

Percentage of Cases Meeting the ITP Initiation Criteria and Probability of Loosing Separation during an ITP Maneuver

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The percentage of initial condition cases meeting the initiation criteria for an In-Trail Procedure (ITP) is calculated for various aircraft Mach distributions, random geometries and wind speeds. Given that the ITP initiation criteria are met, the probability of loosing separation during the maneuver is calculated. The separation minima for ITP is assumed to be 10 nautical miles. The probability of passing a Reference aircraft within 5 nautical miles is also calculated. A Monte Carlo Simulation is used to perform the calculations.

1 Introduction

The ITP (In-Trail Procedure) is a separation method to perform a flight level change in non-radar environments using surveillance data provided by the flight crew to the air traffic controller. During an ITP, an aircraft performing the procedure will climb/descend in front/behind a Reference aircraft. The ITP can be requested by the flight crew and approved by ATC when a set of criteria is met [1]. The probability of collision has been calculated for this procedure in reference [2]. A hazard analysis is also being performed for the ITP [3].

In this paper, the percentage of initial conditions that meet the ITP initiation criteria is calculated. The probability of losing separation is calculated given that the initial conditions meet the ITP criteria. Separation minima for ITP is assumed to be 10 nautical miles for the purpose of these simulations. The probability of passing the Reference aircraft within 5 nautical miles is also calculated. A Monte Carlo simulation is used to select the initial conditions based on selected distributions. The simulation estimates the distance between the ITP and Reference aircraft at co-altitude using position error, velocity error, flight technical error, and winds.

2 Method

A Java program has been written to simulate an ITP maneuver. The set of initial conditions for the maneuver are assigned at random within given bounds or using actual data collected for flights occurring over the North Atlantic. The initial conditions are first checked to see if they meet the ITP criteria. If the ITP criteria are met, then the maneuver is performed and the distance that the ITP aircraft passes the Reference aircraft is calculated when both aircraft are at the same flight level. Figure 1 shows the initial configuration.

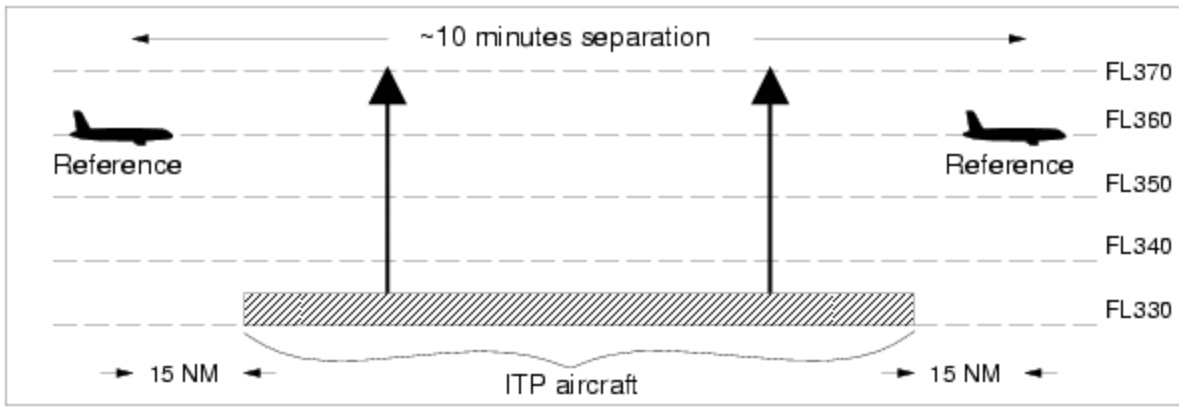


Figure 1. Initial Geometry.

There are two Reference aircraft at the intervening flight level above the ITP aircraft. The reference aircraft could be at FL340, FL350, or FL360. Figure 1 shows the reference aircraft at FL360. The Reference aircraft are 80 nautical miles apart or approximately 10 minutes separation. The ITP aircraft is at flight level FL330 and will perform a 4000 feet climb to FL370. The location of the ITP aircraft along the track is randomly selected at a location between the Reference aircraft but no closer than 15 NM in front or behind a Reference aircraft. The Mach numbers for the Reference and ITP aircraft are assigned using two methods: 1. A distribution obtained from flight plans filed to fly over the North Atlantic on the 7th of March 2005; 2. a random uniform distribution in the range between 0.75 to 0.85 Mach. The data distribution for 7MAR2005 is shown in Figure 2.

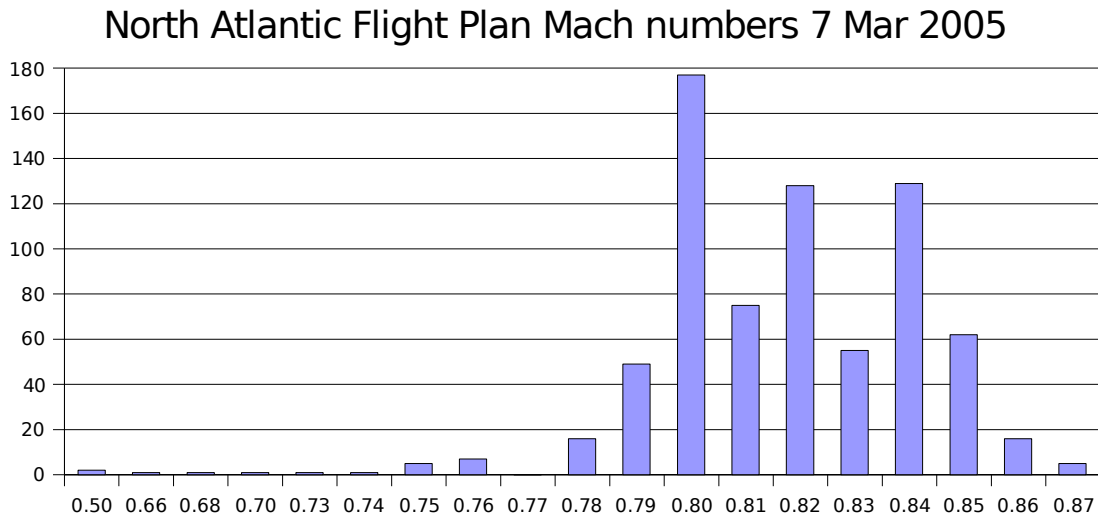


Figure 2. North Atlantic Flight Plan Mach Numbers for 7 March 2005.

The wind at flight level FL360 is the wind at FL330 plus a random gradient normally distributed with a standard deviation of 16.03 knots.

Based on these initial conditions, the simulation calculates if the ITP criteria for ground speed and Mach difference are met. If the ITP criteria are met, the maneuver is performed and the simulation calculates if the ITP aircraft will be closer than 10 nautical miles and closer than 5 nautical miles to either of the Reference aircraft at co-altitude. The climb rate for the ITP aircraft is 300 feet/min. Calculation of distance to a Reference aircraft includes position, velocity, altitude, and track intercept error and winds at altitudes between FL330 and FL360.

The following parameters are used for the ITP criteria and error estimations:

Maximum ground speed (GS) difference = 20 knots for distances of 15 to 20 NM

Maximum ground speed (GS) difference = 30 knots for distances > 20 NM

Maximum Mach difference = 0.03, 0.05 or 0.07 Mach

Navigation Accuracy Category for position, NACp = 6 (NUCp = 5)

Navigation Accuracy Category for velocity, NACv = 2 (NUCr = 2)

Flight Technical Error, FTE = 2 NM

For the given parameters, the results are shown in Table 1.

Number of samples	Alt.	Mach diff.	Mach range	Not meeting the Mach criterion	Not meeting the GS criterion	Not meeting the GS or Mach criteria	Meeting the GS and Mach criteria	Closer than 10 NM to Reference a/c	Closer than 5 NM to Reference a/c
6×10^9	1000 to 3000	0.07	7 Mar 2005 data	1.5%	13.9%	14.0%	86.0%	1.1×10^{-4}	5.7×10^{-9}
6×10^9	1000 to 3000	0.05	7 Mar 2005 data	4.4%	13.9%	14.9%	85.1%	5.1×10^{-5}	1.7×10^{-9}
6×10^9	1000 to 3000	0.03	7 Mar 2005 data	16.9%	13.9%	22.0%	78.0%	3.3×10^{-5}	$< 1.6 \times 10^{-10}$
6×10^9	1000 to 3000	0.07	0.75-0.85	4.5%	17.7%	18.4%	81.4%	1.4×10^{-4}	7.3×10^{-9}
6×10^9	1000 to 3000	0.05	0.75-0.85	12.5%	17.7%	21.2%	78.8%	8.1×10^{-5}	4.0×10^{-9}
6×10^9	1000 to 3000	0.03	0.75-0.85	24.5%	17.7%	28.5%	71.5%	2.7×10^{-5}	$< 1.6 \times 10^{-10}$

Table 1. Percentage of Initial Condition Cases Meeting the IPT Criteria and Proximity Probability.

For a Mach difference of 0.07, an ITP aircraft will come closer than 10 NM approximately every 9 thousand ITP operations and closer than 5 NM approximately every 175 million ITP operations. When the Mach difference is restricted to 0.03, an ITP aircraft will come closer than 10 NM approximately every 30 thousand ITP operations and closer than 5 NM less than once every 6,000 million ITP operations.

When the Mach difference criterion is 0.07, almost all states that do not meet the ITP criteria are due to the ground speed criterion not being met. The Mach criterion contributes a negligible percentage. When the Mach difference criterion is 0.03, the initial states not meeting the ITP criteria increases from 14.0% to 22.0%. This is based on data collected on the North Atlantic from aircraft flight plans as shown in Figure 2. A uniform distribution in the range of 0.75 to 0.85 produces a slightly higher number of instances where the ITP criteria are not met.

3 Criteria for Preservation of Separation; Nominal Conditions

Nominal conditions are defined as a linear wind gradient between the ITP aircraft flight level and the Reference aircraft flight level. Velocity, position, and flight technical errors are not considered. Table 2 shows the required minimum initiation distance to maintain a 10 nautical mile separation for a 20 knots maximum ground speed difference at FL350. A 300 feet/minute climb/descent rate is assumed.

<i>Vertical Distance between ITP and Reference aircraft</i>	<i>Mach Number Difference</i>				
	0.03	0.04	0.05	0.06	0.07
1000 feet	13 NM	13 NM	13 NM	14 NM	14 NM
2000 feet	14 NM	14 NM	15 NM	15 NM	16 NM
3000 feet	15 NM	15 NM	16 NM	17 NM	17 NM

Table 2. Initiation distance to Preserve 10 NM Separation under Nominal Conditions.

All initiation distances have been rounded to the nearer largest integer. Preservation of separation is defined as maintaining a 10 nautical mile horizontal separation until a 1000 feet (300 meters) vertical separation has been achieved.

4 References

- [1] Requirement Focus Group; Operational Services and Environment Definition (OSSED) In-Trail Procedure, October, 2005.
- [2] Carreño, Muñoz; Safety and Performance Analysis of the Non-Radar Oceanic/Remote Airspace In-Trail Procedure, August 2006.
- [3] Requirement Focus Group; Operational Safety Assessment (OSA) In-Trail Procedure (ITP), February, 2006.