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Pair-Wise Trajectory Management-Oceanic (PTM-O)

Concept of Operations—Version 3.9

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April 2014

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1. Introduction/Scope

This document describes the Pair-wise Trajectory Management-Oceanic (PTM-O) Concept of Operations (ConOps). Pair-wise Trajectory Management (PTM) is a concept that includes airborne and ground-based capabilities designed to enable and to benefit from, airborne pair-wise distance-monitoring capability. PTM includes the capabilities needed for the controller to issue a PTM clearance that resolves a conflict for a specific pair of aircraft. PTM avionics include the capabilities needed for the flight crew to manage their trajectory relative to specific designated aircraft. Pair-wise Trajectory Management PTM-Oceanic (PTM-O) is a regional specific application of the PTM concept. PTM is sponsored by the National Aeronautics and Space Administration (NASA) Concept and Technology Development Project (part of NASA's Airspace Systems Program). The goal of PTM is to use enhanced and distributed communications and surveillance along with airborne tools to permit reduced separation standards for given aircraft pairs, thereby increasing the capacity and efficiency of aircraft operations at a given altitude or volume of airspace.

This document is consistent with FAA guidance for ConOps development, and provides concept-level requirements for supporting services, systems, technologies, tools, procedures, and airspace changes. Scenarios and procedures to be enabled by PTM-O are the focus of this document. PTM-O is limited to oceanic en route operations. It is intended to be effective in all oceanic airspace route structures. Aircraft data transmitted via Automatic Dependent Surveillance – Broadcast (ADS-B) will be used by the PTM-equipped aircraft. The end-state operational concept of PTM-O will be integrated with the controller's decision-support tools.

1.1 Background

To prepare the National Airspace System (NAS) for the traffic volume increases predicted by 2025 and to improve the efficiency of the air transportation system, Congress enacted the Vision 100 – Century of Aviation Reauthorization Act in 2003, and created the Joint Planning and Development Office (JPDO). The JPDO – composed of representatives from the Federal Aviation Administration (FAA), NASA, the aviation industry, the Departments of Transportation, Defense, Homeland Security, and Commerce, and the White House Office of Science and Technology Policy – was tasked to develop a vision of the NAS in the year 2025 that promotes scalability of air traffic operations. The JPDO published a Concept of Operations for NextGen that describes a high-level vision for the air transportation system for the year 2025, including a description of the roles for the various operating elements within the air transportation system. The PTM-O ConOps is thematically consistent with this JPDO NextGen ConOps.

1.2 Problem Statement

The FAA predicts continued growth in oceanic operations. Due to limitations in surveillance and communications, required separation standards in oceanic airspace are large enough to cause

inefficiencies. These inefficiencies include flights being unable to operate at their desired altitude for extended periods of time, flights being unable to operate on their desired routes, and flights required to change altitudes for crossing traffic. These system inefficiencies increase flight time and fuel burn (from both operating at less than fuel-efficient speeds and operating at other than optimal altitudes).

1.3 Concept Overview

Pair-wise Trajectory Management (PTM) is a concept that includes airborne and ground-based capabilities designed to enable and to benefit from airborne pair-wise distance-monitoring capability. The controller, using ground-based decision-support automation, issues a pair-specific PTM clearance to a PTM aircraft that resolves a conflict for the specific pair of aircraft. This clearance, when accepted, requires the flight crew of the PTM aircraft to use their ADS-B-enabled onboard equipment to remain at a defined minimum distance or greater from the designated aircraft. When the controller assesses that the operation is completed and the PTM clearance is no longer required, the PTM clearance is terminated. PTM is used to resolve a specific traffic conflict (or conflicts), identified by the ground system, with a potentially more efficient maneuver or altitude assignment and a possible reduction in controller workload.

Due to the precision of ADS-B In and the elimination of communication delays, the PTM minimum required distance will be less than distances that the controller can support with current ground automation, and the PTM aircraft may not need to maneuver at all in many crossing situations. Also, this reduction in minimum distance will permit more aircraft to operate at a desired altitude for extended periods (in track operations). The objective of PTM and resulting benefits are achieved by permitting the controller to assign a PTM clearance so that the flight crew will resolve specific conflicts identified by the ground when the ground automation system indicates that PTM is available. The flight crew can then rely on the PTM equipment to ensure operations no closer than the PTM distance while flying a more desired trajectory.

PTM should save fuel and reduce delays by improving operations that increase time on an aircraft's optimal trajectory (track and altitude). The airborne managed distance can allow for higher throughput and generally more efficient aircraft operations.

2. Changes to Current Operations and Capabilities

This section provides a description of the present-day oceanic operations in US-managed oceanic airspace, with emphasis on aspects that PTM-O proposes to change.

2.1 Roles and Responsibilities in Current and Proposed Operations

Currently, oceanic operations are characterized by aircraft flying on long-range routes and making position reports to enable the air traffic authority to provide separation from other aircraft. These position reports are often automated. Of significance, the operational

environment for PTM-O applications is one in which no radar surveillance is available to the controller.

2.1.1 Air Traffic Controller

Within the current oceanic system, a controller has an assigned section of airspace. This airspace might cover a geographic area, involve a limited altitude band, or in some cases be for a particular route or a track within an organized track structure. In each case, the controller is responsible for maintaining separation between all aircraft in their assigned airspace. This is accomplished by having a method of determining aircraft position and projected positions (position reports and ground automation support), and applying rules, techniques, and skill to identify conflicts in a timely manner and resolve them prior to a loss of separation. In addition to position reports from the aircraft, the controller has a method of communicating with the flight crew. For most oceanic operations this communication is done over Controller Pilot Data Link Communications (CPDLC).

The roles and responsibilities change little with PTM-O. The controller is still responsible for identifying conflicts and taking timely action to ensure resolution. This basic concept is not intended to change with PTM-O; however, the controller will have an additional tool (PTM) to use to resolve conflicts.

2.1.2 Flight Crew

A flight is qualified for PTM-O when certified PTM-O avionics are installed and the flight crew has completed the training necessary to file PTM-O operations in the flight plan. When a controller issues a PTM-O clearance to a flight crew, the flight crew will use the onboard automation to determine if they are capable and willing to accept the clearance. If they accept the clearance, they are accepting responsibility to monitor the distance to the designated aircraft, and if necessary maneuver, so as to ensure that they operate no closer than the minimum distance from the assigned designated aircraft. The flight crew responsibility is to follow the PTM-O avionics guidance. The PTM-O avionics identify any potential conflicts with designated aircraft.

The guidance (along with suitable alerting) will be provided to the flight crew with an interface function that resides either within the current displays, or through an auxiliary display function.

2.2 Current and Required Supporting Infrastructure

Currently, US-controlled oceanic airspace is managed with the Advanced Technology and Oceanic Procedures (ATOP) system (which includes the Ocean 21 system and controller interface). This system gathers aircraft position information either through ADS-C position reports or HF voice position reports. Using this information and the aircraft's flight plan, the system projects the future position of each aircraft. The system includes a conflict probe that is used to identify potential traffic conflicts up to two hours in the future. The separation standard that is applied for conflict detection may vary by aircraft, and is a function of the type,

frequency, and/or quality of the position reports received from each aircraft as well as aircraft equipment.

Conflicts that are projected to occur between two hours and 30 minutes prior to loss of separation are displayed to the controller with an advisory conflict alert indication. Conflicts displayed to the controller that are not resolved within 30 minutes prior to loss of separation are given a higher level of alerting in their display. The ATOP system displays a list of all active (unresolved) conflicts.

The Ocean 21 system uses intent information on all aircraft (via the flight plan) to predict future trajectories. It also provides a method of communication between the controller and flight crew. Finally, as appropriate clearances are input into the system, it removes resolved conflicts from the conflict list. All three of these capabilities will be utilized in supporting PTM-O operations.

3. Justification and Description of Changes

The core concept of PTM is continued strategic management of traffic conflicts by the controller with tactical trajectory management assigned to the aircraft.

With the current tools, the controller is often forced to have a negative impact on aircraft operations in order to provide required separation. This can be in the form of being unable to grant a desired altitude, being required to give an altitude change for aircraft that are crossing, providing more than the required minimum separation for a safety buffer, or even restricting the capacity of a section of airspace based on controller workload.

PTM-O should enable more aircraft in-trail at a given altitude, better-managed and closer crossing traffic, and more flexible weather deviations. PTM-O is able to achieve this with enhanced (and localized) surveillance and communication along with hardware and software support for the controllers and flight crews.

The PTM-O ConOps addresses essential elements of NextGen by integrating several important flight-deck and ground-based technologies to achieve trajectory-based operations that resolve ATC-identified conflicts on a local level. PTM-O implementation will:

- Maximize localized en route capacity at a specific altitude by implementing:
 - Reduced separation distances,
 - Flight deck and ground-based systems to improve the controller's and flight crew's ability to identify, assign, and resolve specific conflicts.
- Reduce controller workload:
 - Controller is only required to identify PTM designated conflicts,
 - ATOP system communicates the clearance for the controller and shows PTM as the resolution.
 - ATOP identifies when non-PTM separation is re-established.
- Increase the efficiency of en route aircraft operations by:
 - Reducing fuel burn by permitting more time at optimal altitudes,
 - Reduce flight time by eliminating traffic avoidance maneuvers,

- Increase passenger safety and comfort by allowing more route flexibility in the avoidance of en route weather or turbulence.
- Promote accelerated ADS-B equipage, particularly ADS-B In, and enable other advanced capabilities.

3.1 PTM-O System Changes

Implementation of PTM-O will require new functionality in ground-based decision-support automation for ATC as well as in flight-deck avionics.

3.1.1 ATC Ground Automation Support

PTM-O operations will require significant integration with the controller's ground automation system. Some of the anticipated ground system functionality should include:

- a) Identify potential PTM situations.
- b) Formulate clearances for the controller to issue.
- c) Send data directly to the PTM avionics to include intent information on designated aircraft and limits on maneuver options for the PTM operation.
- d) Recognize accepted PTM clearances (and consider designated conflicts resolved).
- e) Identify when non-PTM separation is re-established.
- f) Notify the controller that PTM is no longer required, and be able to send a pair-specific PTM cancellation message to the avionics.

3.1.2 PTM-O Avionics

The PTM avionics will need numerous functions certified. Some of the anticipated functions include:

- a) The ability to receive PTM clearance data from the ground system.
- b) Conflict detection on the designated aircraft (possible multiple designated aircraft).
- c) Conflict resolution on all designated aircraft within the issued maneuver constraints (or notification to the flight crew when a resolution is not available).
- d) Status monitoring and appropriate notification of status of PTM system elements.
- e) Interface with flight crew suitable for trajectory management.
- f) Adequate alerting to crew of failure to comply with resolution instructions that may result in a loss of PTM separation.

4. PTM-Oceanic Concept of Operations

The following subsections describe the PTM concept, the capabilities of the air and ground PTM decision-support tools, and the roles of the controllers and flight crews that enable the PTM operations.

4.1 Assumptions and Constraints

PTM is employed, depending on local constraints and traffic characteristics, to support several different types of operations. For example, a PTM clearance could be used to resolve a short-term conflict (such as one aircraft climbing through the altitude of another) or could be used for an extended period of time (same track). The controller issues PTM clearances to instruct the flight crew to resolve specific conflicts using the PTM equipment and procedures. PTM is not an available option for the controller in all situations. Additionally, some conditions may cause the flight crew to refuse the PTM clearance. Certain geometries may prevent the availability of PTM to be used by either the controller or flight crew. The availability of a PTM resolution to a conflict does not necessarily make it the preferred option for the controller. PTM is not intended to take away the controller's discretion in the management of their sector.

The controller, with information provided by supporting ground-based automation, identifies the aircraft in conflict, and determines that a PTM clearance is an available option (based on a number of factors including aircraft equipment and the likelihood that the conflict aircraft is within the ADS-B signal range of the PTM aircraft). The controller determines whether the PTM clearance can be issued immediately or if there is any delay until the aircraft involved are expected to be within a nominal ADS-B signal range.

The controller then issues a PTM clearance, which may include maneuver limitations (e.g., lateral deviation from flight plan track or Mach constraints) to avoid creation of additional conflicts. Maneuvers are always limited to lateral, longitudinal, or both. For PTM-O, the vertical maneuver remains in the domain of the controller and PTM-O procedures will not include consideration of vertical separation. In other words, all conflict detection (CD) and conflict resolution (CR) must be performed as if all designated aircraft are co-altitude.

The PTM aircraft must also have target aircraft intent data. This data will be transmitted to the PTM aircraft along with the PTM clearance. When received, the PTM clearance data and intent information are loaded into the PTM avionics. The PTM system will check that the target aircraft is identified and suitable for a PTM maneuver. If suitable, the PTM avionics will indicate to the flight crew that the PTM clearance can be accepted. Once accepted, the PTM system provides guidance to the flight crew to avoid or resolve the conflict until controller-managed separation is again established (and the controller sends a pair-specific PTM termination message).

4.2 Operational Environment

PTM-O operations can be used in non-surveillance en route airspace with any current type of route structure (organized tracks, User Preferred Routes, and fixed tracks). PTM-O operations are possible regardless of the associated traffic densities and the types of aircraft flying in the airspace. PTM operations can occur in all weather conditions that the aircraft could otherwise operate in.

4.3 Operations

There are two participants in a PTM operation: the controllers and the flight crew of the PTM aircraft. The controllers remain responsible for issuing clearances that ensure separation of all aircraft, including both the PTM aircraft and the PTM designated aircraft. From a controller perspective, the PTM clearance should (from a responsibility perspective) be similar to a controller allowing a pilot to provide his own visual separation from another IFR aircraft in areas where this is authorized. From a pilot perspective, this is different from a visual clearance in terms of the pilot's enhanced ability to comply with the clearance.

4.3.1 Roles and Responsibilities of the Air Traffic Controller

At the initiation of a PTM operation, the controller provides instructions to the flight crew defining the limits of the PTM maneuver. Depending on the characteristics of the airspace, these instructions may include altitudes, speeds, and crossing restrictions. The flight crew will always have an incomplete picture of the controller's traffic and strategic traffic management plan. The pilot and PTM avionics can only manage distance from specifically designated aircraft in a tactical manner. The controller maintains responsibility for all other aircraft.

To make use of the PTM clearance, the controller is responsible for:

- Determining if a PTM clearance is suitable, including PTM equipage.
- Determining and verifying the PTM aircraft and the designated aircraft call signs.
- Ensuring separation between the PTM aircraft and all other aircraft, excluding the designated aircraft. This may require maneuver limits given with the PTM clearance.
- Ensuring that the designated aircraft is not authorized to deviate from its cleared flight plan during the duration of the PTM maneuver.
- Terminating the PTM operation when non-PTM separation is re-established.

4.3.2 Roles and Responsibilities of the PTM-O Flight Crew

The PTM operation puts additional responsibilities on the flight crew of the PTM aircraft. They include:

- Determining whether or not to engage the PTM system.
- Validating the operational status of the PTM equipment.
- Being familiar with and prepared to execute appropriate maneuvers should the PTM equipment fail (failure could include the designated aircraft ADS-B transmitter failing).
- Complying with maneuver instructions displayed by the PTM system.
- Being able to return to the cleared ATC flight plan when appropriate.
- Acknowledging instructions from the controller that terminate the PTM operation and resuming normal operations.
- Returning to the cleared flight plan.

4.4 Benefits to be Realized

This procedure will permit properly equipped aircraft to save fuel and reduce delays by using assigned, pair-wise distance assurance to avoid maneuvers that increase time from an aircraft's optimal trajectory (track and altitude). Additionally, flight crews will be able to use PTM-O operations in conjunction with onboard situation awareness displays to avoid adverse winds and turbulence, thereby increasing operational efficiency and passenger comfort.

5. Operational Scenarios

This section describes in detail the various types of PTM maneuvers supported, multiple simultaneous PTM clearances.

5.1 PTM-O Clearance Maneuvers

There are three types of PTM maneuvers. They are lateral, longitudinal (speed), and a combination of both. The type of PTM maneuver is determined by ATC when the clearance is issued. The clearance may include a limit on the amount of lateral freedom allowed within the specified maneuver, such as 30nm (or less) right (or left) of course, or a limit on longitudinal freedom, such as greater (or less) than a specific Mach number. In every case, both the PTM avionics and the flight crew need to be aware of any restrictions. The flight crew will assess if it is an appropriate constraint (lateral maneuver might enter severe weather, or Mach is too slow), and the avionics needs to confirm a conflict resolution is available with the given constraint.

5.1.1 Lateral PTM

For conflicts with significant crossing angles (to be determined, but perhaps greater than 10 degrees) lateral maneuvers are preferred. The lateral PTM is one in which the aircraft is authorized some amount of lateral maneuvering to resolve a conflict with one or more designated aircraft.

When a PTM aircraft is issued a clearance with a designated aircraft, the PTM avionics will first determine if there is a conflict that needs to be resolved by maneuvering. The PTM designated aircraft might be passing too close for the controller's separation distance, but with more distance than is required for PTM operations. In that case, simply continuing on the planned trajectory will result in no conflict for the PTM system. If the PTM system determines that there is a conflict requiring maneuvering for resolution, it will determine if the lateral maneuvering available is adequate to resolve the conflict. If there is a PTM conflict resolution maneuver available, the PTM avionics will enable acceptance of the PTM clearance. The flight crew will need to review the planned resolution maneuver to determine if the lateral maneuver is acceptable (e.g., it might plan a turn into significant weather).

5.1.2 Longitudinal PTM (Speed Managed)

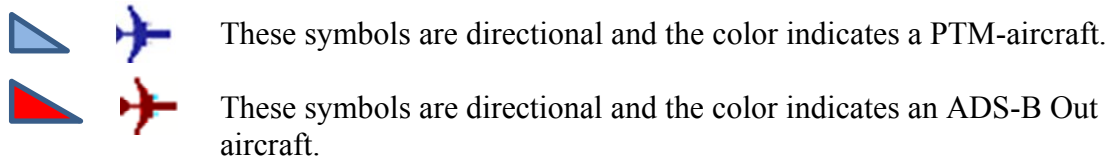
It is anticipated that there are traffic situations (and possibly airspace configurations) where lateral maneuvers are not possible (e.g., an organized track system). Since the PTM aircraft is not able to consider vertical separation, the only conflict resolution left at these times is longitudinal. Longitudinal resolutions involve speed changes or restrictions. In these cases, the crew will be commanded by the PTM avionics to fly a specific Mach, or within a Mach range limit. This may be the preferred CR method for some identical track co-altitude operations.

5.1.3 Combined PTM

If a controller has two aircraft at the same altitude and no relevant proximate aircraft, it would be advantageous to restrict the maneuvering of the PTM aircraft as little as possible. The PTM avionics should be programmed to offer the most efficient resolution to any detected conflict within any maneuver constraints that are given.

5.2 Scenarios

The following scenarios are included to illustrate the concept but are not intended to represent the complete range of possible PTM geometries or supporting systems' functionalities. Each scenario description gives an overview of the operation that is being performed, and what aspects of PTM are being stressed by the scenario. For all graphic depictions, the following applies:



5.2.1 Same-Track, Co-Altitude Scenario

In this first scenario, the PTM aircraft, operating at Flight Level (FL) 330, is overtaking a co-altitude ADS-B Out aircraft on the same route. See Figure 1.

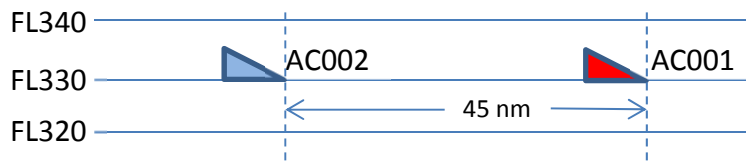


Figure 1. Same-track, co-altitude scenario.

When the controller determines that a conflict exists and an intervention action is required, the controller might issue the overtaking aircraft a speed restriction (to eliminate the overtake). However, if the automation indicates that a PTM clearance is available, the controller would have the option to issue a clearance to maintain current flight level, PTM with AC001.

In this example, if there is no proximate traffic (perhaps on parallel tracks) the clearance would include a message to the PTM avionics authorizing lateral maneuvers. The PTM avionics could then offer a lateral maneuver prompt in lieu of a speed reduction, effectively allowing passing.

5.2.2 Same-Track, Altitude Change Scenario

In this scenario, the PTM aircraft is requesting a climb that would cause a conflict with an ADS-B out aircraft. The same-track scenario is a demonstration of the core PTM capability. Initially, it is possible that this will be the most common application of PTM.

General conditions:

- Aircraft are currently vertically separated
- Aircraft are on the same route

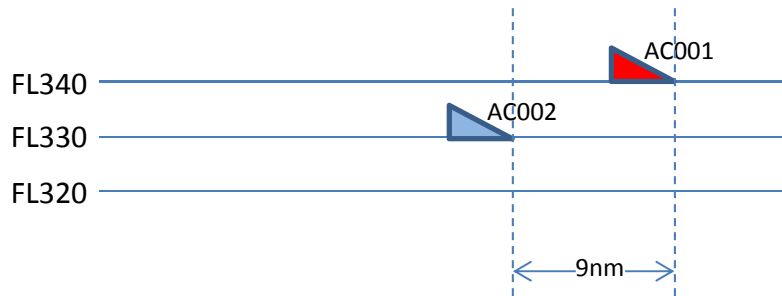


Figure 2. Same-track, altitude-change scenario.

Figure 2 is a profile view representation of two aircraft (AC001 and AC002) operating on same track. In this scenario, the crew of AC002 has requested for operational reasons an altitude change from FL330 to FL340.

The controller receiving the request would observe that the climb would result in an immediate conflict with AC001 at FL340. However, because AC002 has indicated that it is PTM equipped, the ground automation system would indicate the possibility of a PTM clearance (for the controller to issue) that would authorize a climb. The clearance (if issued) would read, “climb and maintain FL340 PTM AC001”.

The PTM avionics will have the PTM clearance loaded and confirm acceptability of the PTM clearance to the flight crew. The PTM system would have the intent information for both aircraft.

If the flight crew elects to accept the PTM clearance, they notify ATC and engage the PTM avionics. The acceptance message to ATC would need to include the PTM portion of the clearance: “Wilco, AC002 climbing FL340 PTM AC001.”

With the PTM operation engaged, a speed (or speed range) will be commanded by the PTM avionics. The PTM pilot interface will show the ATC designated aircraft. The display will also provide information allowing the crew to monitor the operation. Once PTM is engaged, the PTM aircraft can start a normal climb to FL340. In this example the PTM aircraft was the trailing aircraft and the PTM flight crew is responsible for wake turbulence awareness. If the PTM were the lead aircraft, wake issues would be addressed in procedure training and operations.

When the controller determines that non-PTM ground automation system separation is available, the controller will terminate the procedure and instruct the crew to resume normal operations.

5.2.3 Same-Track Loading, Multiple Aircraft Interactions (Track Loading)

It is anticipated that a significant consideration in the benefit case will be the ability to have multiple, co-altitude, same identical track aircraft operating with different equipage levels and with less than standard (non-PTM) separation applied between different pairings. These groups of aircraft are called strings and chains.

5.2.3.1 PTM Strings

A PTM String is formed when:

- There are more than two aircraft in a sequence,
- The separation standard between all aircraft in the sequence is the PTM separation standard,
- There is one (and only one) non-PTM aircraft in the sequence.

A PTM string can be formed in three different ways:

1. The non-PTM aircraft is the leading aircraft
2. The non-PTM aircraft is within the sequence
3. The non-PTM aircraft is the trailing aircraft

5.2.3.2 PTM Chains

A PTM chain is formed when:

- There are more than two aircraft in a sequence,
- There are two non-PTM aircraft in the sequence, one leading and one trailing,
- The separation standard between the two non-PTM aircraft is a non-PTM separation standard,
- All PTM aircraft in the sequence must be assigned and maintain PTM separation from the aircraft in front and aircraft behind

5.2.3.3 PTM Strings and Chains Application and Rules

A common PTM clearance that is bound by the rules of strings and chains occurs when an aircraft on the same track requests a climb that would occur between two aircraft that are flying at the desired altitude in trail of each other with less than twice the minimum standard separation between them. If that is the case, there is no room between them to insert an additional aircraft. If, however, the additional aircraft is PTM equipped, it may be possible to clear the additional aircraft into this otherwise unusable airspace, and thus permit more efficient operations. See Figure 3.

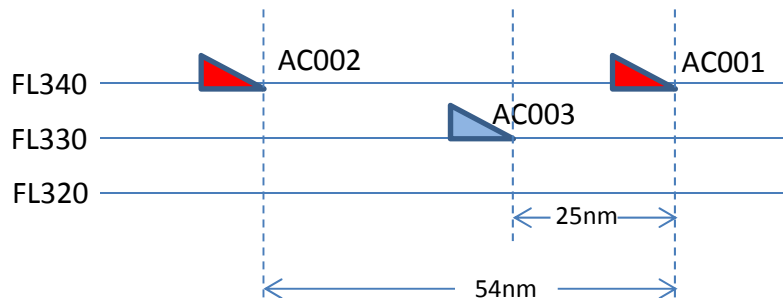


Figure 3. PTM chain.

In this case the controller could use the PTM clearance with: “AC003 climb and maintain FL340 PTM AC001 and PTM AC002.” It is likely that there would also be a requirement to inform the PTM aircraft of the speed assigned to the two designated aircraft so that the PTM aircraft can determine – prior to acceptance – that it is able to maintain position between the two aircraft.

If this clearance were loaded into the PTM avionics, it would enable engagement only if both aircraft are identified with a qualified ADS-B signal and PTM separation is met with both aircraft. Speed guidance would be provided by the PTM avionics to keep the PTM aircraft at a distance greater than the PTM minimum from both aircraft.

The complete set of rules for strings and chains is contained in Appendix A of this document. Because of the complexity of the rules necessary for strings and chains, it is anticipated that they will be included in any ground automation system before the controller is able to apply these rules.

5.2.4 Crossing Scenario

There are two considerations in determining the maximum crossing angle for a pair of aircraft using PTM. One is driven by safety analysis, and the other is due to limitations of the PTM equipment (ADS-B signal range). The safety analysis is not the subject of this paper, but relative closure and time of exposure will be factors to be considered in a safety analysis, the safety analysis might result in crossing angle limits. The other consideration is the requirement that conflicts be resolved by the controller by some time or distance prior to the actual loss of separation. This advance resolution requirement, combined with the range limit on ADS-B signals, will exclude certain crossing geometries.

5.2.4.1 ADS-B Signal Range Impact

Across the world's oceanic regions, there are widely varying separation standards (minimum time or distance) applicable for the controller to use with a specific aircraft pair, from as little as 30nm to as much as 15 minutes (approximately 120nm) between the aircraft. The time or distance prior to the loss of separation when the controller needs to issue a clearance is determined either by local policy and/or controller comfort levels. If a controller has a conflict with two aircraft with a 30nm separation standard, and the controller wants to issue a clearance 40 minutes prior to loss of separation in an environment with a 180nm expected ADS-B range, the crossing angle for PTM would be limited to approximately 30 degrees. The determination of the limiting crossing angle can be managed by the ATC ground automation system if it is aware of the expected ADS-B range, the separation standard being applied, and the clearance lead time.

When the ground automation system reports a conflict with a PTM aircraft and a suitable designated aircraft, it is possible that, at the time that the conflict is reported, the PTM avionics will not have the target aircraft ADS-B signal identified. If a PTM clearance were issued at that time it would be necessary for the flight crew to refuse the clearance. Therefore the controller needs to wait until the ground automation system computes that the two aircraft are close enough to each other (within expected ADS-B range) so that there is a high probability that the PTM avionics will be able to identify the designated aircraft and enable acceptance of the PTM clearance. This will reduce the frequency of PTM refusals.

In the following example, there is an aircraft crossing the PTM aircraft with a 30-degree crossing angle. AC001 is at FL310, and AC002 is at FL300, requesting to climb to FL310. See Figure 4.

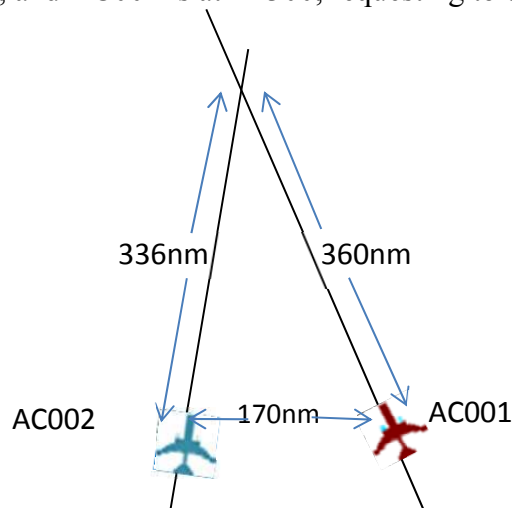


Figure 4. Crossing scenario.

In this example it is assumed that the current minimum separation available with the ATC automation system is 30nm. If the controller probes for a climb, the ground automation will report a conflict with the climb clearance. The controller will review the situation to determine

the best resolution to the conflict, including whether PTM is a suitable solution. An important part of that decision will be determining when it will be possible to issue the PTM clearance. The ATC automation system will indicate whether PTM is available now or at some later time. With a 30-degree crossing geometry, the earliest time to issue a PTM clearance would be approximately 40 minutes prior to the predicted loss of separation. In this example, the predicted loss of separation is in 38 minutes, and the ATC automation would indicate “PTM available now”. The controller could then issue a PTM clearance.

5.2.4.2 Crossing Path

The crossing scenario demonstrates the lateral maneuver capability of PTM operations. In order for a lateral maneuver resolution to be possible for the PTM avionics, the PTM avionics must have intent information for all of the aircraft involved in the PTM maneuver (including ownship).

For the example crossing scenario that was shown in Figure 4, aircraft AC002 and AC001 are moving towards a loss of separation in an oceanic environment (30nm minimum separation). The aircraft are both at FL310, and Mach 0.80. The present time is 1300z. When AC002 passes over the crossing point, the projected path will put AC001 24nm in trail. The ground automation system is reporting that a loss of separation will occur at 1338z, when the distance between the two aircraft will decrease to less than 30nm. The controller may choose to use a PTM clearance to resolve the conflict. The resulting clearance might be: “AC002 maintain FL310 PTM AC001.”

When the PTM clearance is received, the PTM avionics checks against associated criteria, displays to the flight crew the planned maneuver (if any) and enables engagement. In this scenario, it is very likely that, while the aircraft will pass too close for ground automation system separation capability, they will be significantly farther apart than the PTM minimum distance (approximately 24nm vs. a PTM required 5nm). The PTM avionics use data received from AC001 and the ground automation system to predict the time, location, and separation distance of the closest point of approach. Many times the PTM separation standard will result in resolution of the conflict without maneuvering and there is no additional action required by the crew. If the traffic still presents a conflict based on PTM-enabled separation minima, the system displays a resolution, which might be a change in groundspeed or a lateral maneuver. The PTM system provides the appropriate guidance, and additional information that allows the flight crew to monitor the progress of the operation. Once the aircraft have passed the closest point of approach and have achieved a controller-supportable separation distance, the controller can terminate the PTM procedure.

5.2.4.3 Merging Path

PTM crossing functionality can also be utilized when two aircraft merge. This could happen with an aircraft joining an organized route structure at a waypoint along the route. See Figure 5.

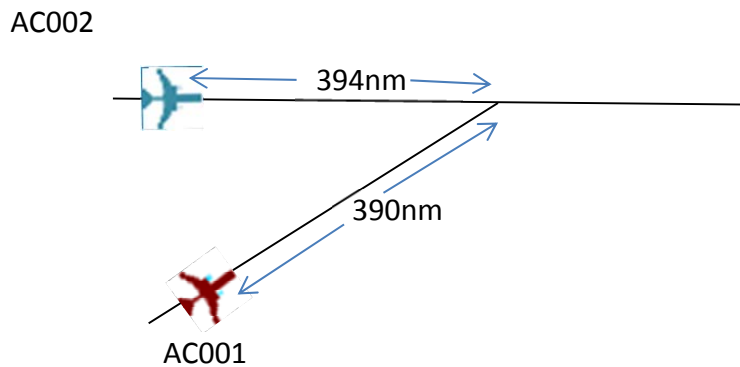


Figure 5. Merging path scenario.

In this scenario, the controller predicts a loss of separation as AC001 joins the track of AC002. Without PTM, the controller would normally change the altitude of either AC002 or AC001, but using PTM, the controller can avoid the altitude change, and transmit the following clearance: “AC002 maintain FL310 PTM AC001.”

The PTM avionics may need to accomplish a path stretch prior to the merge point. While engaged, the PTM avionics compares ownship trajectory with the location and planned trajectory of the designated aircraft, and provides lateral maneuver and/or speed commands that are predicted to result in avoiding a loss of separation.

In the above example, the pair of aircraft will transition to an in-trail maneuver invoking use of the functionality described in earlier scenarios. Once established in the in-trail operation, the avionics will continue to perform a PTM operation on all designated aircraft (it is possible that another aircraft could be designated behind AC002) until a pair-specific terminate message is received from ATC. This could happen after route divergence, if altitude separation is established, or if a speed difference increases the designated aircraft distance to a distance where standard ground automation and the controller are able to maintain non-PTM separation.

5.2.5 Pilot-Managed Route Deviation

While operating en route, it is not uncommon for a flight to need to deviate to avoid weather. When the crew requests a deviation for weather, the controller may need to restrict the amount of deviation or the direction (left or right) due to proximate traffic. See Figure 6.

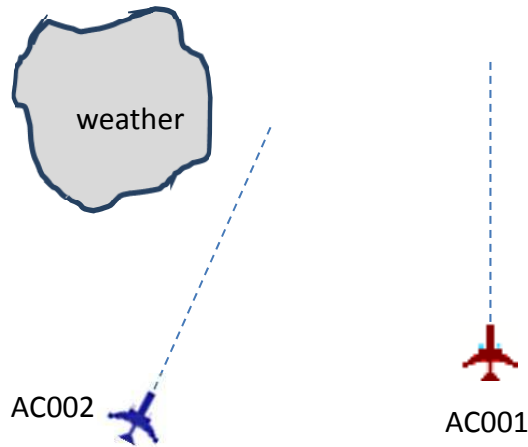


Figure 6. Route deviation due to weather.

However, with PTM available, the controller could now issue a clearance: “AC002, deviate right of course as necessary PTM AC001”. This would enable the crew to maneuver to the right (as preferred and requested), while making the crew of the PTM aircraft responsible for remaining clear of the traffic during the maneuver. In the cockpit, the PTM display would show an alerting band of track angles that, if flown, would produce a conflict.

6. Summary of Impacts

When implemented in oceanic airspace, PTM-O will have significant beneficial impact to both the controller and aircraft operator.

The controller will retain strategic responsibility for all traffic in their sector. However, PTM clearances give them an additional separation standard that they can assign to help them manage traffic. Application of that standard (on a pair-wise basis) should reduce their workload while allowing more flights to operate a greater percentage of time on their desired flight path. If aircraft are able to be cleared as requested, they should make fewer repeat requests, and controllers should have fewer requests in their pending list.

The flight crews, when applying PTM, increase the capacity along the 4D path that they desire to operate on. This should result in more time being spent where the flight crew prefers to fly. The expectation is a better ride, reduced fuel burn and reduced delays.

Appendix A Strings and Chains

This appendix presents a set of definitions, theory, and operational rules for chains and strings in the PTM application.

Section A1 Definitions

PTM separation – PTM separation is an ATC-assigned clearance where a PTM aircraft must maintain a PTM horizontal separation standard between its ownship and one or more designated aircraft. PTM separation does not take into account the vertical dimension.

Legacy separation – Legacy separation is the separation applied by ATC for the given airspace and level of equipment of the aircraft. For example, 50 NM longitudinal and lateral separations could be applied with ADS-C reporting in intervals of 27 minutes and RNP10 aircraft. Legacy separation specifically refers to a separation standard that is not PTM separation.

Separation Standard – A separation standard is a procedure that ATC applies to aircraft traffic to maintain safe separation between aircraft. When ATC is applying a separation standard, the distance between aircraft shall never be less than the separation standard distance.

Separation Standard Distance – The separation standard distance is a minimum distance that shall never be infringed upon during aircraft operations.

PTM Separation Standard Distance – A horizontal distance that must be maintained during a PTM clearance. The horizontal distance between a PTM aircraft and a designated aircraft shall never be less than the PTM separation standard distance while a PTM operation is in effect.

Designated aircraft – an aircraft from which the PTM aircraft must maintain separation.

PTM pair – a PTM pair is a pair of aircraft where one aircraft is a designated aircraft and one aircraft is a PTM aircraft with a clearance to maintain separation from the designated aircraft.

Same Identical Tracks – Two aircraft are on same identical tracks when they are on the same route and following the same waypoints along a track. Same identical tracks are a special case of same track (as defined in ICAO PANS-ATM Doc. 4444 and FAA JO 7110.65) where the angular difference is zero degrees.

Same Tracks – (As defined in ICAO PANS-ATM Doc. 4444 and FAA JO 7110.65) – Same direction tracks and intersecting tracks or portions thereof, the angular difference of which is less than 45 degrees or more than 315 degrees, and whose protected airspaces overlap.

Sequence – An ordered series of aircraft operating on a common track.

PTM String – A sequence of aircraft following the rules stated in Section A2 of this document.

PTM Chain – A sequence of aircraft following the rules stated in Section A3 of this document.

Section A2 PTM Strings

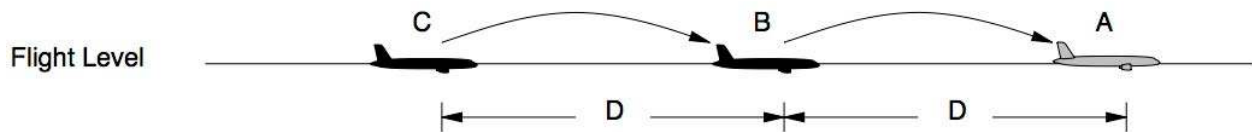
A PTM string is formed when:

- There are more than two aircraft in a sequence,
- The separation standard between all aircraft in the sequence is PTM separation,
- There is one (and only one) non-PTM aircraft in the sequence.

A PTM string can be formed in three different ways:

4. The non-PTM aircraft is the leading aircraft (Figure A2-1)
5. The non-PTM aircraft is within the sequence (Figure A2-2)
6. The non-PTM aircraft is the trailing aircraft (Figure A2-3)

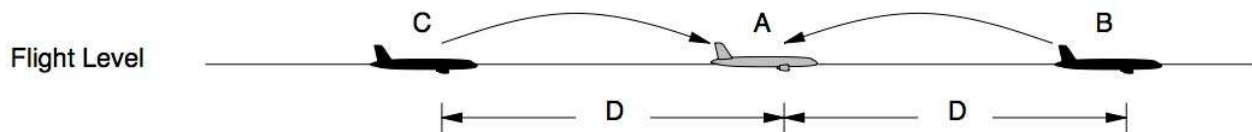
Examples of PTM Strings are shown in Figures A2-1, A2-2 and A2-3. In these Figures, the black aircraft denote PTM aircraft and the grey aircraft denote non-PTM aircraft. Figure A2-1 shows the case where the non-PTM aircraft is the lead aircraft. In the example, aircraft C and B are given PTM clearances to maintain separation from aircraft B and A, respectively. Aircraft A is the designated aircraft for aircraft B and aircraft B is the designated aircraft for aircraft C.



$D \geq$ PTM Separation Standard Distance

Figure A2-1. Case 1. PTM string with non-PTM aircraft in the lead.

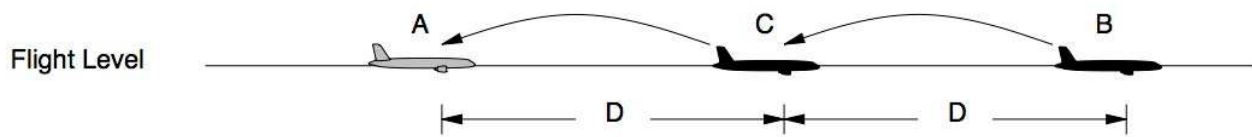
Figure A2-2 shows the case where the non-PTM aircraft is within the sequence. In the example, aircraft B and C are given PTM clearances to maintain separation from aircraft A. Aircraft A is the designated aircraft for both aircraft B and C.



$D \geq$ PTM Separation Standard Distance

Figure A2-2. Case 2. PTM string with non-PTM aircraft inside the sequence.

Figure A2-3 shows the case where the non-PTM aircraft is the trailing aircraft. In the example, aircraft B and C are given PTM clearances to maintain separation from aircraft C and A, respectively. Aircraft C is the designated aircraft for aircraft B and aircraft A is the designated aircraft for aircraft C.



$D \geq$ PTM Separation Standard Distance

Figure A2-3. Case 3. PTM string with non-PTM aircraft as the trailing aircraft.

PTM String Rules

- 1) There can be only 1 non-PTM aircraft in a string. That non-PTM aircraft can be at the front of the string, within the string, or at the end of the string.
- 2) The non-PTM aircraft will be assigned a Mach speed.
- 3) All PTM aircraft in a string will be informed of the assigned Mach as the baseline Mach.
- 4) PTM aircraft with the designated aircraft behind them will be cleared to fly a speed no more than the baseline speed. (The PTM aircraft could increase its speed over baseline speed by 0.01 to 0.02 Mach only to maintain separation from the designated aircraft.)
- 5) PTM aircraft with the non-PTM aircraft in front of them will be cleared to fly a speed no less than the baseline speed. (The PTM aircraft could decrease its speed below baseline speed by 0.01 to 0.02 Mach only to maintain separation from the designated aircraft.)
- 6) In a PTM string, all PTM clearances will have the designated aircraft in the direction of the non-PTM aircraft.
- 7) The string begins and ends with an interval of legacy separation.
- 8) Lateral maneuvers (except SLOP¹) are not authorized for any aircraft which is a designated aircraft in a PTM clearance.

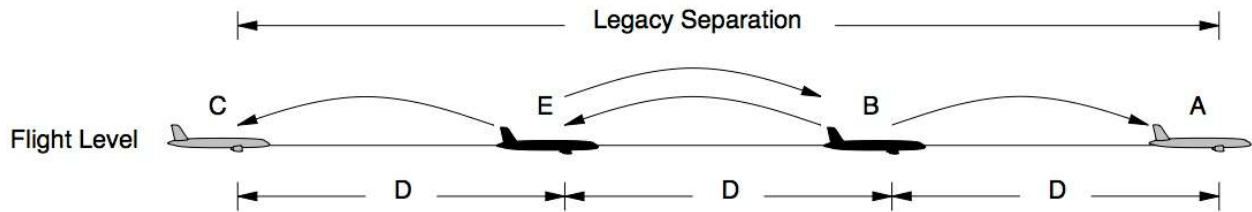
¹ SLOP is the Strategic Lateral Offset Procedure that allows aircraft in Oceanic airspace to move 1 or 2 nautical miles to the right of the track center-line to reduce wake turbulence encounters and risk of collision.

Section A3 PTM Chains

A PTM chain is formed when:

- There are more than two aircraft in a sequence,
- There are two non-PTM aircraft in the sequence, one leading and one trailing,
- The separation standard between the two non-PTM aircraft is legacy separation,
- All PTM aircraft in the sequence must be assigned and maintain PTM separation from the aircraft in front and aircraft behind.

Figure A3-1 shows an example of a PTM chain. The black aircraft denote PTM aircraft and the grey aircraft denote non-PTM aircraft.



$D \geq$ PTM Separation Standard Distance

Figure A3-1. PTM Chain

In the example of Figure A3-1, ATC is implementing legacy separation between aircraft A and C. Aircraft B is given PTM clearances to maintain separation from aircraft A and E. Aircraft E is given PTM clearances to maintain separation from aircraft B and C.

The maximum number of PTM aircraft in a chain where the non-PTM aircraft are at the minimum Legacy separation distance is defined by the following equation truncated to an integer:

$$\frac{\text{Legacy Separation} - \Delta_1}{\text{PTM Separation} + \Delta_2} - 1 \quad (1)$$

where Δ_1 and Δ_2 are separation buffers.

PTM Chain Rules

- All PTM aircraft in a chain must be assigned PTM separation with the aircraft immediately in front and the aircraft immediately behind.
- The first aircraft in the chain, a non-PTM aircraft, will be instructed to maintain the baseline Mach number or greater.
- The last aircraft in the chain, a non-PTM aircraft, will be instructed to maintain the baseline Mach number or less.
- All PTM aircraft in a chain will be informed of the baseline Mach.
- PTM aircraft will be able to deviate from the baseline Mach by 0.01 to 0.02 Mach to maintain separation.
- Lateral maneuvers (except SLOP¹) are not authorized for any aircraft which is a designated aircraft in a PTM clearance.

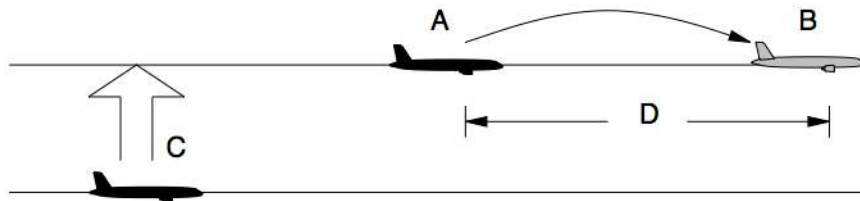
Section A4 Processes for Creating Strings

A string is created when a clearance is given to a PTM-capable aircraft to maintain PTM separation with an aircraft that is already part of a PTM pair (See definition of PTM pair in Section 1). The new PTM clearance could use the designated aircraft in the PTM pair as the designated aircraft or it could use the PTM aircraft in the PTM pair as the designated aircraft. The new aircraft joining the aircraft pair to form the PTM string could climb or descend to the flight level of the PTM pair or it could join the pair horizontally.

PTM Rules for forming strings

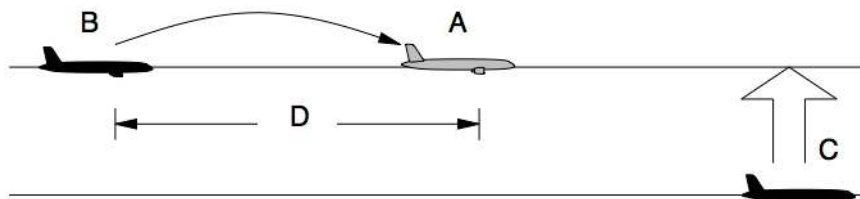
Case 1. Climb or descend to PTM pair flight level, trailing or leading the pair, Figures A4-1 and A4-2.

- 1) ATC must determine if the aircraft to join the PTM pair is trailing, in-between or leading the PTM pair. If the aircraft to join the pair is trailing or leading the pair, Case 1 applies.
- 2) ATC issues PTM clearance to aircraft C, above or below the PTM pair, to maintain PTM separation from aircraft A.
- 3) If PTM separation exists between aircraft C and aircraft A, aircraft C accepts the clearance and maintains separation from A. ATC issues a climb or descent instruction to aircraft C.
- 4) If PTM separation does not exist between aircraft C and aircraft A, aircraft C informs ATC “unable PTM”.



$D \geq$ PTM Separation Standard Distance

Figure A4-1. Formation of a string by climbing or descending to the PTM pair flight level, trailing



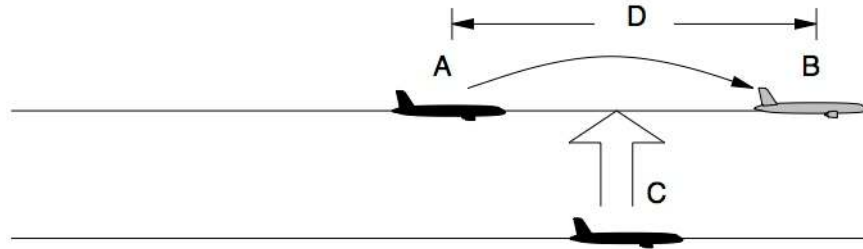
$D \geq$ PTM Separation Standard Distance

Figure A4-2. Formation of a string by climbing or descending to the PTM pair flight level, leading

Case 2. Climb or descend to PTM pair flight level, between the aircraft in the PTM pair, Figure A4-3.

- 1) ATC must determine if the aircraft to join the PTM pair is trailing, in between or leading the PTM pair. If the aircraft to join the pair is between the aircraft in the pair, Case 2 applies.

- 2) ATC gives clearance to aircraft C to maintain separation from aircraft B.
- 3) If PTM separation exists between aircraft C and aircraft B, aircraft C accepts the clearance.
- 4) ATC gives clearance to aircraft A to maintain separation from aircraft C.
- 5) If PTM separation exists between aircraft A and aircraft C, aircraft A accepts the clearance. ATC cancels PTM separation between aircraft A and aircraft B. ATC issues a climb or descent instruction to aircraft C.
- 6) If PTM separation does not exist between aircraft C and B and/or aircraft A and C, the flight crew of C and/or the flight crew of A inform ATC “unable PTM”.



$D \geq$ PTM Separation Standard Distance

Figure A4-3, Formation of a string by climbing or descending to the PTM pair flight level, between the aircraft

Case 3. Join PTM pair horizontally, same identical track, same track or merge, Figure A4-4.

- 1) ATC determines if the aircraft to join the PTM pair is merging behind or in front of the pair.
- 2) Aircraft C is at same flight level as aircraft A and B.
- 3) Aircraft B is maintaining PTM separation from aircraft A.
- 4) Aircraft C has legacy separation from aircraft A.
- 5) ATC assigns a PTM clearance to aircraft C to maintain separation from aircraft A.

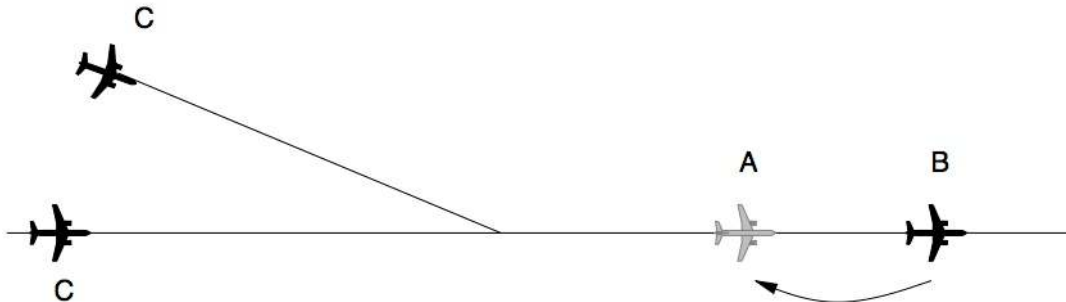


Figure A4-4. Formation of string horizontally, same identical track, same track or merge

Case 4. Join PTM pair horizontally, transition from radar to non-radar, Figure A4-5.

- 1) Radar separation exists between aircraft B and C.
- 2) Aircraft C is maintaining PTM separation from aircraft A.
- 3) ATC gives clearance to aircraft B to maintain PTM separation from aircraft C.

- 4) If PTM separation exists between aircraft B and C, aircraft B accepts the clearance (aircraft goes from being a non-PTM aircraft to a PTM aircraft).
- 5) If PTM separation does not exist between aircraft B and C, aircraft B informs ATC “unable PTM”.
- 6) As the aircraft progress forward into the non-radar environment, aircraft B will maintain PTM separation from aircraft C (distance D)

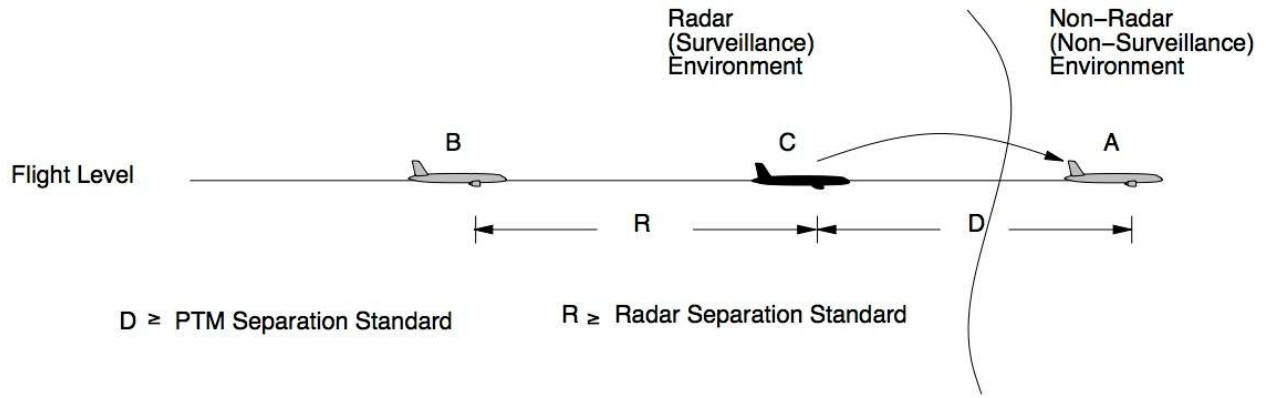


Figure A4-5. Formation of string horizontally, transition from radar to non-radar environment

Section A5 Processes for Creating Chains

A chain can be formed by inserting a PTM aircraft between two designated aircraft or by adding a designated aircraft to a PTM pair. The chain can be formed vertically or horizontally.

PTM Rules for forming Chains

Case 1. PTM aircraft climbs or descends to flight level between two designated aircraft, Figure A5-1.

- 1) ATC must determine if the aircraft that will be given the PTM clearance is between the two aircraft that will become the designated aircraft.
- 2) Aircraft A and B are at the same flight level and have legacy horizontal separation.
- 3) ATC clears aircraft C to maintain PTM separation from aircraft A and B.
- 4) If PTM separation exists between aircraft C and aircraft A and B, aircraft C accepts the clearance. ATC climbs/descends aircraft C.
- 5) If PTM separation does not exist between aircraft C and aircraft A or B, aircraft C informs ATC “unable PTM”.

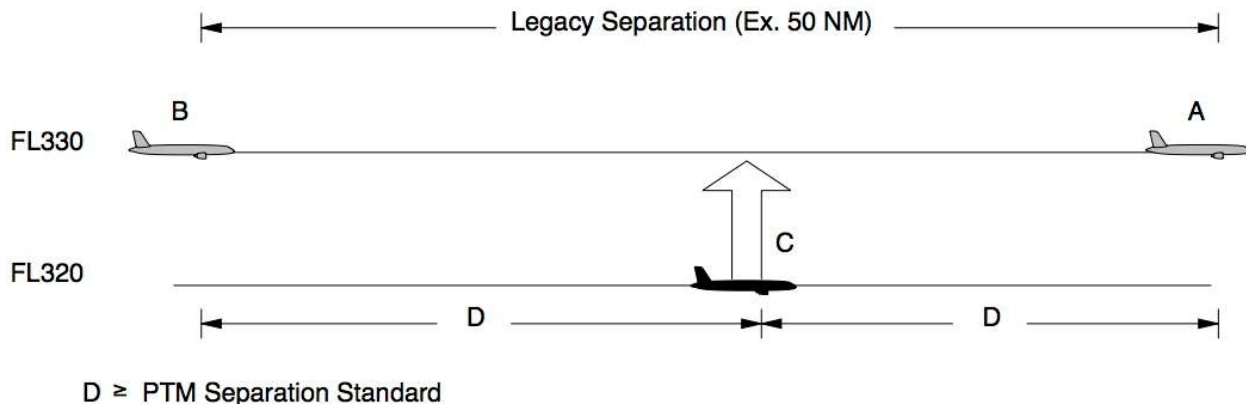


Figure A5-1. Formation of chain by climbing or descending between designated aircraft

Case 2. Designated aircraft climbs or descends to flight level of PTM pair, Figure A5-2.

- 1) ATC must determine if the aircraft that will become the designated aircraft is trailing or leading the PTM pair.
- 2) ATC must determine if horizontal legacy separation exists between aircraft A and B.
- 3) If legacy separation exists between aircraft A and B, ATC issues PTM clearance to aircraft C to maintain PTM separation from aircraft B.
- 4) If PTM separation exists between aircraft C and aircraft B, aircraft C accepts the clearance. ATC climbs/descend aircraft B.
- 5) If PTM separation does not exist between aircraft C and aircraft B, aircraft C informs ATC "unable PTM".

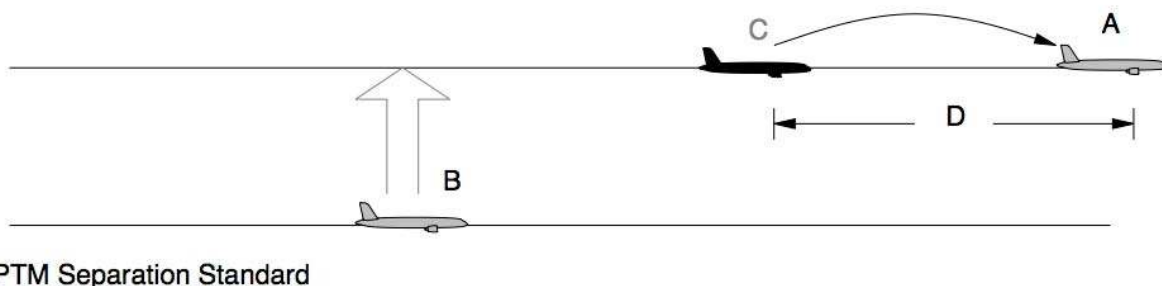


Figure A5-2. Designated aircraft climbs or descends to the flight level of the PTM pair

Case 3. PTM aircraft in a PTM pair is cleared to maintain separation with a designated aircraft at the same flight level.

- 1) ATC must maintain legacy separation between aircraft A and B.
- 2) ATC issues PTM clearance to aircraft C to maintain separation from aircraft B.
- 3) If PTM separation exists between aircraft C and B, aircraft C accepts the clearance.
- 4) If PTM separation does not exist between aircraft C and B, aircraft C informs ATC "unable PTM".

Section A6 Process for adding an aircraft to a string

A PTM-capable aircraft could join an existing string to form a longer string. A non-PTM-capable aircraft can join an existing string to form a chain. When a PTM capable aircraft is going to join an existing string, the relative position of the joining aircraft must be determined with respect to the aircraft in the existing string.

Case 1. Climb or descend to PTM string flight level, trailing or leading the string. Figures A6-1 and A6-2.

- 1) ATC must determine if aircraft to join the PTM string is trailing, in-between or leading the PTM string. If aircraft to join the string is trailing or leading the string, Case 1 applies.
- 2) ATC issues PTM clearance to aircraft E, above or below the PTM string, to maintain PTM separation from aircraft C.
- 3) If PTM separation exists between aircraft E and aircraft C, aircraft E accepts the clearance and maintains separation from C. ATC issues a climb or descent instruction to aircraft E.
- 4) If PTM separation does not exist between aircraft E and aircraft C, aircraft E informs ATC “unable PTM”.

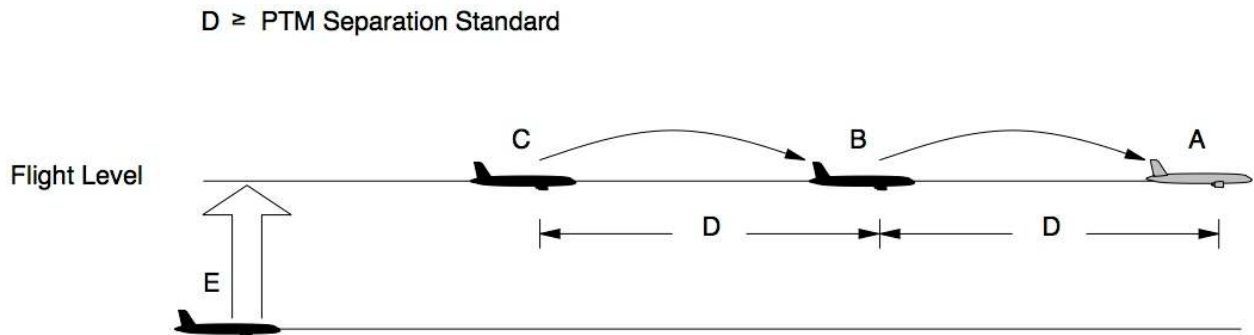


Figure A6-1. Joining a string by climbing or descending to the PTM string flight level, trailing

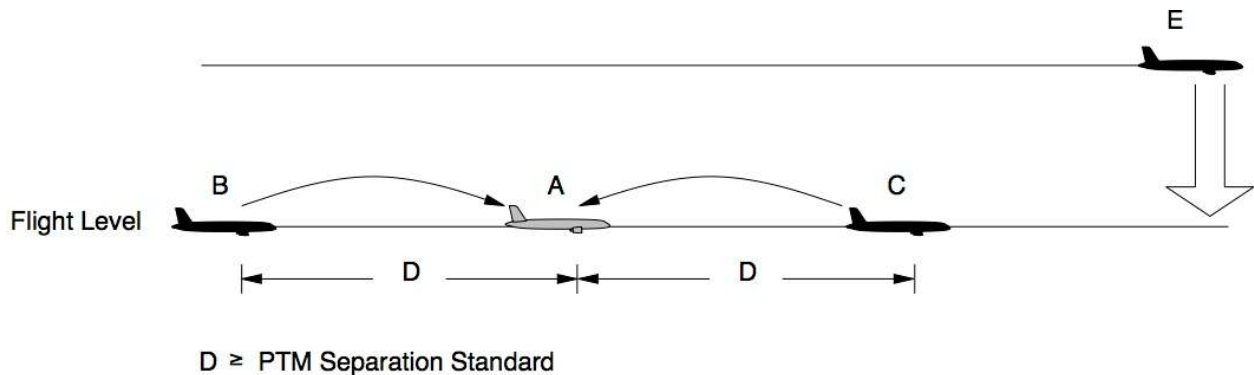


Figure A6-2. Joining a string by climbing or descending to the PTM string flight level, leading

Case 2. Climb or descend to PTM string flight level, between the aircraft in the PTM string, Figure A6-3.

- 1) ATC must determine if the aircraft to join the PTM string is trailing, in-between or leading the PTM string. If the aircraft to join the string is between the aircraft in the string, Case 2 applies.
- 2) ATC gives clearance to aircraft E to maintain separation from aircraft B.
- 3) If PTM separation exists between aircraft E and aircraft B, aircraft E accepts the clearance.
- 4) ATC gives clearance to aircraft C to maintain separation from aircraft E.

- 5) If PTM separation exists between aircraft C and aircraft E, aircraft C accepts the clearance. ATC cancels PTM separation between aircraft C and aircraft B. ATC issues a climb or descent instruction to aircraft E.
- 6) If PTM separation does not exist between aircraft E and B and/or aircraft C and E, the flight crew of E and/or the flight crew of C inform ATC “unable PTM”.

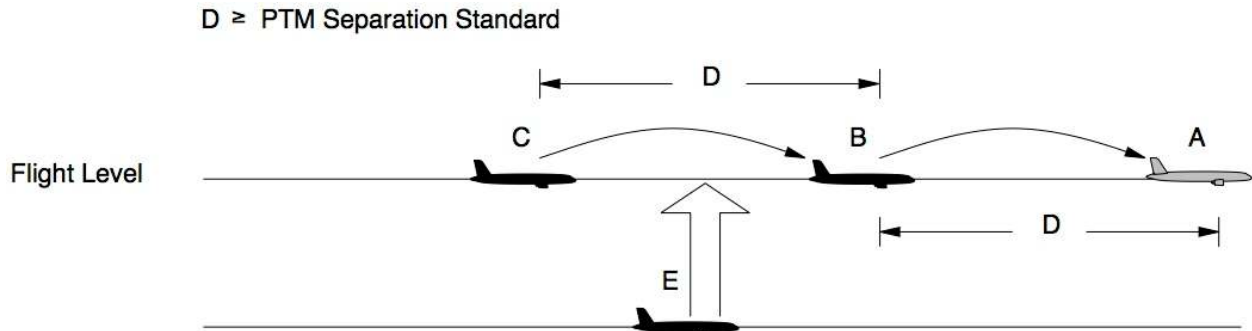


Figure A6-3. Joining a string by climbing or descending to the PTM string flight level, between the aircraft

Cases 3 and 4 for an aircraft joining a string horizontally are similar to cases 3 and 4 for an aircraft joining a pair to form a string.

Section A7 Process for adding an aircraft to a chain

A PTM-capable aircraft could join a chain to form a more numerous chain. When an aircraft is going to join an existing chain, the relative position of the joining aircraft must be determined with respect to the aircraft in the existing chain.

Climb or descend to a chain, Figure A7-1.

- 1) ATC must determine the relative position of the aircraft to join the PTM chain with respect to the aircraft in the chain.
- 2) ATC gives clearance to aircraft F to maintain separation from aircraft B and E.
- 3) If PTM separation exists between aircraft F and aircraft B and E, aircraft F accepts the clearance. ATC cancels the clearance for aircraft E to maintain separation from B and issues clearance to maintain separation from F. ATC cancels the clearance for aircraft B to maintain separation from E and issues clearance to maintain separation from F. ATC climbs/descends aircraft F to the flight level of the chain.
- 4) If PTM separation does not exist between aircraft F and aircraft B or E, aircraft F informs ATC “unable PTM.”

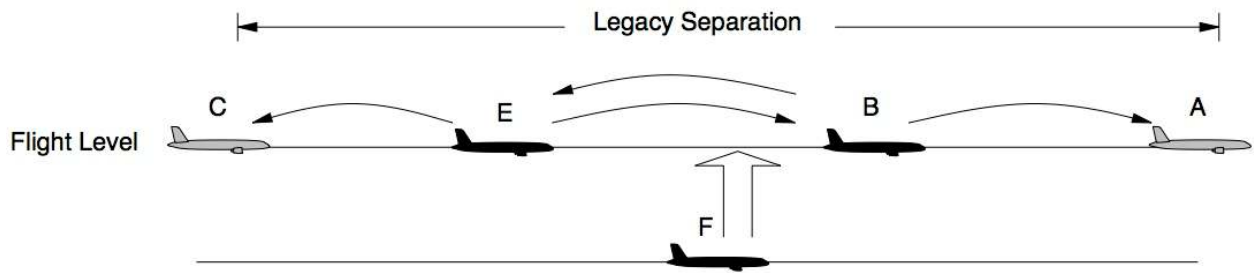


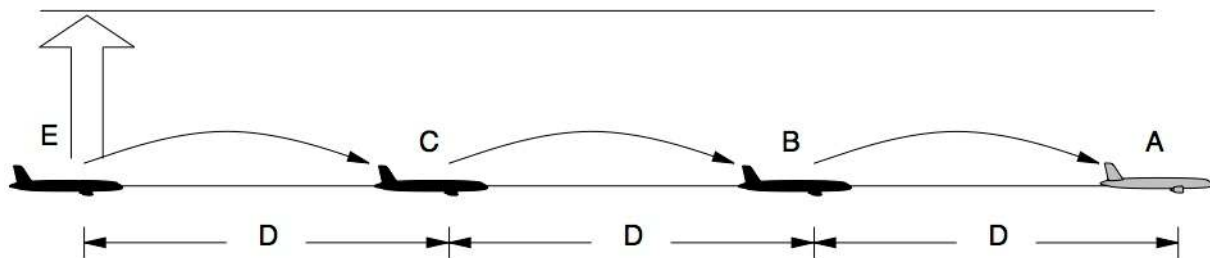
Figure A7-1. Joining a chain by climbing or descending to the chain flight level

Section A8 Process for an aircraft departing a string

An aircraft can depart a string vertically or horizontally. When an aircraft departs a string, a shorter string or pair will remain.

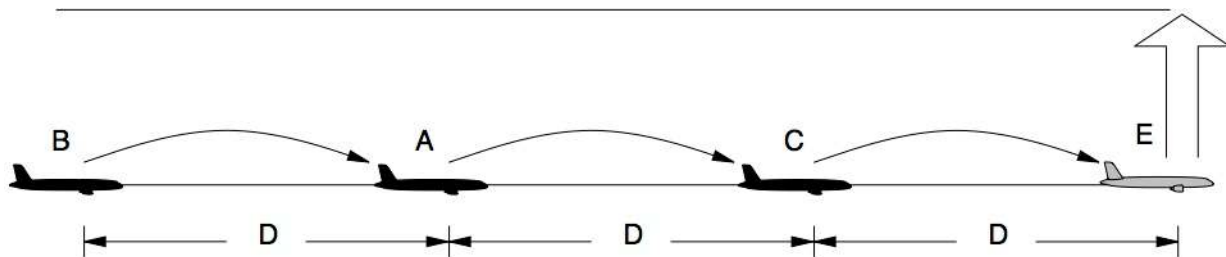
Case 1. Departing a string from the leading or trailing position by climb or descend, Figures A8-1 and A8-2.

- 1) ATC clears aircraft E, in the PTM string, to climb.
- 2) Trailing (Figure A8-1): After aircraft E reports reaching the new altitude, ATC cancels PTM clearance for aircraft E to maintain separation from aircraft C.
- 3) Leading (Figure A8-2): After aircraft E reports reaching the new altitude, ATC cancels the PTM clearance for aircraft C to maintain separation from aircraft E.



$D \geq$ PTM Separation Standard

Figure A8-1. Departing a string by climbing or descending, trailing



$D \geq$ PTM Separation Standard

Figure A8-2. Departing a string by climbing or descending, leading

Note that in the example of Figure A8-2, the aircraft departing the string might or might not be PTM-capable. In this example, aircraft C is PTM-capable but it becomes a designated aircraft and is not performing a PTM clearance.

Case 2. Departing a string from inside the string by climbing or descending, Figure A8-3.

- 1) ATC clears aircraft C, in the PTM string, to climb or descend.
- 2) After aircraft C reports reaching the new flight level, ATC instructs aircraft E to maintain PTM separation from aircraft B and cancels PTM separation from aircraft E to aircraft C.
- 3) ATC cancels PTM separation from aircraft C to aircraft B.

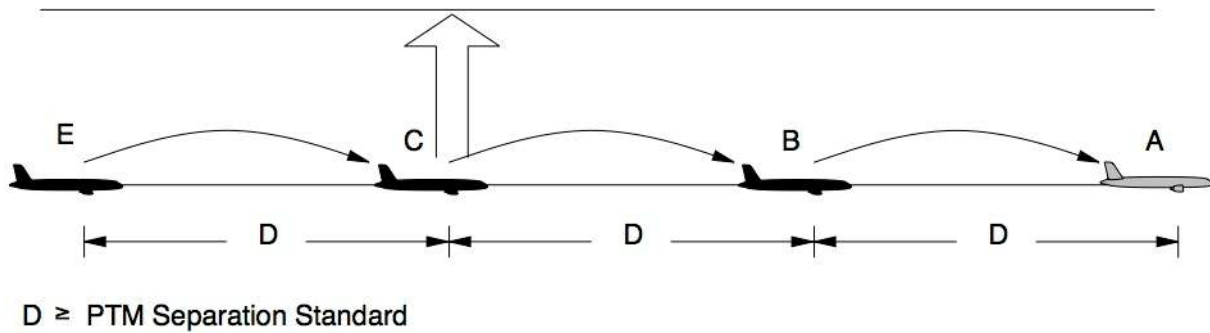


Figure A8-3. Departing a string by climbing or descending, inside the string

Case 3. Departing a string horizontally, Figure A8-4.

- 1) Aircraft E is cleared for a route that diverges horizontally from the string or is travelling at a slower speed than the string. ATC establishes legacy separation between aircraft E and aircraft C.
- 2) ATC cancels PTM separation for aircraft E to maintain separation from aircraft C.

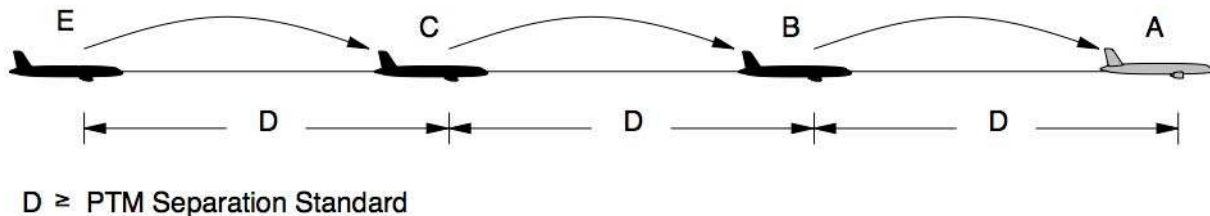


Figure A8-4. Departing a string horizontally

Section A9 Process for an aircraft departing a Chain

An aircraft can depart a chain vertically or horizontally. When an aircraft departs a chain, a less numerous chain, a string, a pair, or legacy operations could result.

Case 1. Departing a chain vertically with a chain remaining, Figure A9-1.

- 1) ATC gives clearance to aircraft B to climb or descend.
- 2) After aircraft B reports reaching the new flight level, ATC gives clearance to aircraft E to maintain separation from aircraft A.
- 3) ATC cancels PTM clearance for aircraft E to maintain separation from aircraft B and cancels PTM clearances for aircraft B to maintain separation from aircraft A and E.

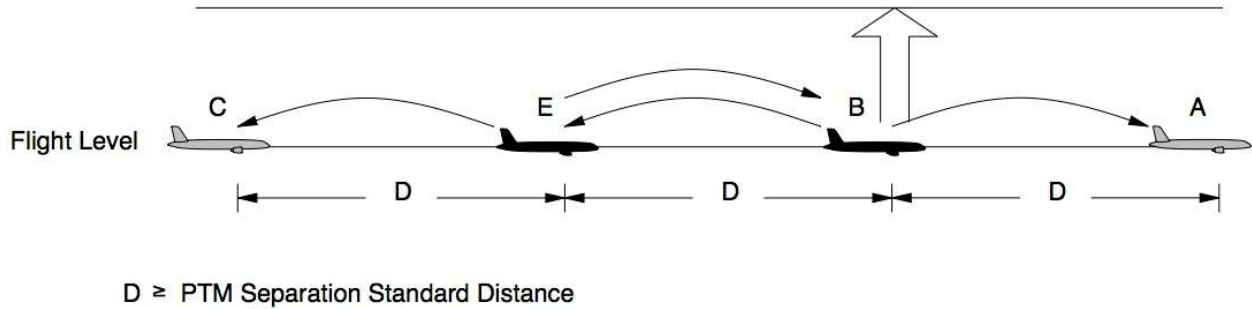


Figure A9-1. Aircraft leaving a chain vertically with a chain remaining

Case 2. Departing a chain horizontally with a string remaining, Figure A9-2.

- 1) ATC establishes legacy separation between aircraft A and B.
- 2) ATC cancels PTM clearance for aircraft B to maintain separation from A.
- 3) ATC cancels PTM clearance for aircraft E to maintain separation from B.



Figure A9-2. Aircraft leaving a chain horizontally with a string remaining

Section A10 Linking Pairs, Strings and Chains

Pairs, strings and chains can be linked together using a PTM clearance. Two PTM pairs could be linked to form a chain and a pair. A chain could be linked to a string in which a designated aircraft is the end of a chain and the beginning of a string.

Example 1. Two pairs are linked to form a chain and a pair, Figure A10-1.

- 1) ATC gives PTM clearance to aircraft B to maintain separation from aircraft E.

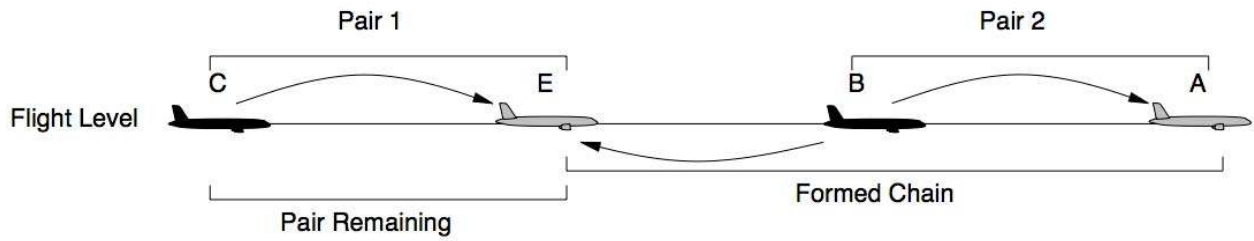


Figure A10-1. Linking Pair 1 and Pair 2 to form a chain and a pair

Example 2. A string and a chain are linked where the end of the chain becomes the beginning of the string, Figure A10-2.

- 1) ATC gives a PTM clearance to aircraft E to maintain separation from aircraft C. Aircraft E must be PTM capable.

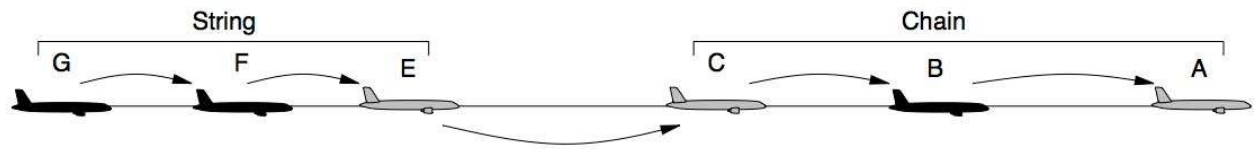


Figure A10-2. Linking a chain to a string

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14. ABSTRACT This document describes the Pair-wise Trajectory Management-Oceanic (PTM-O) Concept of Operations (ConOps). Pair-wise Trajectory Management (PTM) is a concept that includes airborne and ground-based capabilities designed to enable and to benefit from, airborne pair-wise distance-monitoring capability. PTM includes the capabilities needed for the controller to issue a PTM clearance that resolves a conflict for a specific pair of aircraft. PTM avionics include the capabilities needed for the flight crew to manage their trajectory relative to specific designated aircraft. Pair-wise Trajectory Management PTM-Oceanic (PTM-O) is a regional specific application of the PTM concept. PTM is sponsored by the National Aeronautics and Space Administration (NASA) Concept and Technology Development Project (part of NASA's Airspace Systems Program). The goal of PTM is to use enhanced and distributed communications and surveillance along with airborne tools to permit reduced separation standards for given aircraft pairs, thereby increasing the capacity and efficiency of aircraft operations at a given altitude or volume of airspace.					
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