve a conflict, the first task of the controller is to decide which aircraft will have to change its heading. Generally, there are three situations:

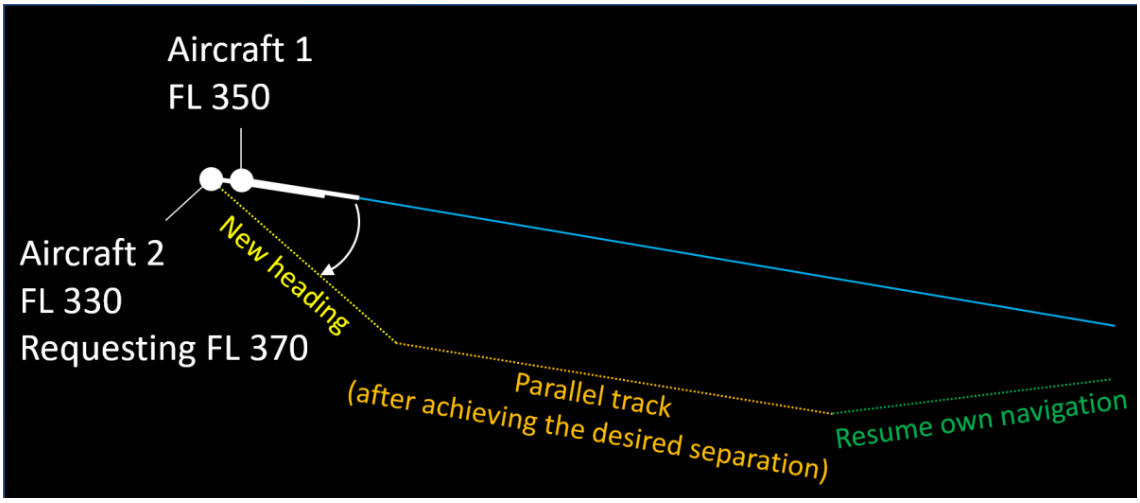
- Vector both aircraft. This is mostly used to solve conflicts of aircraft on reciprocal (opposite) tracks. This method increases the controller workload (due to having more communication exchanges on the frequency) but offers the benefit of less impact on each aircraft trajectory. Consequently, the increase of the distance flown is usually negligible. While turn direction is determined based on other factors (see next section), the general idea that both aircraft turn, and in the same direction, remains.



- Vector the aircraft that is behind. This is usually used when the two aircraft are maintaining altitude and one is considered to be overtaking the other. This is the more convenient choice from ATC perspective as well, since it requires less intervention (there is already some separation).



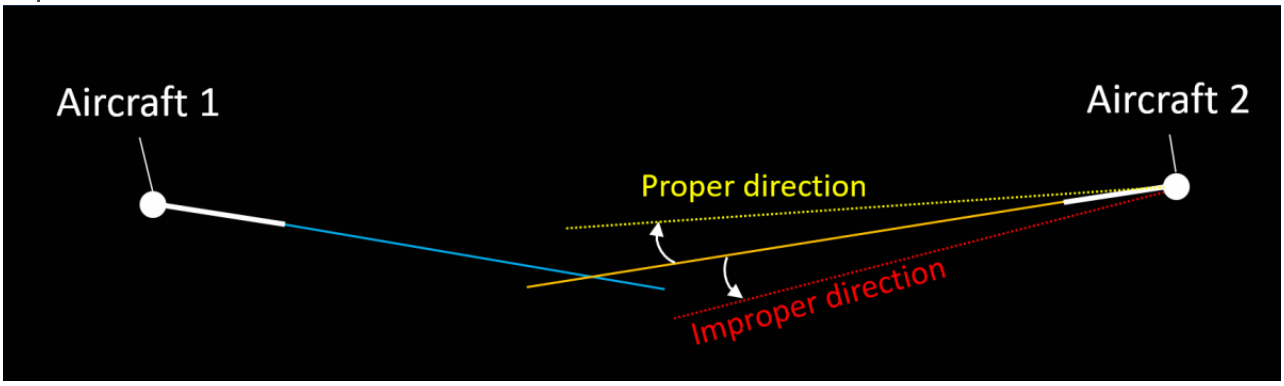
- Vector the requesting aircraft. If a pilot makes a request (usually to climb) and accommodating this request would result in insufficient separation with another aircraft, then the general choice is to vector the requester. Sometimes two vectors are used in such situations - the first one to achieve the desired separation and a second one to maintain it by flying on a parallel track.



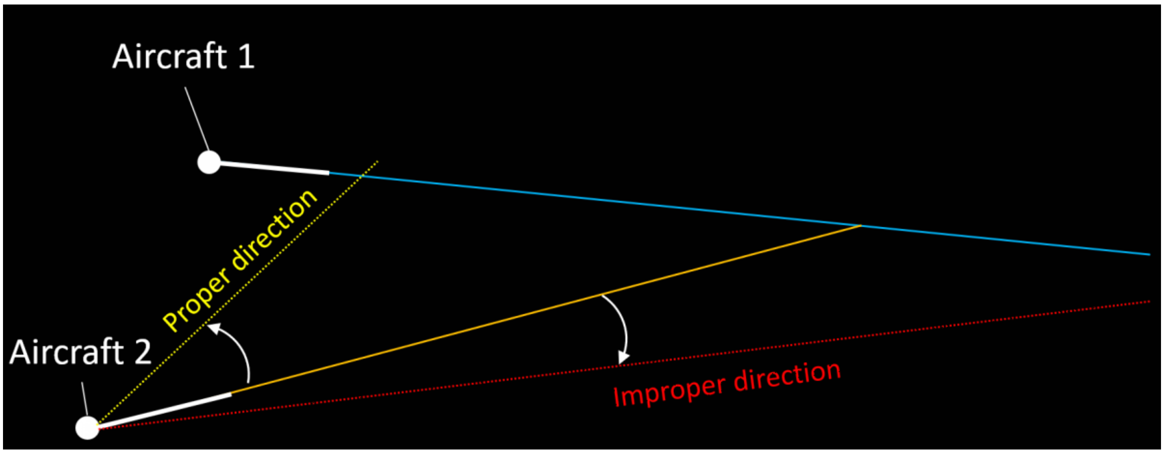
Turn Direction

After the aircraft to be vectored has been chosen, the controller decides the direction of the turn. The following general principles are used:

- Aircraft flying on opposite tracks are turned in a direction that would increase the separation.

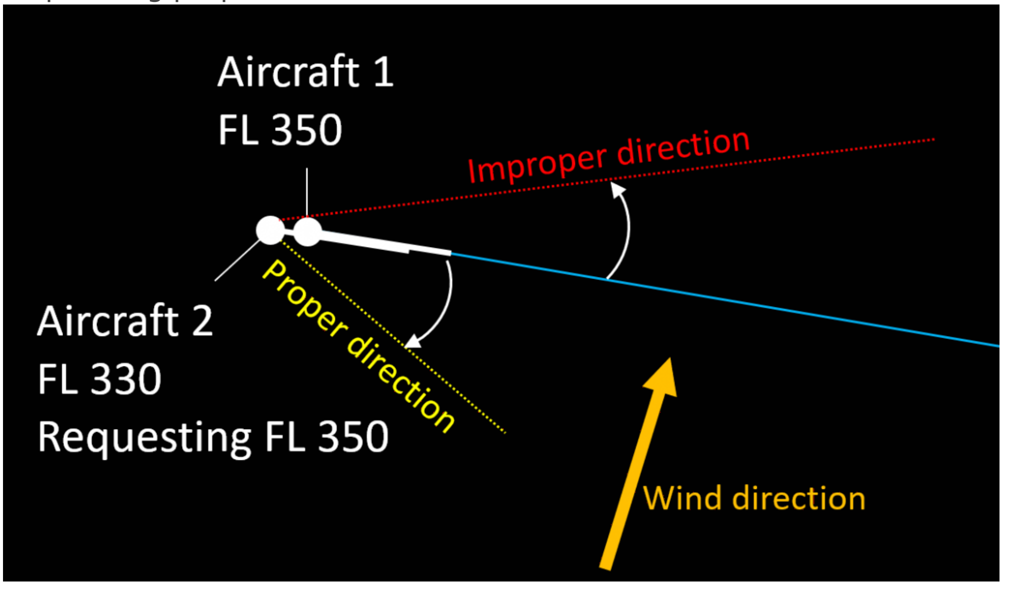
  

  Turning Aircraft 2 slightly to the right is enough to solve the conflict while turning it to the left, even by more degrees, does not.
- "Aiming" at the first aircraft's current position. The crossing point is moved in such a way that the distance from the first aircraft is reduced significantly while the distance from the second one is reduced marginally. This results in the second aircraft passing further behind.

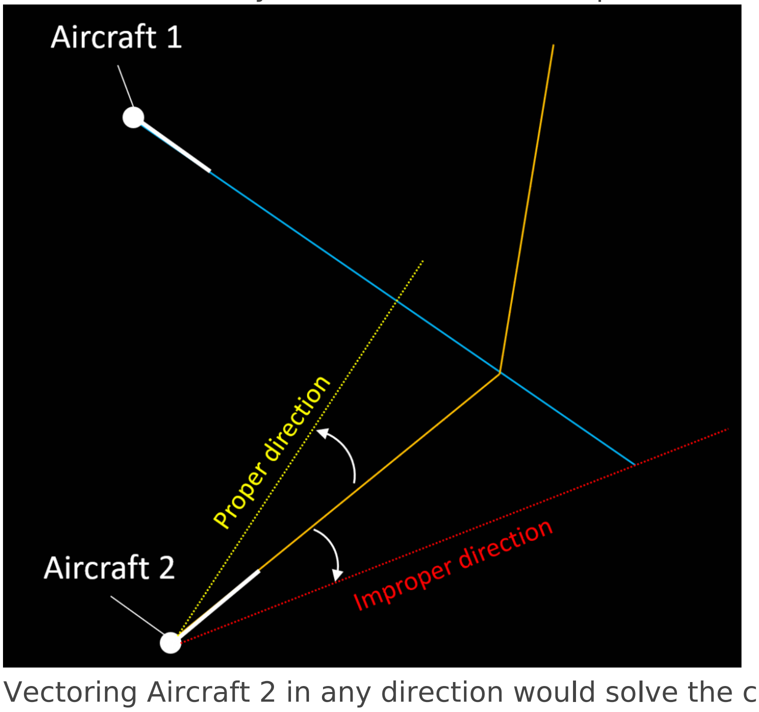
  Turning Aircraft 2 to the left solves the conflict by placing it behing Aircraft 1. A vector to the right, while prolonging the time to the conflict, does not solve it.

- Turning an aircraft against the wind. This reduces the ground speed, effectively placing the aircraft being vectored further behind. In some situations, if the wind is strong enough, vectoring against the wind can be much more effective than speed control for sequencing purposes.



Turning Aircraft 2 to the right allows it to safely climb to FL 350. Due to the speed reduction caused by the wind Aircraft 2 can be sequenced behind Aircraft 1.

- Turning in a direction that is in line with the flight planned trajectory is preferable. Thus when the aircraft resumes own navigation its overall flight distance will be only marginally increased and may even be reduced (compared to the flight planned).



Vectoring Aircraft 2 in any direction would solve the conflict but the left turn would not cause a delay.

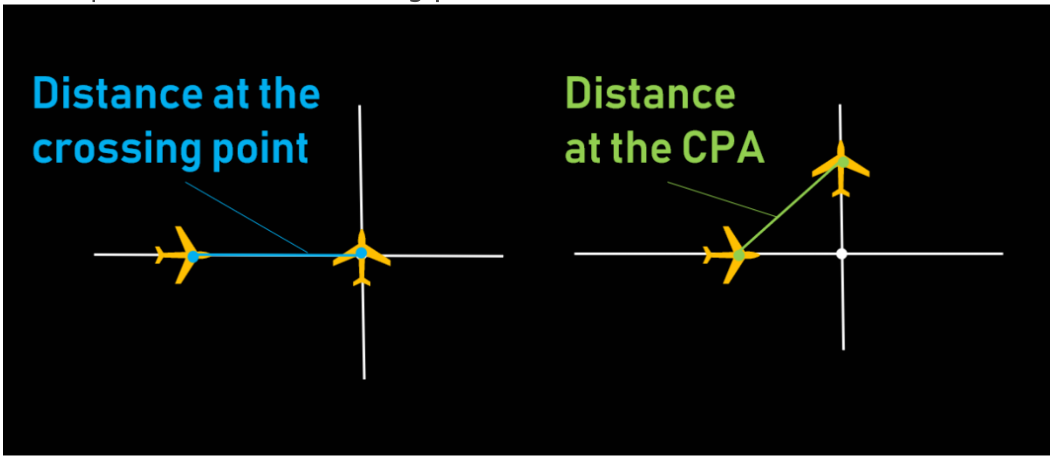
- Turning away from other traffic, special use areas and sector boundaries when practicable. Otherwise additional controller actions may be necessary (e.g. coordination, solving other conflicts, etc.).

Associated Risks

- Forgetting that an aircraft is being vectored. This has a negative impact on flight efficiency but may also "surprise" the next ATS sector or unit, especially if the airway makes a sharp turn at the transfer of control point and the aircraft does not.
- Miscalculation of wind impact (level flight). If a controller tries to sequence an aircraft after another one by vectoring but instructs it to turn so that the tailwind component increses, then the manoeuvre may have no effect (the tailwind will increase the aircraft's speed effectively reducing the expected benefit from vectoring).
- Miscalculation of wind impact (climbing and descending aircraft). Wind may be different at different levels. Even if the direction is somewhat the same, the windspeed can vary significantly. Consequently the headwind/tailwind/crosswind component will also vary and this may impact the desired result. For example, the drifting angle at different levels may be different if the windspeed (and therefore the crosswind component) increases with height. This may lead to parralel tracks becoming converging. A common mitigation for this is to assign a parallel or slightly diverging heading to the aircraft being vectored.
- Miscalculation of aircraft performance (climbing and descending aircraft). Generally, climbing aircraft increase their groundspeed and descending aircraft reduce it. The speed at cruising level can be twice that at e.g. FL 150. If this is not taken into account properly, the result may be loss of separation.

Things to consider

- **Crossing point.** In most cases vectoring is used to solve crossing conflicts. It is usually most efficient to turn the aircraft that would reach the crossing point later and in the direction of the other aircraft, i.e. if the conflicting traffic is to the left, then the turn should also be to the left. The manoeuvre effectively places the aircraft being vectored behind the other one. If for some reason the first aircraft needs to be vectored, this would require a much larger deviation.
- **Closest Point of Approach (CPA).** This is the moment when the distance between the two aircraft reaches its minimum. It should be noted that in general, the separation between aircraft continues to reduce for some time even after the first aircraft to reach the crossing point has crossed the track of the second one. The difference between the separation when the first aircraft reaches the crossing point and the moment of CPA depends on the conflict geometry. For example, if the tracks cross at right angle and both aircraft fly at the same ground speed then the separation at the CPA will be about 70% of the separation at the crossing point.



- **The sooner, the better.** An instruction given well in advance will have (almost) no impact on flight efficiency while solving the situation safely. For example, even a 5 degree heading change would result in about 6 miles displacement to the left/right after 10 minutes. On the other hand, if the conflict is happening after 3-4 minutes, the deviation may need to be 20 degrees or even more in some situations.
- **Wind direction and speed.** Generally, it is advisable to take advantage of the wind e.g. by turning the second aircraft into the wind to reduce its speed. This may reduce the necessary time an aircraft has to fly on a heading and generally help in resolving the situation faster.
- **Aircraft speeds.** Vectoring the faster aircraft would result in more spacing after the same amount of time.
- **Limitations**, e.g. during weather avoidance vectoring may not be a feasible method for conflict solving.
- Track crossing angle. An acute crossing angle means a larger deviation would be necessary to reach the desired separation (compared to a right angle). Generally, the bigger the angle of crossing, the smaller the necessary vector (0 degrees meaning the same direction and 180 - opposite).
- **Turn direction.** If the instruction "*turn left/right heading [ABC]*" is used **and** the present heading is unknown then the manoeuvre performed may surprise the controller (e.g. if the heading is 360 then "Turn left heading 005" would result in the aircraft making an orbit instead of a small turn to the left).
- **Misunderstanding.** Sometimes it is possible for the flightcrew to confuse instructions like "Turn left 10 degrees" and "Turn left heading 010".

Source: www.skybrary.aero

Speed Control

This article describes the use of speed control by air traffic controllers to manage the traffic flow and solve conflicts. It is focused on the en-route phase and describes the general provisions, typical uses and also gives some advice about the practical use of the method. Note that the advice is derived mostly from good practices and experience, and is in no way intended to replace or supersede local procedures and instructions.

Description

Speed control is used to facilitate a safe and orderly flow of traffic. This is achieved by instructions to adjust speed in a specified manner.

Speed adjustments should be limited to those necessary to establish and/or maintain a desired separation minimum or spacing. Instructions involving frequent changes of speed, including alternate speed increases and decreases, should be avoided. Aircraft should be advised when a speed control restriction is no longer required. The flight crew should inform ATC if unable to comply with a speed instruction.

The future position of an aircraft (and, consequently, separation) is determined by the ground speed. Since it is impractical to use it directly, the indicated airspeed (IAS) and Mach number are used instead to achieve the desired ground speed. At levels at or above FL 250, speed adjustments should be expressed in multiples of 0.01 Mach. At levels below FL 250, speed adjustments should be expressed in multiples of 10 kt based on IAS. It is the controller's task to calculate the necessary IAS or Mach number that would result in the appropriate ground speed. The following factors need to be taken into account:

- Aircraft type (range of appropriate speeds)
- Wind speed and direction (in case the two aircraft are not on the same flight path)
- Phase of flight (climb, cruise, descent)
- Aircraft level (especially if the two aircraft are at different levels)

Restrictions on the use of speed control:

- Speed control is not to be applied to aircraft in a holding pattern.
- Speed control should not be applied to aircraft after passing 4 NM from the threshold on final approach.

Phraseology

- **Report indicated airspeed / report mach number / speed** (in case the current speed cannot be obtained by other means, e.g. Mode S information)

- **Maintain/increase/reduce** [**speed**] [**or greater/or less**] [reason] [condition]. Examples:
  - Maintain 300 knots or greater
  - Maintain Mach .83 or less due converging traffic until [point name]
  - Reduce speed 260 knots or less for sequencing
  - Increase speed Mach .82 or greater for the next 10 minutes.
- **Resume normal speed** (cancels a previously imposed speed restriction)
- **No *ATC* speed restrictions** (cancels a previously imposed speed restriction)
- **On conversion** [**speed**]. This instruction is sometimes used for climbing or descending aircraft when the speed control includes the moment of swithcing between IAS and Mach number. ***Note:*** *while this instruction is used in a number of countries, it is **not** part of the ICAO standard phraseology.*

Typical Uses

- Separation adjustment (e.g. two successive aircraft are separated by 9 NM and the required separation over the FIR exit point is 10 NM)
- Separation preservation (e.g. two successive aircraft have the necessary separation but this may change if one of them or both change their speed)
- Delay absorption (an alternative to flying a holding pattern)
- Avoid or reduce vectoring:
  - in some situations speed control may be used instead of vectoring
  - in some situations speed control may be used in combination with a vectoring instruction, in order to reduce the time an aircraft flies on heading and/or the heading change.

Rules of Thumb

- Generally, 0.01 M equals 6 kt
- Speed difference of 6 kt gives 1 NM in 10 minutes
- Speed difference of 30 kt gives 1 NM per 2 minutes
- Speed difference of 60 kt gives 1 NM per minute

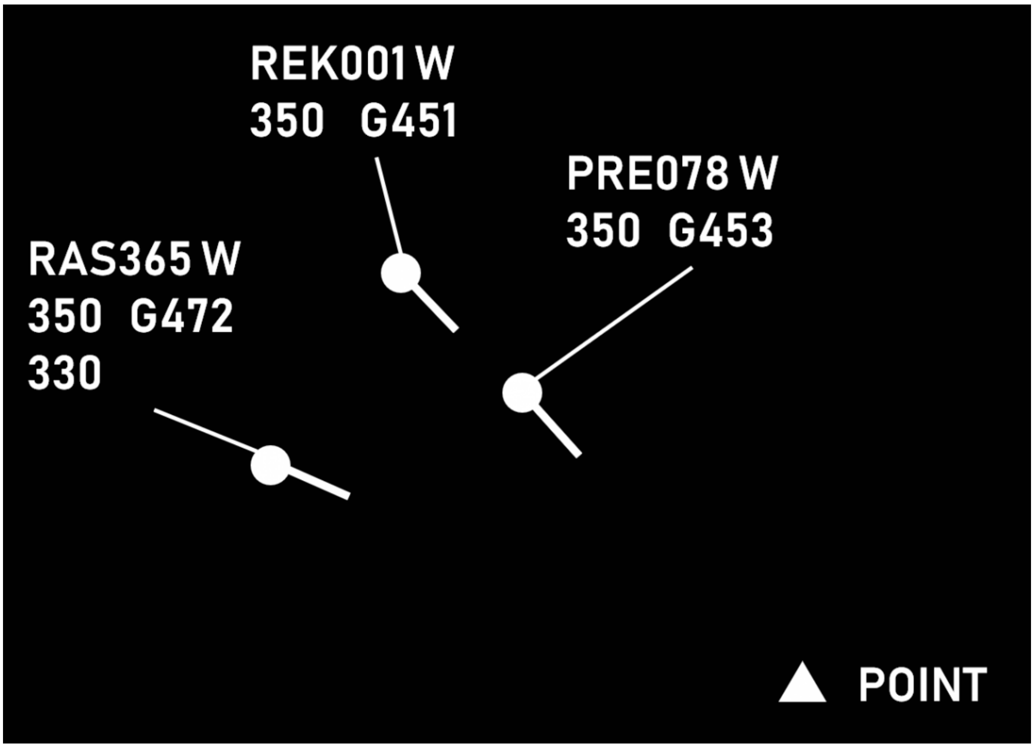
Benefits

- Speed control is often the most efficient way for solving conflicts and traffic sequencing.
- The added workload is relatively low, especially for thinner sectors where most level changes need to be coordinated with the neighbouring upper/lower sector.

Things to Consider

- Transition times should be taken into account. It usually takes a few minutes before the aircraft reaches the desired speed due to inertia.
- When an aircraft is heavily loaded and at a high level, its ability to change speed may be very limited.

- Aircraft experiencing turbulence often fly at reduced speed. Under such circumstances it is advisable to coordinate instructions for speed increase with the flight crew.
- Speed control needs more time to achieve the necessary separation compared to other methods (vectoring, level change, vertical speed control). For shorther ATS sectors (e.g. 10 minutes transit time) this method is effective for:
  - Separation adjustment (e.g. if the aircraft already have some separation and need a few NM more, this could be achieved by speed control even in shorter ATS sectors)
  - Preservation of achieved separation (e.g. if two successive aircraft of similar type already have the nevessary separation, an instruction to maintain the same speed would be appropriate)
- Impact of wind. Winds can make a slower aircraft (in terms of M or IAS) have higher groundspeed than a faster one. In a complex situation, it is usually better to use speed control for successive aircraft and other method (e.g. level change) for a converging conflict.

  In this situation the three aircraft are of the same type and flying with the same Mach number. However, due to the strong winds, RAS365 is considerably faster. It is therefore advisable to use speed control for PRE078 (e.g. M078 or greater) and REK001 (e.g. M078 or less) and change the level of RAS365 (in this case, descend to FL330).
- Maintaining the Mach number during climb (in unchanged wind) results in reduction of TAS (and therefore groundspeed). It is therefore possible that a succeeding aircraft catches up with the preceeding one even if the preceeding aircraft is assigned a higher speed.
- Maintaining IAS during descent (in unchanged wind) results in reduction of TAS (and therefore groundspeed). It is therefore possible that a succeeding aircraft catches up with the preceeding one even if the preceeding aircraft is assigned a higher speed.
- An instruction for speed reduction is generally incompatible with one for maintaining a high rate of descent. Such combinations are best avoided and should only be used after explicit coordination with the flight crew that the desired combination of lateral and vertical speeds is achievable.

- Speed reductions to less than 250 kt IAS for turbojet aircraft should be applied only after coordination with the flight crew.

Source: www.skybrary.aero

Vertical Speed

This article describes the use of vertical speed (rates of climb and descend) by air traffic controllers to control the traffic flow and solve conflicts. It describes the general procedures, typical applications and associated risks. It also gives some advice on the use of this method by air traffic controllers. Note that any part of this article is not intended to act as or replace any existing local procedures.

Description

In order to facilitate a safe and orderly flow of traffic, aircraft may be instructed to adjust rate of climb or rate of descent. Vertical speed adjustments should be limited to those necessary to establish and/or maintain a desired separation minimum. Instructions involving frequent changes of climb/descent rates should be avoided.

Climbing/descending aircraft may be instructed to maintain a specified rate of climb/descend, a rate of climb/descent equal to or greater than a specified value or a rate of climb/descent equal to or less than a specified value.

An aircraft may be instructed to expedite climb or descent as appropriate to or through a specified level, or may be instructed to reduce its rate of climb or rate of descent.

Aircraft must be advised when a rate of climb/descent restriction is no longer required. The flight crew must inform the ATC unit concerned if unable, at any time, to comply with a specified rate of climb or descent.

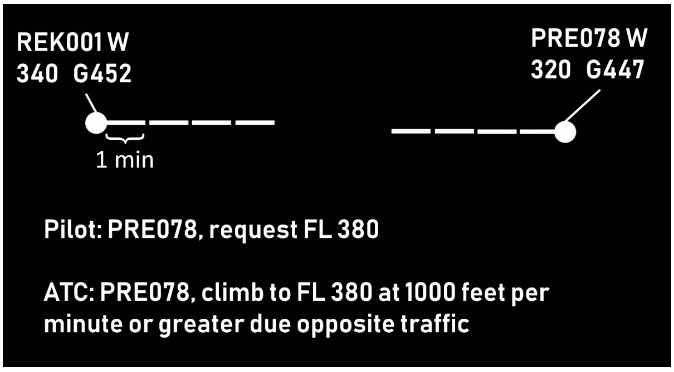
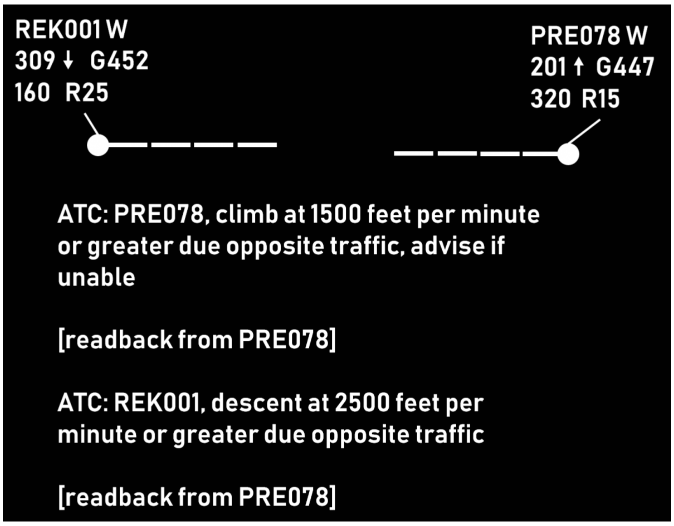
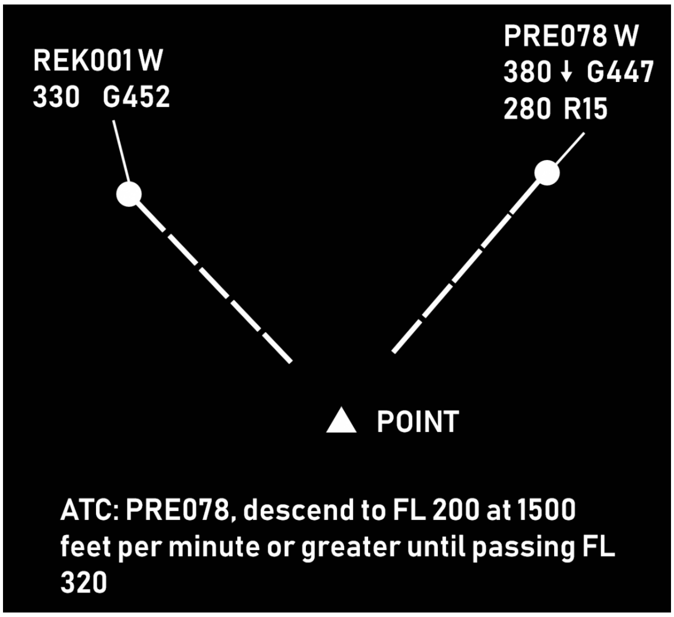
Phraseology

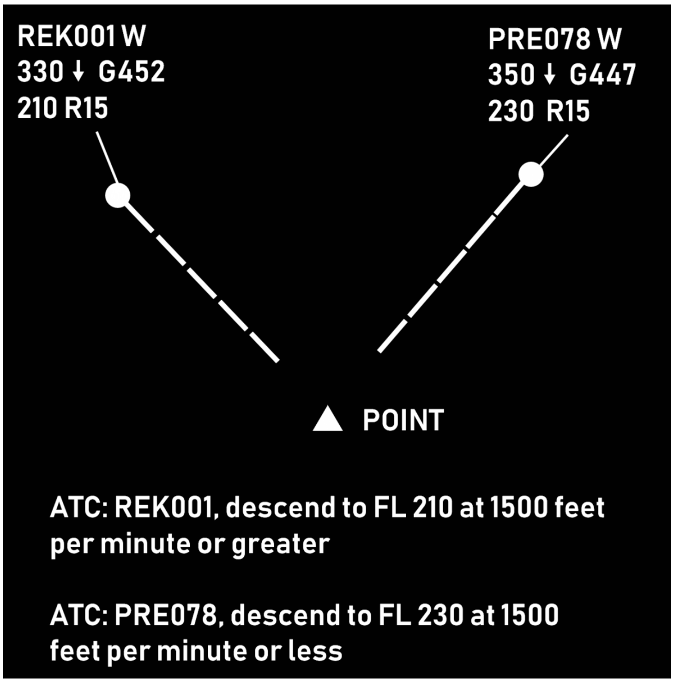
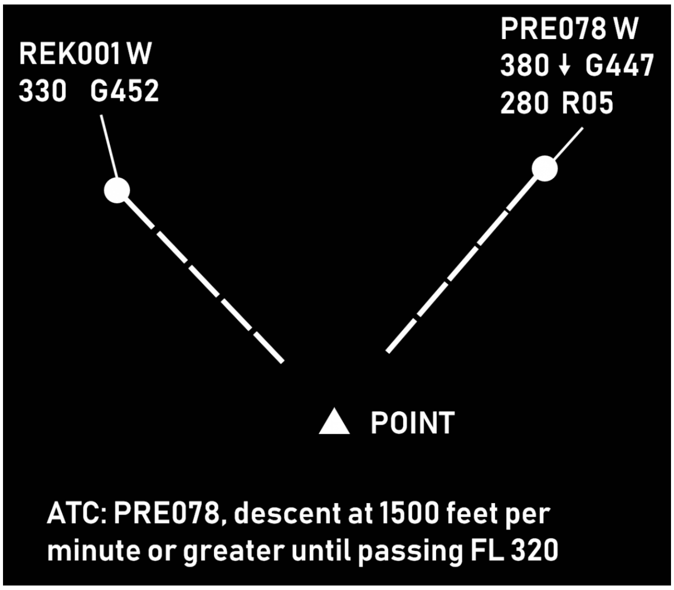
The vertical speed clearance may be a part of a vertical clearance or a separate one. It specifies the required rate of climb/descent, usually in feet per minute and may also contain:

- upper or lower limit of the vertical speed, if applicable. The phrases "*or greater*" and "*or less*" are used in this case. If no limit is specified, then the aircraft is expected to maintain an exact vertical speed.
- a condition, if applicable (e.g. until passing a level or a point)
- further information (e.g. reason for the restriction, e.g. traffic, special use area, etc.)

> PRE078 climb FL 370 at 1000 feet per minute or greater until passing FL 360 due crossing traffic.

Typical Uses

Accomodation of climb requests	
Separation of departing and arriving traffic	
Descending arriving aircraft below the overflying traffic	

<table>
<tr><td>Vertical sequencing, i.e. establishing and maintaining vertical separation between two (or more) climbing or two (or more) descending aircraft</td><td>
</td></tr>
<tr><td>Corrective action (e.g. when the unrestricted vertical speed is considered insufficient)</td><td>
</td></tr>
</table>

Benefits

When properly used, vertical speed control helps to achieve

- continuous climb/descend (fewer level offs), therefore better efficiency
- descents starting close to the top-of-descent
- timely accommodation of climb (mostly) and (sometimes) descent requests
- reduced workload due to reduced need for vectoring. A proper vertical speed ensures that horizontal separation will be preserved at least until vertical separation is achieved.

Associated Risks

- The margin for error is often reduced. This method relies mostly on maintaining vertical separation, which is much smaller than the horizontal one (e.g. 1000 ft as opposed to 5

NM). Therefore, any misunderstanding or non-compliance can easily result in loss of separation.

- Harder to monitor aircraft compliance (as opposed to e.g. vectoring). While the information for vertical speed is usually available, it may require some effort to present it. Furthermore, the interpretation of two (or more) numbers and the comparison of clearances versus performance takes more time than just having a look at the situational display (which is used to monitor horizontal separation).
- Aircraft may be unable to maintain the assigned rate of climb after certain level. If this happens, flight crew may or may not inform the controller.
- Wrong readback may easily ruin the plan (e.g. both aircraft descending with "or greater")

Things to Consider

- Rates of climb should be coordinated with the flight crew, especially:
  - when approaching the cruising level
  - when the climb is not desired by the flight crew
  - when temperatures are high
- Some aircraft types are generally unable to maintain a high rate of climb (e.g. AIRBUS A-321, AIRBUS A-340-300)
- In order to mitigate the risks for crossing or opposite traffic situations, a safety buffer of 1 or 2 minutes should be used. This can be done by e.g.
  - Issuing the clearance(s) a bit earlier
  - Assigning vertical speeds that are a little higher (e.g. 1500 instead of 1000)
- High rates of descent are generally incompatible with low speeds. A combined instruction to reduce speed and increase the RoD should be coordinated with the flight crew.
- The aircraft needs time to achieve higher rates (2000 ft/min or higher). The transition period should be considered when calculating the necessary vertical speed.
- During the final 1000 ft, the vertical speed is usually 1000 ft/min or less. This is done to avoid level busts. It is therefore impractical to assign a rate of 2000 ft/min or greater if the aircraft is to climb or descend some 2000-3000 ft.
- The phrases **"Expedite climb" and "Expedite descent", while being standard ICAO phraseology do not prescribe specific vertical speeds and should be used with caution.** The general expectation in such case would be that:
  - a climbing aircraft would climb at the highest rate possible (which may or may not be enough to achieve the desired result). It is therefore advisable that larger safety buffers are used or an alternative plan is ready for implementation.
  - a descending aircraft would increase the rate of descent to at least 2000 ft/min. It is therefore advisable that this method is used for the first few thousand feet (e.g. for an aircraft at FL 390 "Descend FL 290, expedite passing FL 370 due crossing traffic")
- There should always be an alternative plan to accommodate for an aircraft being unable to continue climb with the desired rate.

Rules of Thumb

- Vertical speed of 2000 ft/min gives 10 FLs in 5 minutes
- Vertical speed of 2500 ft/min gives 10 FLs in 4 minutes
- Combined vertical speed of 4000 ft/min (e.g. RoD 2500 and RoC 1500) gives 20 FLs in 5 minutes

> *Combined vertical speed is the sum of the vertical speeds of a climbing and a descending aircraft, e.g. if aircraft A is climbing at 1500 ft/min and aircraft B is descending at 2000 ft/min, then the combined vertical speed is 3500 ft/min.*

Source: www.skybrary.aero

Level Change

While there are various reasons for a level change, this article focuses on the conflict solving aspect.

Description

Changing an aircraft's level is often the easiest way for a controller to solve a conflict, i.e. a situation where two (or more) aircraft are expected to be closer than the prescribed separation minima.

Advantages:

- Comparatively smaller intervention. The aircraft continues to fly using own navigation (as opposed to vectoring) and follows the planned route (as opposed to proceeding direct to some distant waypoint).
- Faster to achieve. Even when the aircraft is to climb or descend by 2000 ft, only 1000 are often enough to ensure separation with the conflicting aircraft (see section Opposite Levels for details). This means that the conflict is usually solved within less than a minute.
- Easier to monitor on a situation display. Wind can influence both aircraft speed and flight direction. Additionally, speed vectors can change direction due to specifics of the surveillance system (especially the presence or absence of a tracker). On the other hand, all modern ATS systems provide an indication for climb or descend (an arrow next to the aircraft level). This makes it much easier for a controller to monitor aircraft compliance.
- Less controller workload. Changing an aircraft's level normally requires one instruction and about a minute to achieve the required separation. By contrast, speed control usually requires prolonged monitoring (the required separation "builds up" gradually). Vectoring requires more instructions - at least one for the heading change and one for the return to own navigation but more can be necessary depending on the circumstances. This will also require a longer period of monitoring.

Disadvantages:

- The main disadvantage of a level change is that aircraft normally fly at their optimal cruise levels. Therefore, any level change leads to reduced efficiency. This effect gets worse when increasing the difference between the desired and the cleared level.
- The use of temporary level change (i.e. the aircraft climbs/descends to a safe level to solve a crossing conflict and then returns to its cruising level) requires two vertical movements (one climb and one descend) which is also sub-optimal in terms of efficiency.

- There is an inherent risk of a blind spot, i.e. the controller may solve a medium term (e.g. 15 minutes ahead) conflict while at the same time create a new one with an aircraft just below or above the one being instructed to change level.
- When vertically split sectors are used, the level change may require coordination with an adjacent upper or lower sector which increases the workload for both controllers.

Climb Vs. Descent

After deciding to solve a conflict by a level change, the controller must choose between climb and descent. The former is generally preferred, as it leads to better flight efficiency. However, in some situations descent is the better (or the only) option, e.g.:

- The aircraft is unable to climb due to weight. Note that weight reduces as fuel is burnt so a higher level may be acceptable later. In this case the controller should take into account that the climb rate could be less than usual.
- The aircraft is approaching its top-of-descent. Instructing an aircraft to climb shortly before it would request descent is not very beneficial to flight efficiency and can increase controller workload (the higher the aircraft, the more potential for conflicts during the descent).
- Turbulence is reported at the higher level. Vectoring, direct route or speed control are generally preferable in this situation.
- The manoeuvre is to be performed quickly (e.g. due to a conflict being detected late). In this case, if a climb instruction is issued, it may be declined by the crew, thus losing precious time.

If the controller is in doubt as of which option is preferable (and if both are available), the controller may first ask the pilot (time and workload permitting). The fact that the range of available speeds is reduced at higher levels should also be considered. If the climb is to be combined with a speed restriction, this should be coordinated with the crew beforehand.

Opposite Levels

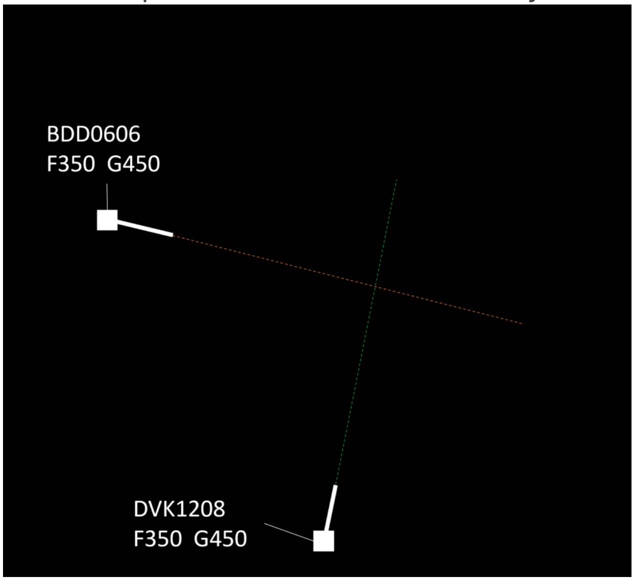
In many situations a level change would require the aircraft to climb or descend by 2000 feet (so that the new level is appropriate to the direction of the flight). However, sometimes it is better to use an opposite level, i.e. one that is only 1000 feet above/below. This is often a good solution in case of crossing conflicts, i.e. where the paths of the two aircraft only intersect at one point and the level change is expected to be temporary.

- The solution is better in terms of flight efficiency because the aircraft will fly as close as possible to the desired level and the need for vertical movement will be reduced
- The opposite level may happen to be within the own sector, therefore no coordination with an adjacent upper or lower sector would be necessary. This reduces the workload of both controllers and is especially useful when there are multiple, vertically-split sectors.

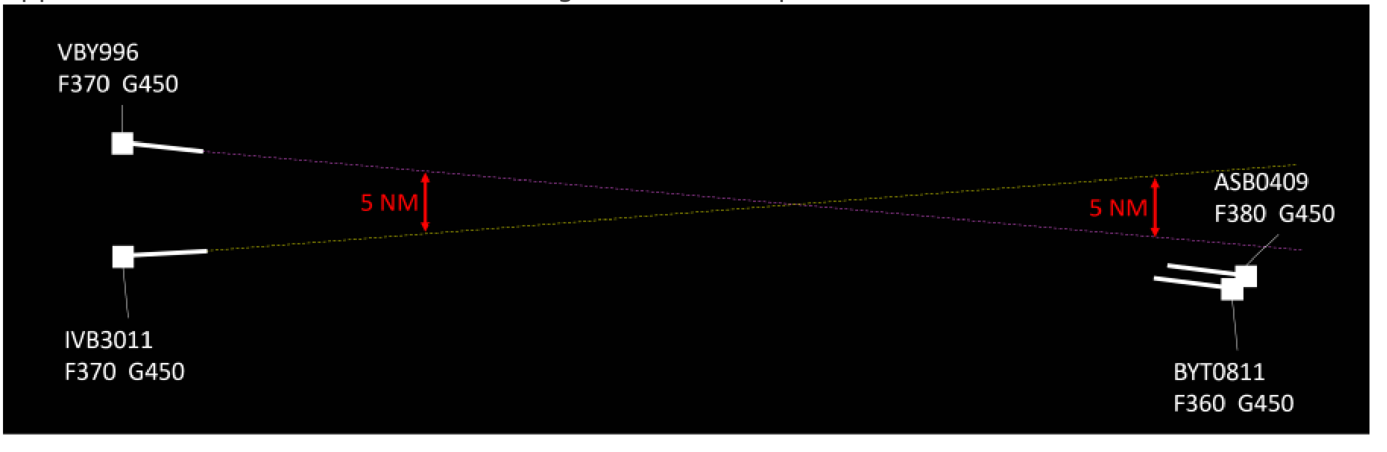
It should be noted, that a few risks exist with this solution:

- If there is a flight on an opposite track, the normally expected 1000 ft separation would not exist
- In case of radio communication failure, the aircraft may fly at an opposite level much longer than expected and the exact moment of returning to the previous level may not be easy to determine.

The picture below show a situation where the use of opposite level is preferable. The level change will be required for a few minutes only and there is no opposite traffic.



The picture below show a situation where the use of opposite level is not feasible because of opposite traffic. Therefore, a level change of 2000 ft is preferable.



The use of opposite levels can sometimes be justified when the conflict is at the sector exit point. This solution, however, is subject to approval from the downstream controller. The feasibility of this option depends on the geometry of the conflict (are the aircraft diverging after the point of conflict) and on the traffic situation (are there aircraft that are flying at the same level on an opposite track).

Priorities

As a general rule, when two aircraft are at the same cruising level, the preceding aircraft would have priority, i.e. the succeeding aircraft will have to climb or descend. Other criteria may be specified in the manual of operations or other documents containing local procedures. In any case, the controller may deviate from these procedures based on the traffic situation. For example, if changing the level of the succeeding aircraft would create a new conflict (and thus, a new intervention would be necessary), the controller may opt to work with the preceding aircraft. Naturally, flights in distress, or those performing SAR operations, would have priority over other traffic. This includes obtaining (or maintaining) the desired level while a lower priority traffic (e.g. a commercial or general aviation flight) would have to change level. Other priorities may be specified in local procedures (e.g. flights with head of state on board).

Vertical Speed Considerations

Normally, vertical speed is not considered an issue in case of a level change solution to a conflict. This is because in most cases the instruction is issued well in advance (5-15 minutes before the potential separation breach) and the level change is 1000 or 2000 ft, which means that vertical separation will be achieved comfortably prior to losing the required horizontal spacing. Nevertheless, there are some situations where it might be necessary to ensure that the vertical speed will be sufficient. These include:

- There is a reason to believe that the aircraft will not (be able to) climb fast, e.g. a heavy long-haul flight in the initial cruise stage, the aircraft type is known to climb slower than others, the new level is near the ceiling, etc. While 1000 ft/min means that 1000 ft separation will be achieved in one minute, if the rate drops to 200 ft/min, the required time will be 5 minutes. In the scenario where 2000 ft level change is necessary (e.g. converging traffic at the sector exit point and an opposite traffic 1000 ft above), a 200-300 ft/min climb rate will result in a 7-10 minute climb.
- Sometimes, if a descent rate is not specified, the manoeuvre may start at rates in the range of 500 ft/min. In this case, a 2000 ft level change will require 4 minutes as opposed to only 1 or 2 if "normal" vertical speeds of 1000-2000 ft/min are used.

In such situations the controller should either:

- ensure the vertical speed will be sufficient (e.g. by specifying a desired rate of climb or descent), or
- issued the instruction early enough, or
- if the above are not possible, an use an alternative solution.

Source: www.skybrary.aero