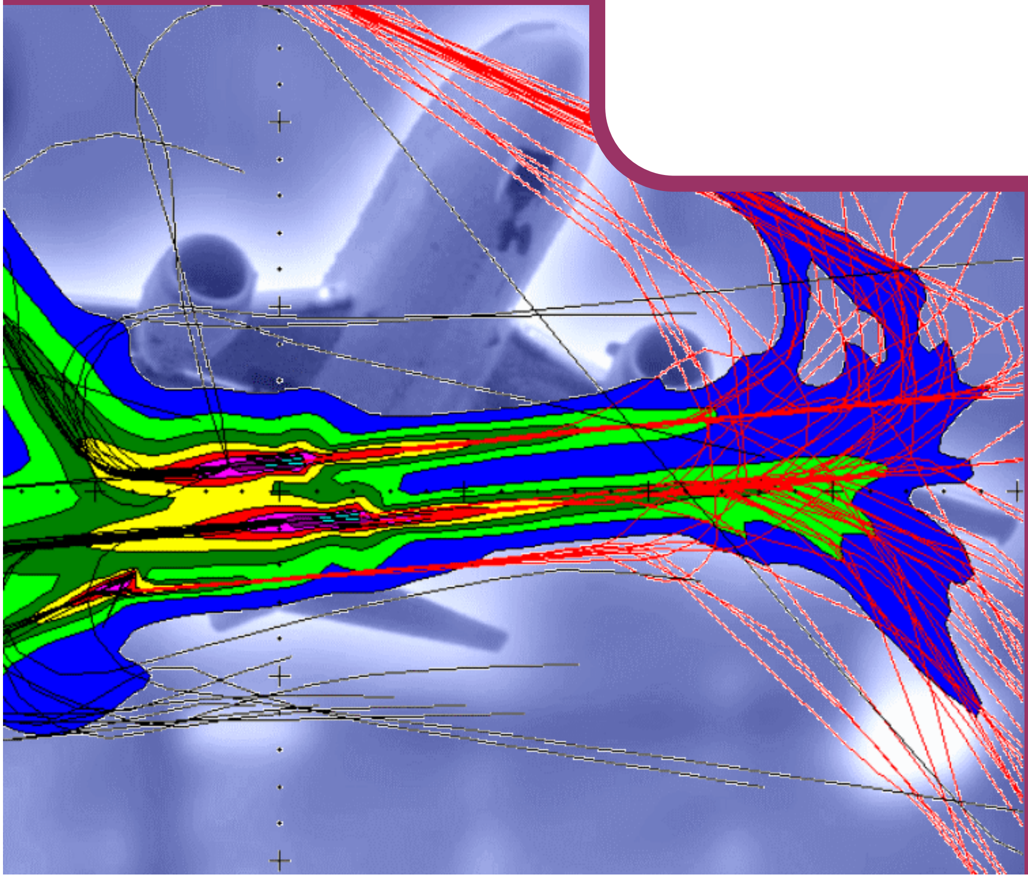
EUROCONTROL
Experimental Centre

Kevin Restrick

Error Sensitivity Analysis of the Integrated Noise Model

EEC/ENV/2002/006



EUROCONTROL

Error Sensitivity Analysis of the Integrated Noise Model

Kevin Restrick
QinetiQ
Cody Technology Park
Farnborough
UK

EEC Note: EEC/ENV/2002/006

REPORT DOCUMENTATION PAGE

Reference: EEC Note No. EEC/ENV/2002/006	**Security Classification:** Unclassified
Originator: Kevin Restrick QinetiQ Ltd Originator's Reference; QINETIQ/FST/CAT/CR020623	**Originator (Corporate Author) Name/Location:** QinetiQ Ltd Cody Technology Park Farnborough GU14 0LX United Kingdom +44 1252 397684
Sponsor: EUROCONTROL Experimental Centre	**Sponsor (Contract Authority) Name/Location:** EUROCONTROL Experimental Centre Centre de Bois des Bordes, BP15 91222 BRETIGNY SUR ORGE France +33 1 69 88 75 00

TITLE:

ERROR SENSITIVITY ANALYSIS OF THE INTEGRATED NOISE MODEL

Authors :	Date	Pages	Figures	Tables	Appendix	References
Kevin Restrick	28/06/2002	98	22	45	10	5

EATMP Task Specification	Project	Task No. Sponsor	Period
C/1.100/CE/VL/99/TRS182/01	ENHANCE	-	2001

Distribution Statement:

(a) Controlled by:	EUROCONTROL Project Manager
(b) Special Limitations:	None
(c) Copy to NTIS:	~~YES~~ / NO

Descriptors (keywords):
INM – Integrated Noise Model – Error Analysis – SAE – AIR 1845

Abstract:

The Integrated Noise Model (INM) is an average value model used to predict aircraft noise levels in the vicinity of airports. The calculation is based on the equations developed by the Society of Automotive Engineers (SAE) in their aerospace information report AIR 1845.

Input variables into INM consist of average values of the local atmospheric conditions (averaged over the period being modelled), while the aircraft's flight path and performance characteristics are approximated either using user-defined values or standard values contained in the INM database. The approximation, although necessary, will result in errors between the predicted noise level, and the actual single-event noise level on any given day.

The noise calculation process relies on the use of a number of algorithms that approximate the effect of aircraft noise, and a database of Noise-Power-Distance (NPD) data.

A method is developed for analysing and calculating the effect of errors in the inputs to each of the equations used within INM. A number of examples are considered covering a range of aircraft types over various flight conditions. The most influential variables are found to be aircraft weight, local pressure, and a number of aircraft flap and engine coefficients. The suitability of the approximative algorithms is not considered, however the effects of an error arising from them is.

The main recommendation of this work is for the development of a computational method of analysing the effect of errors throughout the entire flight profile, perhaps as an addition to the INM.

Table of Contents

This page is intentionally blank

Introduction

The Integrated Noise Model (INM) is a computer program produced by the United States Federal Aviation Authority (FAA) to predict aircraft noise levels in the vicinity of an airport. It has a number of uses including the assessment of changes in noise impact resulting from changes in runway configuration, and the assessment of the impact of new traffic demands and fleet mix.

The INM has progressed through a number of versions, and this report considers the model at version 6.0c.

The INM is a flexible tool with the following properties;

- The model includes data for a large number of US airports and gives the option to alter any of the local properties. In addition to performing studies at these standard airports, INM also allows an airport to be defined by a user by specifying an elevation, runway latitude and longitude, and an average value for the local pressure, temperature, and humidity over the course of the period being modelled.

- A number of standard built-in aircraft flight paths allow an airport's flight operations to be modelled. These profiles are based on industry standard departure and arrival profiles, and are included for a comprehensive range of aircraft.

- In addition to the built-in profiles, user-defined flight profiles can also be created by specifying a number of flight segments. Each segment is defined by specifying a number of variables such as final altitude, speed, power setting, and flap setting.

- The segments that have been defined can be "flown" by a range of aircraft contained in the INM database. The aircraft data that are held by the INM are composed of values that represent the aircraft at an average weight, with flap and engine coefficients defined at a number of levels.

  In addition to the aircraft contained in the database, the user can define aircraft characteristics to model different configurations, for example, modelling of a summer charter flight that is more heavily loaded than the database aircraft. There is also the option of substituting aircraft that INM does not have a full set of data for, with similar aircraft.

- For each aircraft and engine pair, the INM contains Noise-Power-Distance (NPD) data. These data consists of sets of decibel (dB) levels for different noise metrics, and for various combinations of aircraft engine corrected thrusts and distances from observer to aircraft. User-defined NPD data can be added to allow the modelling of non-standard aircraft configurations.

- Noise levels are calculated at a number of points laid out in a grid around the airport. The use of standard grids can be used, or they can be defined by the user to suit requirements. In addition to specifying the position of each grid point, the INM also allows their elevation to be included, so as to model the effect of the local topography.

An INM study is constructed by specifying the properties discussed above. The values which INM requires are mean values designed to estimate the long-term average annual conditions and flight operations at a particular airport. This approach introduces errors into the model in a number of ways;

- Local ambient conditions such as air pressure are averaged over the period that is being modelled (for example, a year), hence conditions on a given day will differ from those included in the model.
- The number and time of flights are averaged over the time period. Seasonal variation and changes in number of flights may vary throughout the time period giving a greater or lesser amount of traffic at an airport.
- Aircraft may not fly the exact flight profile being modelled. This can occur for both the standard flight profile and user-defined flight profile. Errors may also arise in the user-defined profile not accurately modelling the aircraft's flight path.
- The type and configuration of an aircraft may change over the period of the model.

Once the study has been constructed, the noise levels are calculated at each of the grid points defined. The INM noise calculation includes algorithms to adjust the database noise levels, which are calculated at reference conditions, to local noise levels that are representative of the local conditions.

This report does not cover in detail the noise calculation process, but instead assumes the reader has knowledge of the INM and the method that it uses. A full nomenclature of the terms used in the report can be found in Appendix J.

An analysis of the errors in actual noise level on a given day, compared to those estimated from a model requires an understanding of the variables and the equations in which they occur. This section presents an overview of the variables used by the INM and how the variables flow between the equations.

The use of English units throughout this report is for consistency with the INM.

Local Conditions

Reference Day and Standard Day Conditions

Standard day atmospheric conditions (ISA) correspond to a temperature of 59°F (15°C), an air pressure of 29.92 in-Hg (1.013207 E5 Pa), and 70% relative humidity.

Reference day atmospheric conditions (ISA + 10°) correspond to a temperature of 77°F (25°C), an air pressure of 29.92 in-Hg (1.013207 E5 Pa), and 70% relative humidity. These are the conditions at which aircraft noise certification data are specified.

Airport Average Annual Air Pressure

The INM uses a first order approximation of the ISA atmosphere to calculate a value of pressure ratio (delta) between the ambient air pressure and the standard-day sea level value. All of the flight profile calculations, and a number of the noise adjustment calculations, use the pressure ratio term, making airport pressure one of the most influential variables.

Airport Average Annual Day Temperature

The INM calculates the temperature ratio (theta) between the ambient air temperature and the standard-day sea level value, by assuming a constant ISA temperature lapse rate above the airport's elevation, and starting at the local airport temperature.

Local temperature and temperature gradient have important affects on the refraction of noise waves, and affects the level of turbulence. For accuracy, Aircraft noise levels (NPD data) and aircraft coefficient data should only be used when the local temperature is less then 30°C.

Airport and Observer Elevation

Although an airport's elevation is fixed, there is the possibility of small measurement errors in elevation between studies at an airport. In addition, there are further errors in specifying the observer's elevation, whether this is the accuracy of the built-in grid points, or the accuracy of user-defined observer positions and location points. Without resorting to an accurate Global Positioning System, errors in elevation would expect to be of the order of ±3 ft (approx. 1m)

Runway Ends Elevation and Runway Length (Runway Gradient)

The runway gradient affects the takeoff and landing ground track distances.

Headwind Speed and Direction

A datum headwind of 8 knot (4.12 m/s) is used by the INM.

In addition to altering an aircraft’s flight profile, the direction and magnitude of the headwind affects the propagation of aircraft noise and the level of turbulence. These effects cause distortion of the noise level. To be valid the aircraft and engine data that the INM includes should only be used for wind speeds lower than 15 knots (8m/s).

Aircraft Variables

The user has the option of either specifying the aircraft’s configuration, or using the database values. In either case, errors will arise in the approximation of the configuration and the number of flight operations of a particular aircraft at a given moment, compared to the aircraft in the model

Aircraft Weight

Aircraft weight is approximated for each aircraft type, hence a large range of errors are possible between the aircraft used in the INM model, and those operating on a given day. The range of errors can be minimised by modelling the exact aircraft over a manageable time period, for example a day. This however is unrealistic and requires a vast number of studies to be performed.

In addition, the INM assumes the aircraft’s weight is constant during the departure profile, and the approach profile. In reality, the aircraft burns fuel and becomes lighter through out the flight. The effect of this should be considered on an aircraft-by-aircraft basis, as fuel burn is specific to an aircraft and it’s the operation.

Aircraft Flap and Engine Jet Coefficients

These performance coefficients are evaluated by the manufacturer using the method outlined in SAE AIR 1845 [1]. The values are calculated at the reference conditions given above and only are suitable for use within this envelope.

The calculation or the suitability of the values of the coefficients is not considered here, only the effect of a possible error in coefficient value.

Further errors in coefficient value could arise from inappropriate substitution of aircraft type, and from the approximation of grouping flights together.

User Defined Flight Profile Variables

This option allows user-defined flight profiles to be built up to suit study requirements by specifying position, thrust, speed, and configuration. Errors arise due to oversimplification of the actual flight path, and the approximation of the aircraft's performance.

Similar errors will arise when using the standard departure and approach profiles included in the INM, due to the differences between an aircraft's actual profile and the profile that is being modelled.

Dispersion of the flight path can be modelled within the INM. However individual variations in aircraft position due to air traffic control vectoring and variations in performance for a given configuration may give a much larger dispersion both laterally and vertically.

INM Approximations and Errors

Database Noise Levels

The development of the NPD technique can be found in SAE AIR 1845 [1], and a full analysis of the suitability of the model is beyond the scope of the work. However, it has been recognised that errors in noise level will exist because the data are specified for a given flap setting and undercarriage deployment [2]. For example, for nominally the same engine power settings, an aircraft with a flap setting and undercarriage position differing from the measured configuration can produce different noise levels.

Version 6.0c of the INM goes part way to minimising this effect by including data for approach configurations and departure configurations.

Atmospheric Absorption

Atmospheric absorption is the small loss of noise to the air through a number of physical processes. It increases with frequency and increases linearly with distance, and becomes increasingly important far from the noise source. The adjustment is a function of relative humidity, temperature, and atmospheric pressure.

The spectral data that the INM 6.0c includes is corrected to reference day conditions, using the SAE AIR 1845 [1] standard atmosphere, at a distance of 1000ft (305 m). The noise calculation process includes adjusting the database noise levels, using the calculation model from SAE ARP866A [3], to account for the actual conditions being modelled.

Although an analysis of this procedure is beyond the scope of the project, it should be noted that the Sutherland model [4] provides a better representation of the sound attenuation in the atmosphere than SAE ARP866A does. At the higher frequencies the SAE method is seen to give differences of the order of 4dB.

Directivity Adjustment

When calculating noise behind the start-of-takeoff ground roll (and for runup operations) a field-based directivity adjustment is employed. The adjustment is a function of azimuth angle, defined as the angle formed between the aircraft's centre line and the line connecting the aircraft to the observer.

Although an analysis of the suitability of the adjustment is not considered, it should be noted that the directivity of aircraft noise could vary on either side of the aircraft. As there is little or no information in the public domain on the azimuthal directivity of aircraft noise (other than those derived from ground measurement corrected for lateral ground attenuation), there exists the potential for errors in the adjustment [5].

Noise Calculation Equations

The calculation process is spilt into three parts: firstly the flight segment characteristics are calculated; secondly the geometric parameters relating the aircraft's position to the observer position are calculated for each grid point, and finally the noise adjustments and the noise level metrics are calculated.

Flight Profile Calculations

A flight profile is built up by defining a number of flight segments, e.g. climb segment, acceleration segment. The calculations for each segment requires a number of equations, which are used to calculate the values of speed, altitude, engine power level, and ground track distance at the start and end of each segment.

Flight Path Segment Parameters

The calculations outlined above define the start and end of segment values of speed, altitude, engine power level, and ground track distance. For each observer position (grid point), these values are interpolated along the flight path to give local values for the noise adjustment and noise level calculations.

Noise Adjustment and Noise Level Metrics

For each observer position, the noise level is calculated by adjusting the interpolated NPD noise level to take into account the differences between the database noise level that has been measured under reference conditions and the noise level that would be heard during the actual flight segment.

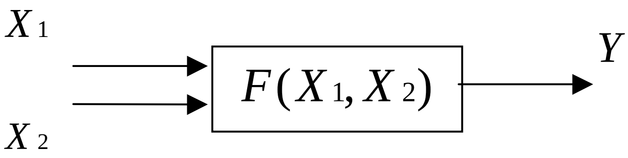
These adjustments are calculated for each observer position using the interpolated segment variables from above.

Error Analysis

The previous section has highlighted the errors that can occur during the modelling of noise levels, and also shows how they flow through the calculation process. This section outlines the theory used to calculate the effect of an error in the input variables, on the output of each equation.

Theory

Each of the calculations that make up the flow of variables through the three sections of the calculation process can be modelled as the simple system shown below.



The effect of a small variation of the input parameter to the output parameter for the above system of equations can be modelled using linear small approximation theory to show a small error in the output (δY) due to an incremental error in either or both of the inputs ($\delta X_1, \delta X_2$);

$$\delta Y = \frac{\partial F(X_1, X_2)}{\partial X_1}\delta X_1 + \frac{\partial F(X_1, X_2)}{\partial X_2}\delta X_2$$

Such error analysis equations can be constructed for each of the flight profile equations, interpolation equations, and noise calculation equations.

Assumptions

The theory above relies on two main assumptions;

1. The equations are linear.

   Figure1. shows as an example the comparison between the error in ground track distance for the take-off segment calculated using linear approximation, and the error in ground track distance for the take-off segment calculated using the full equations (error values are calculated at a datum condition, and then recalculated at this condition with the inclusion of a small error). Only curves for the error due to coefficient E, airport pressure, and aircraft weight are shown, as the calculation of error using linear approximation for the other variables shows considerably greater accuracy.

   Under about 3% error in the input variable, the linear approximation is seen to produce accurate results.

2. The errors in the input variables are small.

   The error between the input values and the actual conditions on a given day is dependent on the range of values that occur at a particular airport. For now we shall assume that the range of variables is small enough to meet this assumption. In the event of there being a large variation in values for a given airport study, then this method should be used with caution and validation of the results required.

Application to the INM Equations

For each of the equations used by the INM to calculate the flight path, the interpolated local variables, and the noise adjustments, flow charts showing the interaction of the variables and the flow of errors are given in Appendix A. In addition to the flow diagrams, the full linear approximation error analysis equations are also given relating small errors in the input variables to the final output variable.

There are two equations where the error analysis equations are not given;

1. Acceleration Segment

   The calculations for the acceleration segment are iterative. The errors in ground track distance and final altitude are analysed using an iterative approach using the full equations and calculating the output at a datum condition, and then recalculating at the datum conditions but with a small error included.

2. Noise Fraction Adjustment

   The noise fraction adjustment equations are considerably more non-linear than the others considered in the report, and as such the calculation of the output error using linear approximation does not give the degree of accuracy seen with other equations. Instead the equations are analysed by calculating the adjustment value at a datum condition, and then at the same condition but with a small error included.

Validation of the Method

The error analysis equations that have been developed in Appendix A have been validated on two levels;

1. In a similar manner as shown in Figure 1, each of the linear approximation equations are used to calculate an output error for a range of input conditions. At the same conditions the full INM equations are used to calculate datum output values, which are then compared with output values calculated at the same conditions but with a small error included. A high degree of accuracy between the two methods was found, further confirming the use of linear approximation in the calculation of the errors.

2. The output from the full INM equations used above was validated against the output from the INM program. For example, the outputs from the flight profile calculations were checked using the flight-path calculated by the INM.

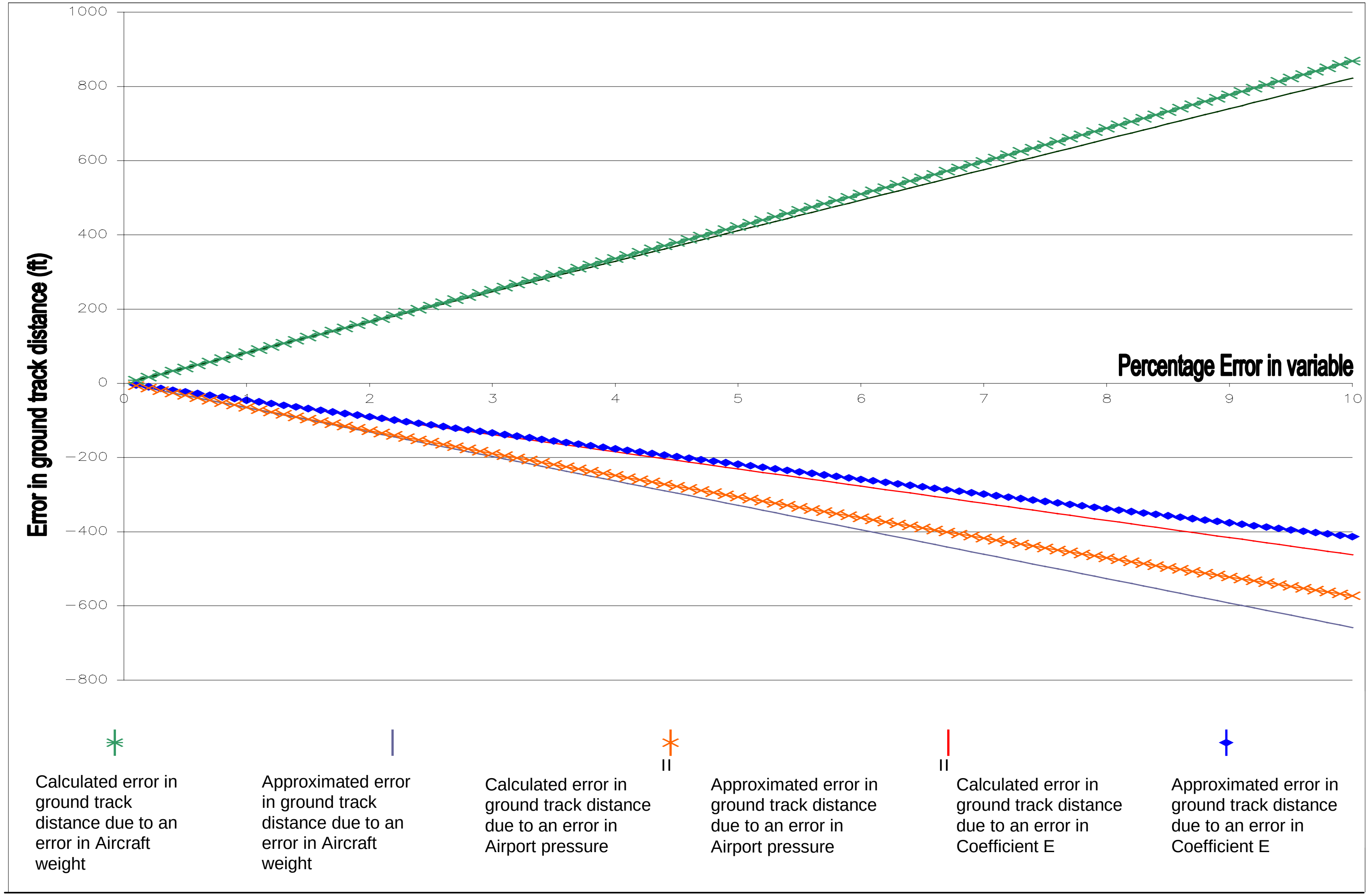


Figure 1. Graph to show the accuracy of linear approximation in calculating the error in ground track distance for the take off segment, when compared to the error in ground track distance calculated using the full equation.

This page is intentionally blank

The preceding section shows the theory that has been applied to each of the equations in turn, and subsequently built up to show how errors propagate through the complete set of equations, and results in the total error in noise level.

A complete analysis of the propagation of errors through the equations can be performed for a particular INM noise study by considering the vast range of user input variables, over an almost limitless range of observer positions.

To give an understanding of the process and the errors involved, a number of flight segments have been considered, over a representative range of input values.

It should be noted that because of the high degree of interaction between the variables, the results given are only applicable over the conditions that they cover.

Flight Profile Calculations

To give a realistic range of values for the aircraft input variables, e.g. flap coefficients, weight, etc, the flight profile calculations have been performed using a range of typical civil aircraft from the INM database, and listed below in Table 1.

Boeing B717-200	(BR715)	Airbus A300B4-200	(CF6-50C2)
Boeing B737-700	(CFM 56-7B)	Airbus A310-300	(CF6-80C2A2)
Boeing B747-400	(PW4056)	Airbus A319-131	(V2522-A5)
Boeing B757-200	(RB211-533E4)	Airbus A320-232	(V2527-A5)
Boeing B767-400ER	(CF6-80C2b)	Airbus A330-301	(CF6-80 E/A2)
Boeing B777-200	(GE90-76B)	Airbus A340-211	(CFM 56-5C2)
Lockheed L1011	(RB211-22B)		

Table 1. Aircraft and Engine Types Considered

Six flight segments have been considered, and are summarised in Table 2. These are based on the INM departure profile DEP-STANDARD1, and the approach profile APP-STANDARD1. In a number of approach cases, INM does not support a full set of segment parameters, hence no analysis has been performed.

The data that are required for each individual calculation are a combination of the input flight profile data, and data obtained from the INM calculated flight profile data.

The study airport has been taken as New York’s John F Kennedy International.

Takeoff	Takeoff using max takeoff thrust and extended flaps
Climb	Climb to 1000ft using max takeoff thrust
Acceleration	Accelerate as for first acceleration segment in DEP-STANDARD1
Climb	Climb to 3000ft using max climb thrust and minimal flaps
Descent	Descend at 3°, from 1000ft with landing gear/flap configuration
Landing	Touchdown-roll as 10% of roll-out distance

Table 2. Summary of Flight Segments Considered

The error in the output for each equation has been defined as a result of a +1% error in the input variable. As a result of the application of linear approximation to the equations, the output can be scaled to the size of the input, e.g. if the input error is +0.5% of the original value, then the error in output is half that for the +1% input error. Although a +1% error is used in the calculation of the errors, the use of linear approximation means that a –1% error causes an error of the same magnitude as the +1% error but of opposite sign.

The results for each of the segments are tabulated in Appendix B to Appendix G.

As the spread of data over the range of aircraft considered is small (the standard deviation is greatest for the errors due to aircraft weight, local pressure and coefficient E) the average error for each of the output variables can be calculated and is shown in Table 3. The errors are given as a percentage of the segment output parameter.

Errors in variables that produce a negligible effect are denoted by 0.00% in the table, whilst the greyed-out cells indicate variables which are not used in the calculation of the respective segment parameter. The yellow coloured cells represent the most influential variables i.e. where the error is greater then ±1%, these variables are summarised in Table 4.

For the analysis of the effect of multiple errors occurring in a single calculation the total error is the sum of the individual errors. However, for a full sensitivity analysis where the ‘worst case scenario’ is considered, then the total error is the square root of the sum of the errors squared.

	Takeoff Segment				1st Climb Segment			Acceleration Segment					Second Climb Segment			Descent segment		Landing segment	
Input Variable	Ground Track (ft)	Initial Thrust (lb.)	Final Thrust (lb.)	Final Speed (knot)	Climb Angle (°)	Ground Track (ft)	Final Thrust (lb.)	Final Altitude (ft)	Ground Track (ft)	Initial Thrust (lb.)	Final Thrust (lb.)	TAS (knot)	Climb Angle (Deg)	Ground Track (ft)	Final Thrust (lb.)	Ground Track (ft)	Thrust (lb.)	TAS (knot)	Thrust (lb.)
Coefficient B	1.00%																		
Coefficient C/D	0.20%		-0.20%	1.00%														1.00%	
Coefficient R					-0.30%	0.40%		0.30%	0.80%		0.00%	0.00%	-0.40%	0.30%			1.40%		
Coefficient E	-1.20%	1.00%	1.20%		1.60%	-1.70%	1.20%	-1.30%	-3.30%	1.20%	1.20%	0.00%	1.60%	-1.10%	1.10%				
Coefficient F	0.20%	0.00%	-0.20%		-0.20%	0.30%	-0.20%	0.20%	0.60%	-0.20%	-0.20%	0.00%	-0.20%	0.20%	-0.20%				
Coefficient G_a	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	-0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
Coefficient G_b	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
Airport Elevation	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%						0.00%	
Airport Pressure	-1.80%	-0.20%	-0.20%		0.90%	-1.00%	-0.30%	-0.70%	-2.10%	-0.30%	-0.40%	-0.50%	1.00%	-0.70%	-0.20%		-1.00%	-0.50%	
Airport Temp	0.10%	0.00%	0.00%					0.00%	0.10%		0.00%	0.10%						0.10%	
Aircraft Weight	2.10%		-0.10%	0.50%	-1.40%	1.40%		1.00%	2.70%		0.00%	0.00%	-1.40%	1.00%			1.00%	0.50%	
Headwind	-0.10%				0.10%	-0.10%							0.10%	0.00%			0.00%		
Runway End 1	0.00%																		
Runway End 2	0.00%																		
Runway Length	0.00%																		
Initial Altitude								0.70%	0.10%	0.00%	0.00%	0.00%	0.00%	-1.30%		1.70%			
Final Altitude					0.00%	1.00%	0.00%						-0.10%	2.00%	0.00%	0.00%	0.00%		
CAS1					-0.20%	0.30%	-0.20%	-1.50%	-4.50%	-0.20%	0.00%	0.00%	-0.20%	0.20%	-0.20%				
CAS2								2.00%	6.10%		-0.20%	1.00%					0.00%		
Climb Rate								0.70%	1.10%		0.00%	0.00%							
Descent Angle																-1.70%	-0.50%		
Static Thrust																			1.00%
% Thrust																			1.00%
Average Segment values	3497	42230	35838	147	14	4054	36180	1496	4769	34203	33372	186	13	6603	36855	18833	11417	140	24591

Table.3. Average Percentage Error due to a 1% error in each of the inputs.
Greyed out cells indicate the parameter is not a variable in the calculation of the segment parameter.
Yellow coloured cells indicate the most influential variables, and are expanded on in Table 4.

Flight Path Segment Parameters

The calculation of the interpolated values of noise, speed, power, and altitude is dependent on the segment’s initial and final values of the respective variable, and the geometry of the observer to the position of the aircraft. To give an indication of the effect of a nominal input error, the error analysis calculations have been performed for a range of distances. As above, only output errors due to a 1% error in each input variable have been calculated.

Speed Interpolation.

To give an indication of the error in interpolated speed, the performance of the A320-232 aircraft over the takeoff and acceleration segments has been considered. The error in interpolated speed for each of the input variables is tabulated in Appendix H, in table H.1.1 to table H.1.3.

The linearity of the equation with respect to the variables of final speed, d_{AS}, and segment length means that the error in interpolated speed can be defined not only with respect to the input error but also with respect to d_{AS}. For example, the error due to a 1% error in final speed when d_{AS} is equal to 2000ft is twice the error when d_{AS} is equal to 1000ft. A range of d_{AS} values has been used for the analysis of initial speed, as the linearity does not exist for this variable.

Engine Power Interpolation.

A similar analysis as above is performed for the engine power interpolation calculation. The error in interpolated engine power due to a 1% error in the input variables is shown in Appendix H, in table H.2.1 to table H.2.3.

Altitude Interpolation.

A similar analysis as above is performed, except that the climb segments have been considered. The error in interpolated altitude due to a 1% error in each of the input variables is shown in Appendix H, in table H.3.1 to table H.3.3.

The effect of an error in terrain or observer elevation has not been considered in the analysis, as from the original INM equation it can be seen that an error in either elevation is purely additive to the total error occurring as a result of the other variables.

Noise Level Interpolation.

A range of power levels and distances from the observer to the CPA on the flight path are considered. The values are such that the interpolation covers the complete range of distance and engine power level contained within the NPD data. The engine considered is the V2527A engine, with departure Sound Exposure Level data used for the analysis

The effect of a 1% error in distance and engine power level are shown in Appendix H, in table H.4.1 to table H.4.6. As above, the error can be sized to the input error.

Noise Adjustment and Noise Level Calculations

A range of values for the geometric position of observer, aircraft performance, and local conditions are used to analyse the noise adjustment and noise level calculations. The results of the analysis are given to 2 decimal places. Where a value of 0.00 is given this indicates the value is beyond this level of precision, as a dB measurement of this size is considered negligible.

Acoustic Impedance Adjustment.

The Acoustic impedance adjustment equation is a function of airport temperature, airport pressure, and altitude, and as such can cover broad range of values. To give an indication of the size and trends that the errors take, a datum condition has been taken and a range of values for each variable considered. The error in Acoustic Impedance adjustment for a range of values of each variable, due to a 1% error in the input variable is shown in Appendix I, in table I.1.1 to table I.1.5.

Noise Fraction Adjustment for Flight Segments (Exposure Based Metrics)

The noise fraction adjustment equation is a function of two distance variables, and two noise level variables. Each of the four variables cover a broad range of values, and so to give an indication of the size and trends of the errors, a datum condition has been taken and a range of values for each variable considered. The error in noise fraction adjustment for a range of values of each variable are shown in Appendix I, in table I.2.1 to table I.2.5.

As the equations are considerably more non-linear than the others considered in the report, the calculation of the output error using linear interpolation does not give the required degree of accuracy. As such the errors are defined using the complete equations by calculating the adjustment at a given condition, and then again at the same condition but with a small error included.

The errors are given due to an input error of 0.5%, and not due to a 1% error used so far. This is to allow limited scaling of the error result to suit the input value.

Speed Adjustments (Exposure Based Metrics)

The speed adjustment equation is such that for any input of aircraft speed the error in the adjustment value is constant. A 1% error in the input of aircraft speed causes an error in the speed adjustment of -0.04 dB.

Lateral Attenuation Adjustment.

A range of values for the sideline distance from the observer to the projection of the Closest Point of Approach (l_{seg}), and flight path height at the Closest point of approach (d_{seg}) have been considered. The error in Lateral attenuation adjustment for an ‘INM aircraft’ due to an error in each of the input distances are tabulated in Appendix I, in table I.3.1 and table I.3.2

The values of l_{seg} and d_{seg} are representative of the distances involved in the vicinity of the aircraft. At higher altitudes (Beta >60°) the adjustment becomes zero, whilst if the aircraft is on the ground far from the observer position then the adjustment is 1.

Ground-Based Directivity Adjustment

A range of values for slant range and distance from start of segment to the perpendicular closest point of approach have been considered. The values represent observer positions that are within a close proximity to the aircraft; as the observer moves away from the aircraft the error is seen to decrease dramatically.

The error in ground-based directivity adjustment due to a 1% error in each of the input distances, for a range of values are shown in Appendix I, in table I.4.1 and table I.4.2. A number of cells are not populated because the input values lie beyond the scope of the equation used to calculate the adjustment.

Computation of Exposure Based Noise Level Metrics

The calculation of the noise level is made up of two parts. Firstly the adjustments that have been calculated above are used to adjust the interpolated reference noise level to a value which is representative of the local conditions and the segment being flown. Secondly, this value is weighted and averaged over time and then converted from a sound exposure ratio to the equivalent dB value.

For an analysis of the effect of errors in the value of the adjustments to the noise level and interpolated noise levels, only the initial calculation of the sound exposure ratio has been considered. The further calculations merely sum or average the effect of any errors. This simplified approach is akin to considering a single flight segment of a single aircraft, with no weighting factors.

The linearity of the calculation of the sound exposure ratio, and the subsequent noise level, allows an error to be calculated for a datum condition. The error for a non-datum condition can be calculated by sizing the datum errors. A datum condition (adopted by inspection of results of the noise adjustment calculations), and the corresponding error in noise level due to a 1% input error are tabulated in Appendix I, table I.5.1.

Computation of Maximum Noise Level Metrics

The calculation of maximum noise level metrics are composed of an adjustment of the NPD noise level data, followed by an analysis to compute the maximum noise level over a number of flight segments, flight operations, and time periods.

As above we need only consider the initial calculation of a single flight-path segment. The equation to compute the maximum noise level is such that errors in the noise adjustment or interpolated noise level are purely additive.

Summary

The data contained in Appendix H and Appendix I, represents a comprehensive analysis of the individual equations over a realistic range of conditions. By considering the single maximum error that occurs over the range of variables used, an understanding of the effect on the final noise level can be made. For each of the sections of Appendix H and Appendix I, the shaded cells highlight the greatest error, and the flow of that error leading to a final error in noise level is given in Table 4.

In reality the analysis presented in Table 4. will be considerably more complicated due to the high degree of interaction of the variables. The consideration of multiple errors would result in a final noise value that depended on the given size and combination of the input errors.

In a number of instances the largest error in terms of a dB value does not relate to the largest error in terms of percent of the original value. However, in all of these cases, the greatest final error in noise exposure level relates to the largest single dB error, and not the largest percent error.

Parameter	**Maximum Source of Error**	**Effect**
Speed Interpolation	Error increases with distance along the flight path. Maximum error is of the order of 1.5 knot, i.e. about 1% of the input	Error in speed of 1% relates to an error in Speed Adjustment of about –0.4dB. This is about 6% of the adjustment for 187 knot, which corresponds to an error in exposure noise level of the order of 0.05dB
Power Interpolation	Maximum error is due to errors in the power level at the start and end of the segment that is being interpolated. The maximum error is of the order of 200lb., about 1%	An error of 1% relates to a maximum error in interpolated sound exposure level of the order of 0.2dB This is about 0.3% of the corresponding 68dB noise level, which relates to an error of about 0.2dB in exposure based noise level.
Altitude Interpolation	Error increases with distance along the flight path. Maximum error tends to the magnitude of the error in end of segment altitude, in this case, 30ft or 1% of the input.	An error of 1% in altitude relates to a maximum error in Lateral Attenuation adjustment of about –0.04dB (or about 0.73%). This corresponds to an error in exposure noise level of –0.04dB Altitude also affects distance used in noise interpolation
Error in NPD Data	Although the suitability of the use of NPD data are not considered, the effect of an error in the database noise level can be analysed. The maximum error in interpolated noise level is of the order of 0.8dB, or about 1% of the noise level.	An error in interpolated noise level of about 1% relates to an error of 0.8dB in sound exposure level. An error in interpolated noise level also affects the noise fraction adjustment to the order of 0.2dB (or 1.8% of the adjustment value), this relates to an error in exposure based noise level of about 0.08dB.

Table 4. Summary of the effect and flow of errors through the noise adjustment, and noise level

Parameter	**Maximum Source of Error**	**Effect**
Acoustic Impedance	Error in acoustic impedance is primarily a function of error in airport pressure. The error is reasonably constant over the range considered, and is of the order of 0.04dB.	Over the range of pressures considered, the 0.04dB error relates to a percentage error of the range of –20% to about 6% of the adjustment value. Over this large range, the error in sound exposure level is always of
Noise Fraction Adjustment	The maximum single error is of the order of -1.4dB which at the conditions corresponds to an error of about 10%).	An error in noise fraction adjustment of this level relates to an error in sound exposure level of the order of 1.4dB.
Lateral Attenuation Adjustment	Errors occur as a result of errors in the aircraft's altitude and the lateral position of the aircraft and observer. The greatest error is about 0.04dB or about 0.7% of the adjustment value for this case	An error in Lateral attenuation adjustment of this order relates to an error in sound exposure level of about –0.04dB
Ground-Based Directivity Adjustment	The maximum error is of the order of 0.1dB, or about 7.8% of the original adjustment value of 1.14dB	An error of 7.8% corresponds to an error of the order of 0.1dB in sound exposure level

Table 4 continued . Summary of the effect and flow of errors through the noise adjustment, and noise level calculations

This page is internationally blank

The analysis of the effect of input errors on the calculation of noise levels has led to the development of a number of linear partial differential equations. However, the high degree of interaction between the variables, and also the large range of values for each of the variables leads to a full error analysis being best implemented by a computational approach.

A qualitative understanding of the effect of errors in the input variables can be gained from the case studies, which cover a broad representation of the values of the input variables. Table 5 below summarises the most influential input variables to the noise level calculations. The input variables are arranged in terms of the output to the flight profile calculations. Errors in the flight profile flow through the calculation of the noise adjustments, resulting in errors in the final noise level.

Segment output variable	**Input Variable causing greatest error in output variable**
Ground Track Distance	Aircraft Flap Coefficients (B,C,D,R depending on segment), Engine Coefficients E and F, Airport Pressure, Aircraft Weight
True Airspeed	Flap Coefficient C, Airport Pressure, Altitude
Altitude	Engine Coefficients E and F, Flap Coefficient R, Speed.
Engine Power	Engine Coefficients E and F, Airport Pressure, Flap Coefficient R, Aircraft Speed (function of Weight and Coefficient C)

Table 5. Summary of the most influential input variables

This page is internationally blank

Recommendations and Suggestions

This report has highlighted a number of areas that require further analysis.

1. The large number of calculations that are to be performed for a large range of variables lends the analysis to be performed computationally. A stand-alone program consisting of a small perturbation model could be constructed using the flow diagrams and the equations presented in Appendix A. However, a simpler approach would be either to modify the INM to implement the methods included in the report, or run batches of INM runs, as the program already calculates the noise level at each of the grid points.

2. The variation in local conditions e.g. airport pressure, and aircraft characteristics, between the average-value used in a noise model and the conditions on any given day is one of the main sources in error.

   A statistical analysis of these values should be performed to highlight areas where these errors occur, and ensure that the average values used are representative of conditions at an airport. In the event of large seasonal variations in local conditions, or differences in the operation of aircraft type, then consideration should be given to segmenting the study to include the broader range of values.

3. The INM contains a number of models that are used to approximate the behaviour of aircraft noise. These models include the NPD curves, and the adjustments applied to the baseline noise level. Although the suitability or accuracy of these models is not considered here, a more accurate representation would introduce smaller errors in the final noise level.

This page is internationally blank

A. Segment Flow Charts and Equations

Appendix A presents the flow diagrams and the complete error analysis equations for each of the equations used in the INM to calculate flight profile, interpolated values, and the noise adjustments and noise levels.

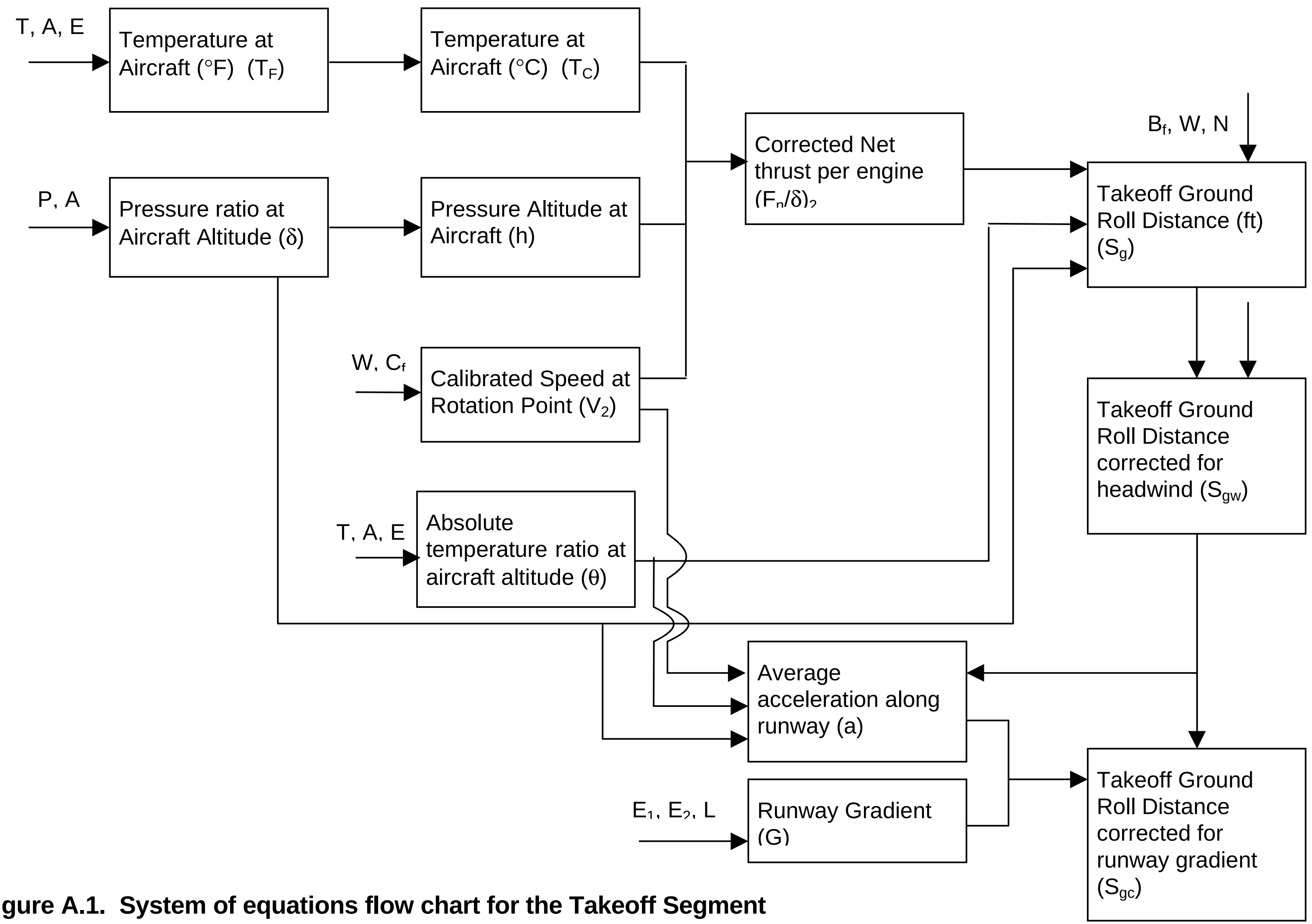


Figure A.1. System of equations flow chart for the Takeoff Segment

A small error in corrected ground track distance (δS_{gc}) is given by;

$$\delta S_{gc} = \frac{\partial S_{gc}}{\partial G}\delta G + \frac{\partial S_{gc}}{\partial a}\delta a + \frac{\partial S_{gc}}{\partial S_{gw}}\delta S_{gw}$$

Where

$$\delta G = \frac{\partial G}{\partial E_2}\delta E_2 + \frac{\partial G}{\partial E_1}\delta E_1 + \frac{\partial G}{\partial L}\delta L$$

$$\delta a = \frac{\partial a}{\partial V_2}\ \frac{\partial V_2}{\partial C_f}\delta C_f + \frac{\partial V_2}{\delta W}\delta W\ \Big| + \frac{\partial a}{\partial \sigma}\ \frac{\partial \sigma}{\partial \theta}\ \frac{\partial \theta}{\partial T}\delta T + \frac{\partial \theta}{\partial A}\delta A + \frac{\partial \theta}{\partial E}\delta E\ \Big| + \frac{\partial a}{\partial \delta}\ \frac{\partial \delta}{\partial P}\delta P + \frac{\partial \delta}{\partial A}\delta A\ \Big|\Bigg|$$

$$+ \frac{\partial a}{\partial S_{gw}}\ \frac{\partial S_{gw}}{\partial V_2}\ \frac{\partial V_2}{\partial C_f}\delta C_f + \frac{\partial V_2}{\partial W}\delta W\ \Big| + \frac{\partial S_{gw}}{\partial w}\delta w + \frac{\partial S_{gw}}{\partial S_g}\delta S_g\ \Big|$$

$$\delta S_{gw} = \frac{\partial S_{gw}}{\partial V_2}\ \frac{\partial V_2}{\partial C_f}\delta C_f + \frac{\partial V_2}{\partial W}\delta W\ \Big| + \frac{\partial S_{gw}}{\partial w}\delta w + \frac{\partial S_{gw}}{\partial S_g}\delta S$$

The small error in S_{gc} is a function of a small error in the uncorrected ground track distance (δS_g), which is given as;

$$\delta S_g = \frac{\partial S_g}{\partial B_f}\delta B_f + \frac{\partial S_g}{\partial W}\delta W + \frac{\partial S_g}{\partial N}\delta N + \frac{\partial S_g}{\partial \theta}\ \frac{\partial \theta}{\partial T}\delta T + \frac{\partial \theta}{\partial A}\delta A + \frac{\partial \theta}{\partial E}\delta E\ + \frac{\partial S_g}{\partial \delta}\ \frac{\partial \delta}{\partial P}\delta P + \frac{\partial \delta}{\partial A}\delta A\ +$$

$$\frac{\partial S_g}{\partial\ \left.\frac{F_n}{\delta}\right|_2}\delta\ \left.\frac{F_n}{\delta}\right|_2$$

Where

$$\delta\ \left.\frac{F_n}{\delta}\right|_2 = \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial E}\delta E + \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial F}\delta F + \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial G_a}\delta G_a + \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial G_b} + \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial H}\delta H +$$

$$\frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial T_c}\ \frac{\partial T_c}{\partial T_f}\ \frac{\partial T_f}{\partial T}\delta T + \frac{\partial T_f}{\partial A}\delta A + \frac{\partial T_f}{\partial E}\delta E\ \Big|\Bigg| + \frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial V_2}\ \frac{\partial V_2}{\partial C_f}\delta C_f + \frac{\partial V_2}{\partial W}\delta W\ \Big| +$$

$$\frac{\partial\ \left.\frac{F_n}{\delta}\right|_2}{\partial h}\ \frac{\partial h}{\partial \delta}\ \frac{\partial \delta}{\partial P}\delta P + \frac{\partial \delta}{\partial A}\delta A\ \Big|\Bigg|$$

Touch and Go Segment

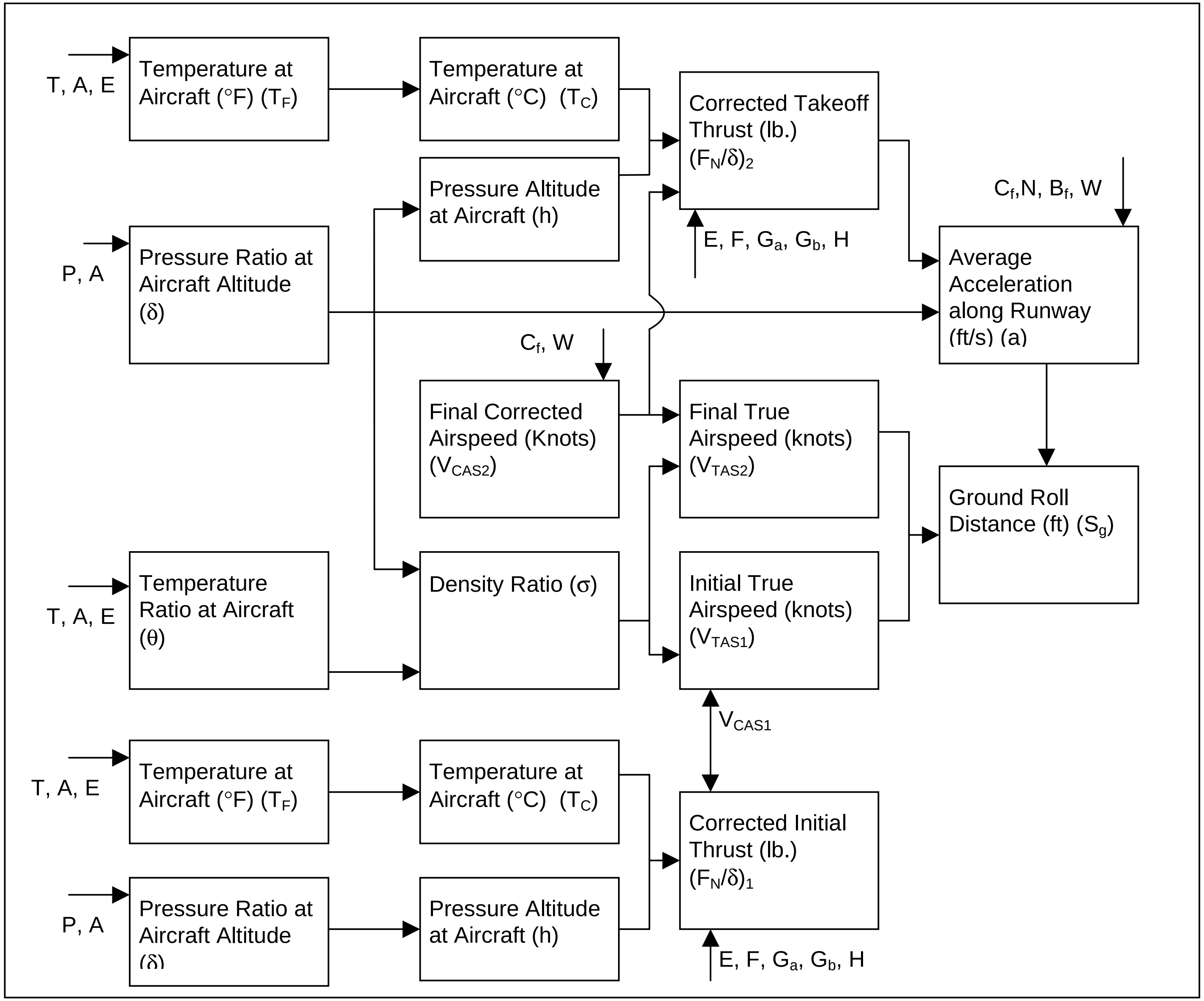


Figure A.2. System of equation flow diagram for the touch-and-Go segment

A small error in the ground roll distance for the touch and go segment (δS_g) is given as;

$$\delta S_g = \frac{\partial S_g}{\partial V_{TAS1}} \frac{\partial V_{TAS1}}{\partial V_{CAS1}} \delta V_{CAS1} + \frac{\partial V_{TAS1}}{\partial \sigma} \frac{\partial \sigma}{\partial \theta} \frac{\partial \theta}{\partial A} \delta A_1 + \frac{\partial \theta}{\partial E} \delta E + \frac{\partial \theta}{\partial T} \delta T + \frac{\partial \sigma}{\partial \delta} \frac{\partial \delta}{\partial P} \delta P + \frac{\partial \delta}{\partial A} \quad |$$

$$+ \frac{\partial S_g}{\partial V_{TAS2}} \begin{array}{l} \frac{\partial V_{TAS2}}{\partial V_{CAS2}} \frac{\partial V_{CAS2}}{\partial C_f} \delta C_f + \frac{\partial V_{CAS2}}{\partial W} \delta W + \\ \frac{\partial V_{TAS2}}{\partial \sigma} \frac{\partial \sigma}{\partial \theta} \frac{\partial \theta}{\partial A} \delta A + \frac{\partial \theta}{\partial E} \delta E + \frac{\partial \theta}{\partial T} \delta T + \frac{\partial \sigma}{\partial \delta} \frac{\partial \delta}{\partial P} \delta P + \frac{\partial \delta}{\partial A} \end{array} \Bigg|$$

$$+ \frac{\partial S_g}{\partial a} \frac{\partial a}{\partial C_f} \delta C_f + \frac{\partial S_g}{\partial N} \delta N + \frac{\partial S_g}{\partial B_f} \delta B_f + \frac{\partial S_g}{\partial W} \delta W + \frac{\partial S_g}{\partial \delta} \frac{\partial \delta}{\partial P} \delta P + \frac{\partial \delta}{\partial A} + \frac{\partial S_g}{\partial \frac{F_N}{\delta}_2} \delta \frac{F_N}{\delta}_2 \Bigg|$$

where a small error in Final net thrust is given as ($\delta(F_N/\delta)_2$) is given as;

$$\delta \frac{F_N}{\delta}_2 = \frac{\partial \frac{F_N}{\delta}_2}{\partial E} \delta E + \frac{\partial \frac{F_N}{\delta}_2}{\partial F} \delta F + \frac{\partial \frac{F_N}{\delta}_2}{\partial G_a} \delta G_a + \frac{\partial \frac{F_N}{\delta}_2}{\partial G_b} \delta G_b + \frac{\partial \frac{F_N}{\delta}_2}{\partial H} \delta H$$

$$+ \frac{\partial \frac{F_N}{\delta}_2}{\partial h} \frac{\partial h}{\partial \delta} \frac{\partial \delta}{\partial P} \delta P + \frac{\partial \delta}{\partial A} \delta A \;| + \frac{\partial \frac{F_N}{\delta}_2}{\partial T_C} \frac{\partial T_C}{\partial T_F} \frac{\partial T_F}{\partial T} \delta T + \frac{\partial T_F}{\partial A} \delta A + \frac{\partial T_F}{\partial E} \delta E \;|$$

$$+ \frac{\partial \frac{F_N}{\delta}_2}{\partial V_{CAS2}} \frac{\partial V_{CAS2}}{\partial C_f} \delta C_f + \frac{\partial V_{CAS2}}{\partial W} \delta W \;|$$

A small error in Initial net thrust ($\delta(F_N/\delta)_1$, for the touch-and-go segment is given as;

$$\delta \frac{F_N}{\delta} \Big|_1 = \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial E} \delta E + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial F} \delta F + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial G_a} \delta G_a + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial G_b} \delta G_b + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial H} \delta H$$

$$+ \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial h} \frac{\partial h}{\partial \delta} \frac{\partial \delta}{\partial P} \delta P + \frac{\partial \delta}{\partial A} \delta A \;| + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial T_C} \frac{\partial T_C}{\partial T_F} \frac{\partial T_F}{\partial T} \delta T + \frac{\partial T_F}{\partial A} \delta A + \frac{\partial T_F}{\partial E} \delta E \;|$$

$$+ \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial V_{CAS2}} \delta V_{CAS1}$$

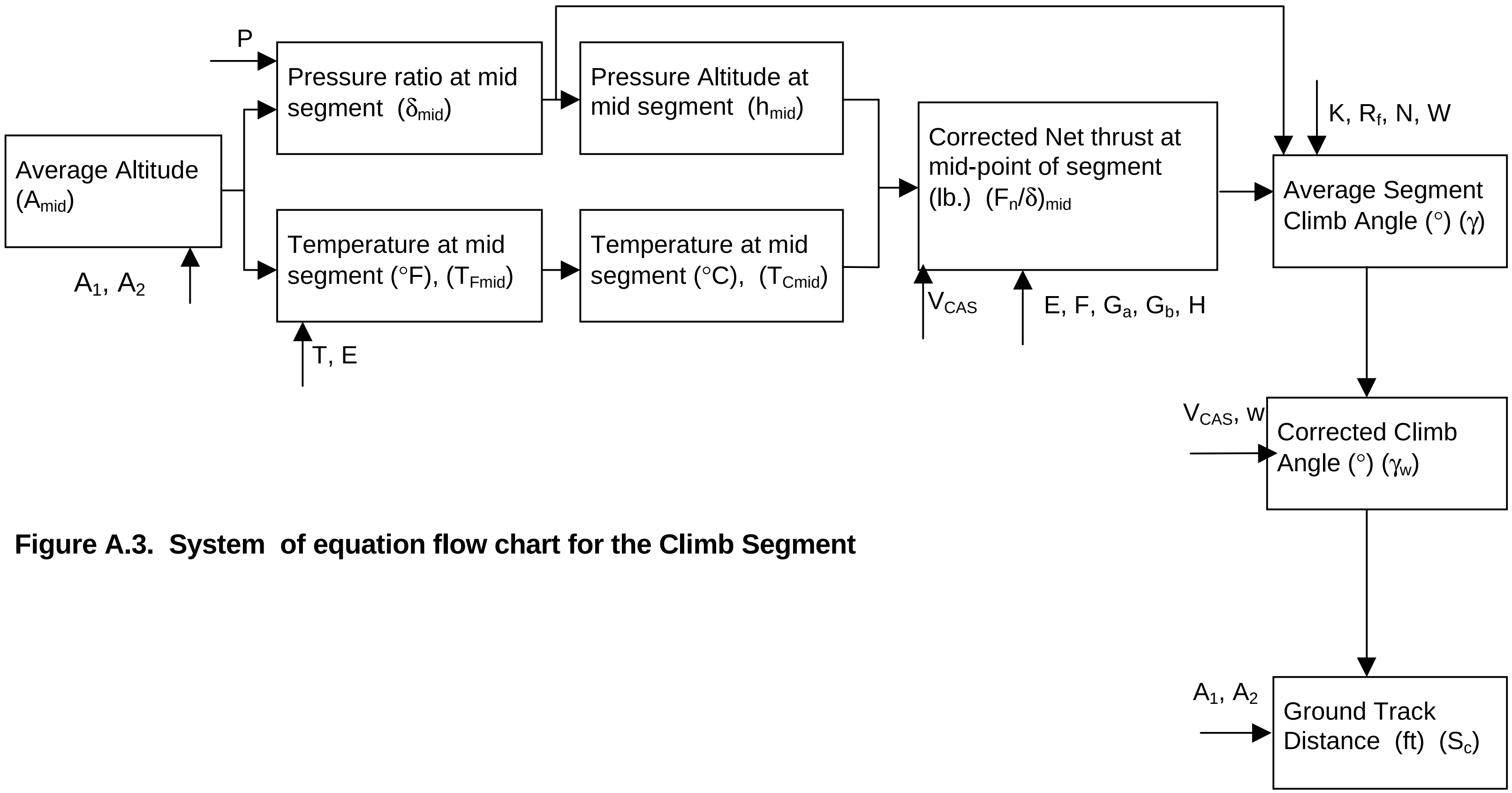


Figure A.3. System of equation flow chart for the Climb Segment

A small error in Ground track distance for the Climb segment (δS_c) is given as;

$$\delta S_c = \frac{\partial S_c}{\partial A_1}\delta A_1 + \frac{\partial S_c}{\partial A_2}\delta A_2 + \frac{\partial S_c}{\partial \gamma_w}\;\frac{\partial \gamma_w}{\partial w}\delta w + \frac{\partial \gamma_w}{\partial V_{CAS}}\delta V_{CAS} + \frac{\partial \gamma_w}{\partial \gamma}(\delta\gamma) \,|$$

where a small error in Climb angle ($\delta\gamma$) is given by;

$$\delta\gamma = \frac{\partial\gamma}{\partial K}\delta K + \frac{\partial\gamma}{\partial R_f}\delta R_f + \frac{\partial\gamma}{\partial N}\delta N + \frac{\partial\gamma}{\partial W}\delta W + \frac{\partial\gamma}{\partial\delta_{mid}}\;\frac{\partial\delta_{mid}}{\partial P}\delta P + \frac{\partial\delta_{mid}}{\partial A_{mid}}\;\frac{\partial A_{mid}}{\partial A_2}\delta A_2 + \frac{\partial A_{mid}}{\partial A_1}\delta A_1 \,|\,\Big| +$$
$$\frac{\partial\gamma}{\partial \left.\frac{F_N}{\delta}\right|_{mid}}\,\delta \left.\frac{F_N}{\delta}\right|_{mid}$$

where a small error in Mid-segment corrected net thrust ($\delta(F_N/\delta)_{mid}$ is given as;

$$\delta \left.\frac{F_N}{\delta}\right|_{mid} = \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial V_{CAS}}\delta V_{CAS} + \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial E}\delta E + \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial F}\delta F + \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial G_a}\delta G_a + \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial G_b}\delta G_b$$
$$+ \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial H}\delta H + \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial h_{mid}}\;\frac{\partial h_{mid}}{\partial\delta_{mid}}\;\frac{\partial\delta_{mid}}{\partial P}\delta P + \frac{\partial\delta_{mid}}{\partial A_{mid}}\;\frac{\partial A_{mid}}{\partial A_2}\delta A_2 + \frac{\partial A_{mid}}{\partial A_1}\delta A_1 \quad |$$
$$+ \frac{\partial \left.\frac{F_N}{\delta}\right|_{mid}}{\partial T_{Cmid}}\;\frac{\partial T_{Cmid}}{\partial T_{Fmid}}\;\frac{\partial T_{Fmid}}{\partial T}\delta T + \frac{\partial T_{Fmid}}{\partial E}\delta E + \frac{\partial T_{Fmid}}{\partial A_{mid}}\;\frac{\partial A_{mid}}{\partial A_2}\delta A_2 + \frac{\partial A_{mid}}{\partial A_1}\delta A_1 \quad |$$

A similar equation as above for a small error in Final corrected net thrust for the climb segment $(F_N/\delta)_2$ is given as;

$$\delta\frac{F_N}{\delta}_2 = \frac{\partial\frac{F_N}{\delta}_2}{\partial V_{CAS}}\delta V_{CAS} + \frac{\partial\frac{F_N}{\delta}_2}{\partial E}\delta E + \frac{\partial\frac{F_N}{\delta}_2}{\partial F}\delta F + \frac{\partial\frac{F_N}{\delta}_2}{\partial G_a}\delta G_a + \frac{\partial\frac{F_N}{\delta}_2}{\partial G_b}\delta G_b +$$

$$\frac{\partial\frac{F_N}{\delta}_2}{\partial H}\delta H + \frac{\partial\frac{F_N}{\delta}_2}{\partial h}\frac{\partial h}{\partial\delta}\frac{\partial\delta}{\partial P}\delta P + \frac{\partial\delta}{\partial A_2}\delta A_2 \;| +$$

$$\frac{\partial\frac{F_N}{\delta}_2}{\partial T_C}\frac{\partial T_C}{\partial T_F}\frac{\partial T_F}{\partial T}\delta T + \frac{\partial T_F}{\partial E}\delta E + \frac{\partial T_F}{\partial A_2}\delta A \;|$$

A small error in True airspeed (δV_{TAS1}) at the start of the climb segment is given by;

$$\delta V_{TAS1} = \frac{\partial V_{TAS1}}{\partial V_{CAS}}\delta V_{CAS} + \frac{\partial V_{TAS1}}{\partial\sigma_1}\frac{\partial\sigma_1}{\partial\delta_1}\frac{\partial\delta_1}{\partial P}\delta P + \frac{\partial\delta_1}{\partial A_1}\delta A_1 \,| + \frac{\partial\sigma_1}{\partial\theta_1}\frac{\partial\theta_1}{\partial T}\delta T + \frac{\partial\theta_1}{\partial E}\delta E + \frac{\partial\theta_1}{\partial A_1}\delta A_1 \,||$$

A small error in True airspeed (δV_{TAS2}) at the end of the climb segment is given by;

$$\delta V_{TAS2} = \frac{\partial V_{TAS2}}{\partial V_{CAS}}\delta V_{CAS} + \frac{\partial V_{TAS2}}{\partial\sigma_2}\frac{\partial\sigma_2}{\partial\delta_2}\frac{\partial\delta_2}{\partial P}\delta P + \frac{\partial\delta_2}{\partial A_2}\delta A_2 \,| + \frac{\partial\sigma_2}{\partial\theta_2}\frac{\partial\theta_2}{\partial T}\delta T + \frac{\partial\theta_2}{\partial E}\delta E + \frac{\partial\theta_2}{\partial A_2}\delta A_2 \,||$$

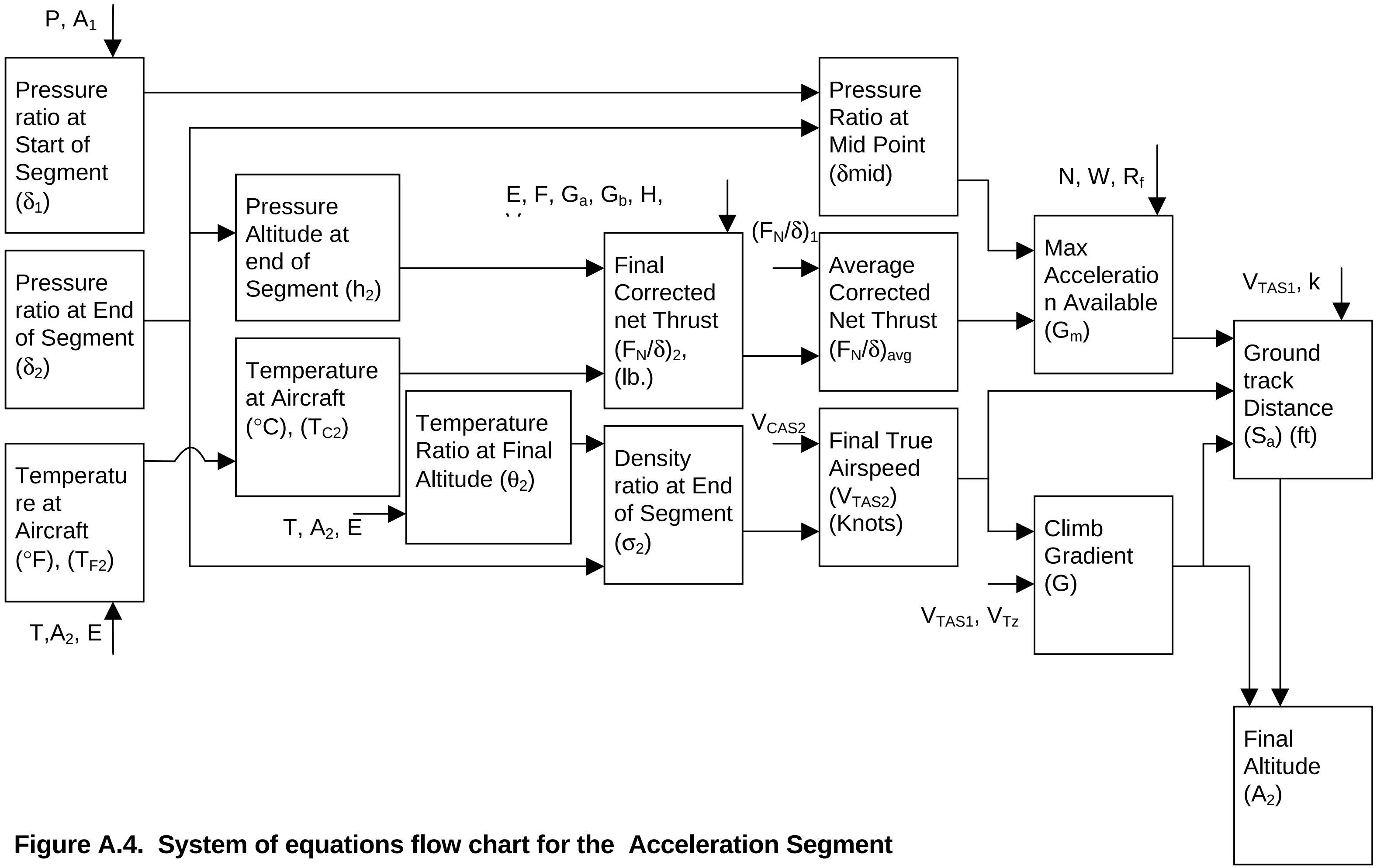


Figure A.4. System of equations flow chart for the Acceleration Segment

Descent segment

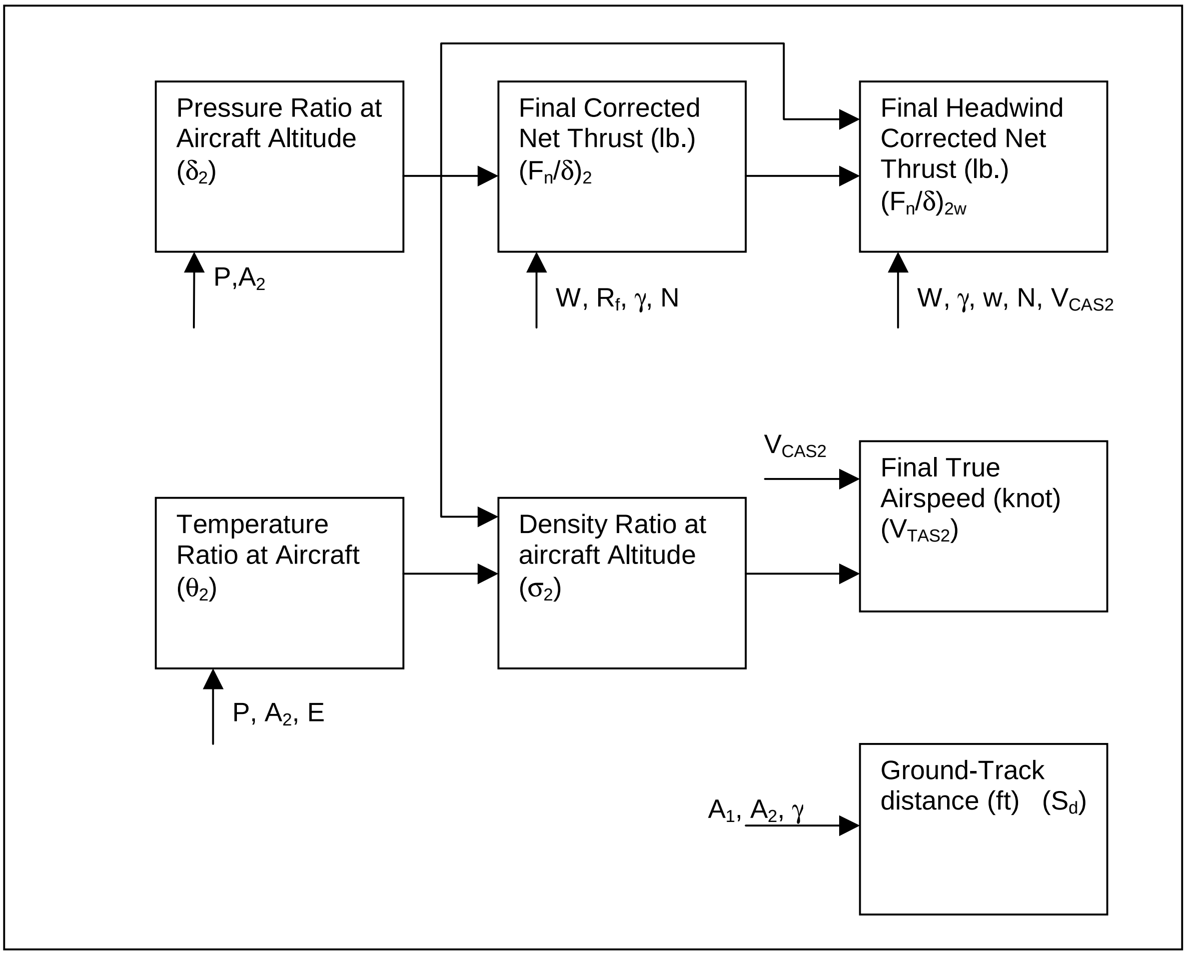


Figure A.5. System of equation flow chart for the Descent segment

A small error in Final Headwind Corrected Net Thrust ($\delta(F_N/\delta)_{2W}$) for the descent segment is given as;

$$\delta\left(\frac{F_N}{\delta}\right)_{2w} = \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial\gamma}\delta\gamma + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial W}\delta W + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial w}\delta w + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial V_{CAS2}}\delta V_{CAS2}$$

$$+ \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial N}\delta N + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial\delta_2}\left(\frac{\partial\delta_2}{\partial P}\delta P + \frac{\partial\delta_2}{\partial A_2}\delta A_2\right)$$

$$+ \frac{\partial\left(\frac{F_N}{\delta}\right)_{2w}}{\partial\left(\frac{F_N}{\delta}\right)_{2}}\left[\begin{array}{l} \frac{\partial\left(\frac{F_N}{\delta}\right)_{2}}{\partial N}\delta N + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2}}{\partial W}\delta W + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2}}{\partial R_f}\delta R_f + \frac{\partial\left(\frac{F_N}{\delta}\right)_{2}}{\partial\gamma}\delta\gamma + \\ \frac{\partial\left(\frac{F_N}{\delta}\right)_{2}}{\partial\delta_2}\left(\frac{\partial\delta_2}{\partial P}\delta P + \frac{\partial\delta_2}{\partial A_2}\delta A_2\right) \end{array}\right]$$

A small error in Final True airspeed (δV_{TAS2}) for the descent segment is given by,

$$\delta V_{TAS2} = \frac{\partial V_{TAS2}}{\partial V_{CAS2}}\delta V_{CAS2} +$$

$$\frac{\partial V_{TAS2}}{\partial\sigma_2}\left[\frac{\partial\sigma_2}{\partial\theta_2}\left(\frac{\partial\theta_2}{\partial T}\delta T + \frac{\partial\theta_2}{\partial E}\delta E + \frac{\partial\theta_2}{\partial A_2}\delta A_2\right) + \frac{\partial\sigma_2}{\partial\delta_2}\left(\frac{\partial\delta_2}{\partial P}\delta P + \frac{\partial\delta_2}{\partial A_2}\delta A_2\right)\right]$$

A small error in Ground Track distance (S_d) for the descent segment is given by;

$$\delta S_d = \frac{\partial S_d}{\partial A_1}\delta A_1 + \frac{\partial S_d}{\partial A_2}\delta A_2 + \frac{\partial S_d}{\partial\gamma}\delta\gamma$$

Level Segment

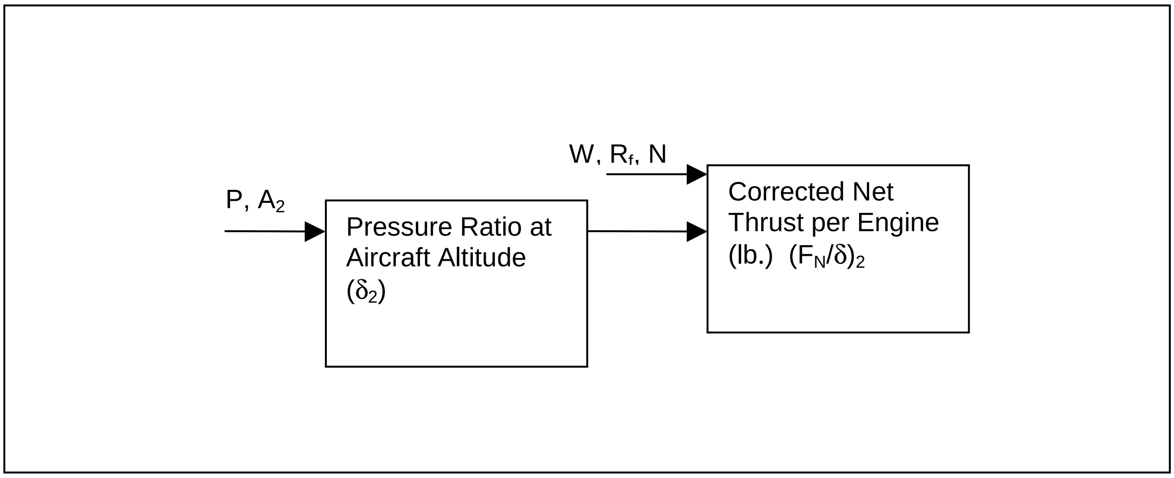


Figure A.6. System of equation flow chart for the Level segment

A small error in Corrected net thrust $(F_N/\delta)_2$ for the level flight segment is given as;

$$\delta \frac{F_N}{\delta}\Big|_2 = \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial W}\delta W + \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial N}\delta N + \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial R_f}\delta R_f + \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial \delta_2}\frac{\partial \delta_2}{\partial P}\delta P + \frac{\partial \delta_2}{\partial A_2}\delta A_2 \Big|$$

Cruise-Climb Segment

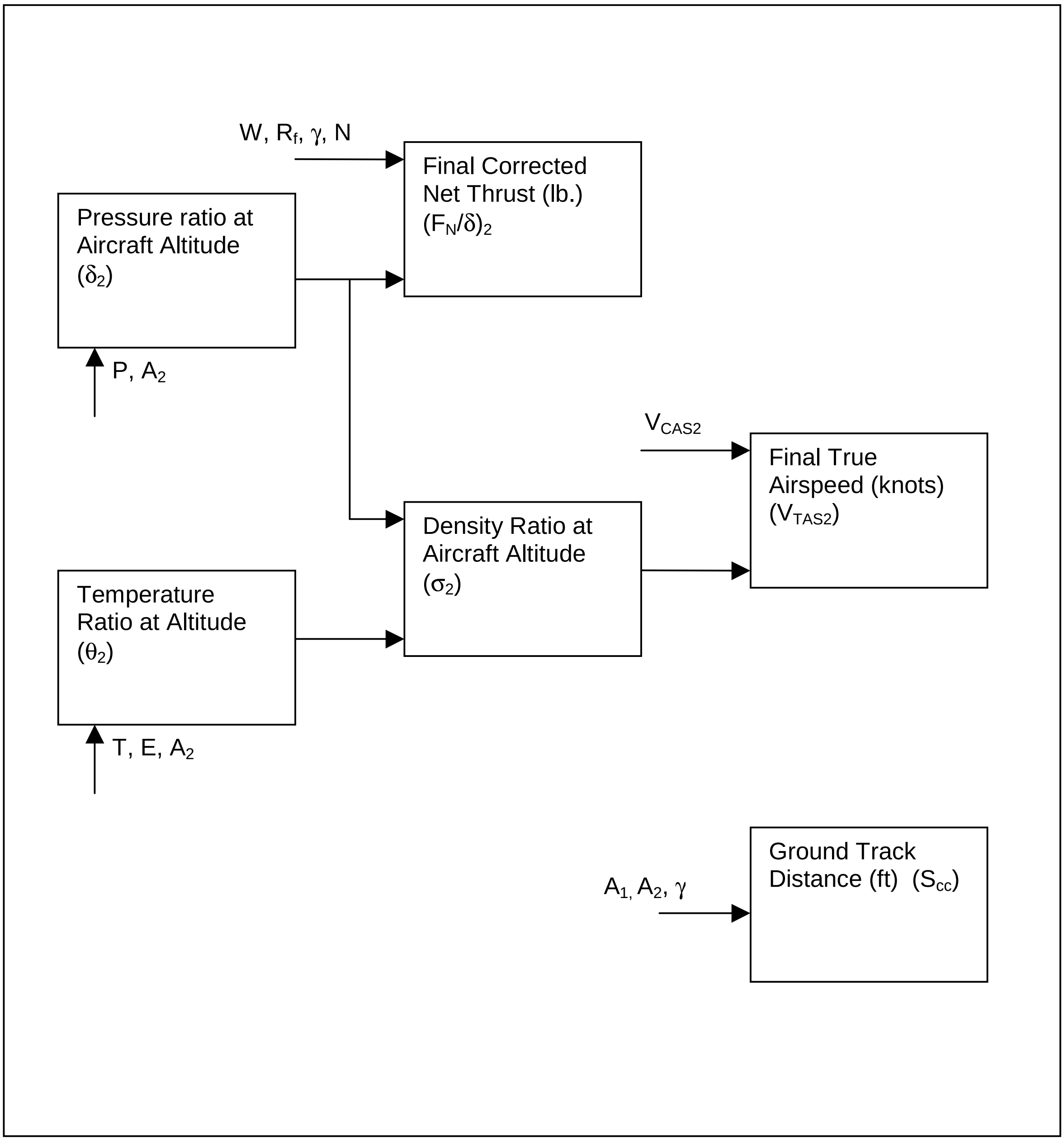


Figure A.7. System of equation flow chart for the Cruise-Climb segment

A small error in Ground Track distance for the Cruise-Climb segment (δS_{cc})is given as;

$$\delta S_{cc} = \frac{\partial S_{cc}}{\partial A_1}\delta A_1 + \frac{\partial S_{cc}}{\partial A_2}\delta A_2 + \frac{\partial S_{cc}}{\partial \gamma}\delta \gamma$$

A small error in Final True Airspeed (δV_{TAS2}) for the Cruise Climb Segment is given as;

$$\delta V_{TAS\,2} = \frac{\partial V_{TAS\,2}}{\partial V_{CAS\,2}}\delta V_{CAS\,2} +$$

$$\frac{\partial V_{TAS\,2}}{\partial \sigma_2}\;\frac{\partial \sigma_2}{\partial \theta_2}\;\frac{\partial \theta_2}{\partial A_2}\delta A_2 + \frac{\partial \theta_2}{\partial E}\delta E + \frac{\partial \theta_2}{\partial T}\delta T \;+ \frac{\partial \sigma_2}{\partial \delta_2}\;\frac{\partial \delta_2}{\partial P}\delta P + \frac{\partial \delta_2}{\partial A_2}\delta A_2 \;\;|$$

A small error in final Corrected Net Thrust ($\delta(F_N./\delta)_2$) for the cruise-climb segment is given as;

$$\delta\;\frac{F_N}{\delta}\Big|_2 \;= \frac{\partial\;\frac{F_N}{\delta}\Big|_2}{\partial W}\delta W + \frac{\partial\;\frac{F_N}{\delta}\Big|_2}{\partial N}\delta N + \frac{\partial\;\frac{F_N}{\delta}\Big|_2}{\partial R_f}\delta R_f + \frac{\partial\;\frac{F_N}{\delta}\Big|_2}{\partial \gamma}\delta \gamma +$$

$$\frac{\partial\;\frac{F_N}{\delta}\Big|_2}{\partial \delta_2}\;\frac{\partial \delta_2}{\partial P}\delta P + \frac{\partial \delta_2}{\partial A_2}\delta A_2 \,|$$

Landing Segment

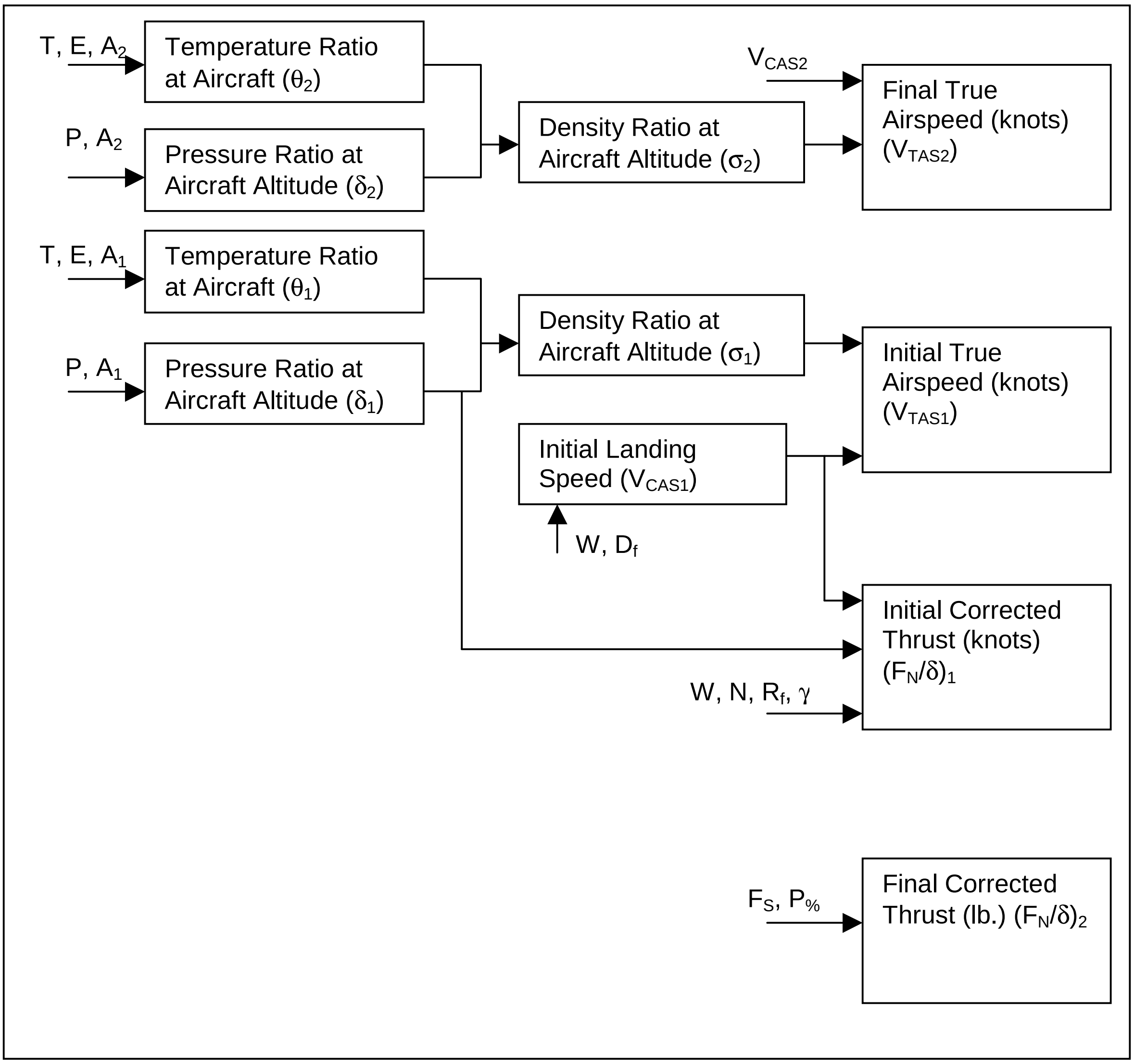


Figure A.8. System of equation flow chart for the Landing segment

A small error in Final true Airspeed (δV_{TAS2}) for the Landing segment is given as;

$$\delta V_{TAS2} = \frac{\partial V_{TAS2}}{\partial V_{CAS2}} \delta V_{CAS2} + \frac{\partial V_{TAS2}}{\partial \sigma_2} \frac{\partial \sigma_2}{\partial \theta_2} \frac{\partial \theta_2}{\partial A_2} \delta A_2 + \frac{\partial \theta_2}{\partial E} \delta E + \frac{\partial \theta_2}{\partial T} \delta T + \frac{\partial \sigma_2}{\partial \delta_2} \frac{\partial \delta_2}{\partial P} \delta P + \frac{\partial \delta_2}{\partial A_2} \delta A_2 \ |$$

Similarly a small error in Initial True Airspeed (δV_{TAS1}) for the Landing Segment is given as;

$$\delta V_{TAS1} = \frac{\partial V_{TAS1}}{\partial V_{CAS1}} \frac{\partial V_{CAS1}}{\partial W} \delta W + \frac{\partial V_{CAS1}}{\partial D_f} \delta D_f + \frac{\partial V_{TAS1}}{\partial \sigma_1} \frac{\partial \sigma_1}{\partial \theta_1} \frac{\partial \theta_1}{\partial A_1} \delta A_1 + \frac{\partial \theta_1}{\partial E} \delta E + \frac{\partial \theta_1}{\partial T} \delta T + \frac{\partial \sigma_1}{\partial \delta_1} \frac{\partial \delta_1}{\partial P} \delta P + \frac{\partial \delta_1}{\partial A_1} \delta A_1 \ |$$

A small error in Initial Corrected Thrust ($\delta(F_N/\delta)_1$) for the Landing segment is given as;

$$\delta \frac{F_N}{\delta}\Big|_1 = \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial W} \delta W + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial N} \delta N + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial R_f} \delta R_f + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial \gamma} \delta \gamma + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial V_{CAS1}} \frac{\partial V_{CAS1}}{\partial W} \delta W + \frac{\partial V_{CAS1}}{\partial D_f} \delta D_f \ | + \frac{\partial \frac{F_N}{\delta}\Big|_1}{\partial \delta_1} \frac{\partial \delta_1}{\partial P} \delta P + \frac{\partial \delta_1}{\partial A_1} \delta A_1 \ |$$

A small error in Final Corrected Net Thrust ($\delta(F_N/\delta)_2$) for the Landing Segment is given as

$$\delta \frac{F_N}{\delta}\Big|_2 = \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial F_S} \delta F_S + \frac{\partial \frac{F_N}{\delta}\Big|_2}{\partial P_{\%}} \delta P_{\%}$$

Decelerate Segment

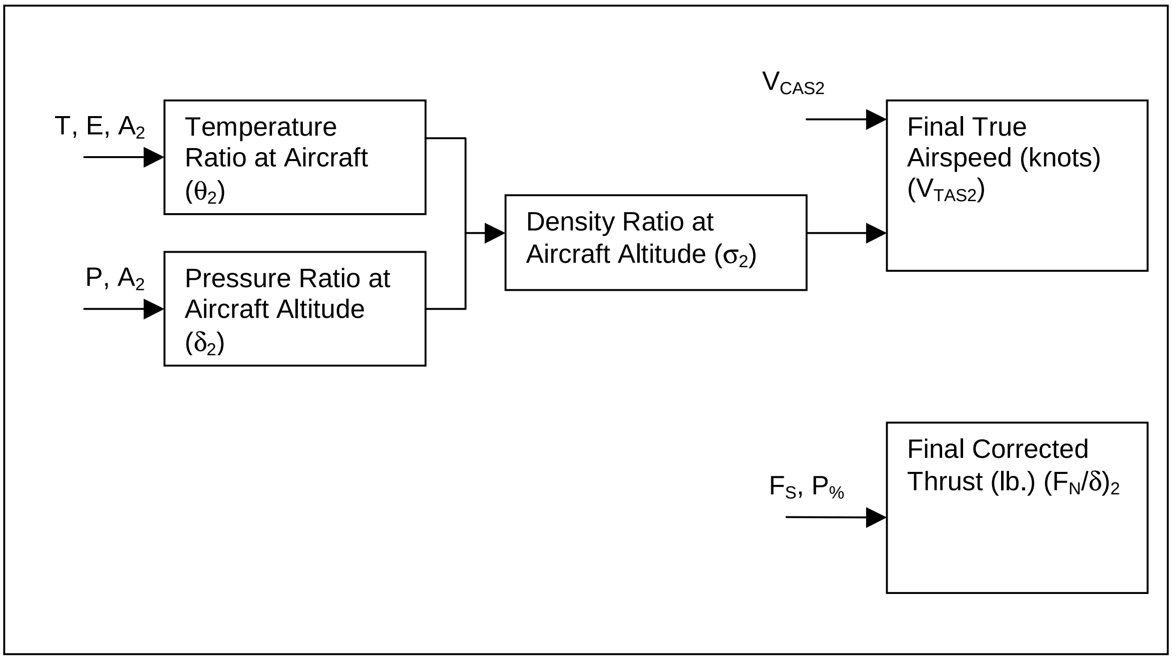


Figure A.9. System of equation flow chart for the Decelerate segment

A small error in Final True Airspeed (δV_{TAS2}) for the decelerate segment is given as;

$$\delta V_{TAS2} = \frac{\partial V_{TAS2}}{\partial V_{CAS2}} \delta V_{CAS2} +$$

$$\frac{\partial V_{TAS2}}{\partial \sigma_2} \frac{\partial \sigma_2}{\partial \theta_2} \frac{\partial \theta_2}{\partial A_2} \delta A_2 + \frac{\partial \theta_2}{\partial E} \delta E + \frac{\partial \theta_2}{\partial T} \delta T + \frac{\partial \sigma_2}{\partial \delta_2} \frac{\partial \delta_2}{\partial P} \delta P + \frac{\partial \delta_2}{\partial A_2} \delta A_2 \quad |$$

A small error in Final Corrected Net Thrust ($\delta(F_N/\delta)_2$) for the Decelerate segment is given as;

$$\delta \left. \frac{F_N}{\delta} \right|_2 = \frac{\partial \left. \frac{F_N}{\delta} \right|_2}{\partial F_S} \delta F_S + \frac{\partial \left. \frac{F_N}{\delta} \right|_2}{\partial P_{\%}} \delta P_{\%}$$

Speed Interpolation

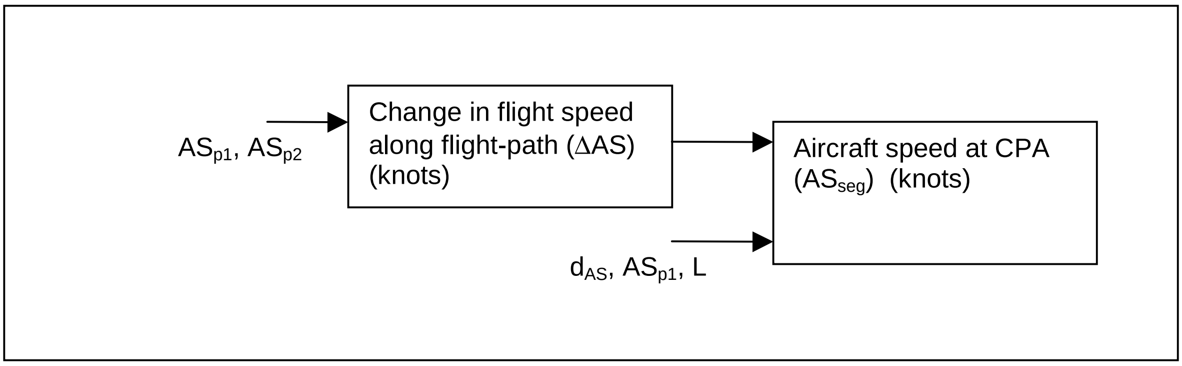
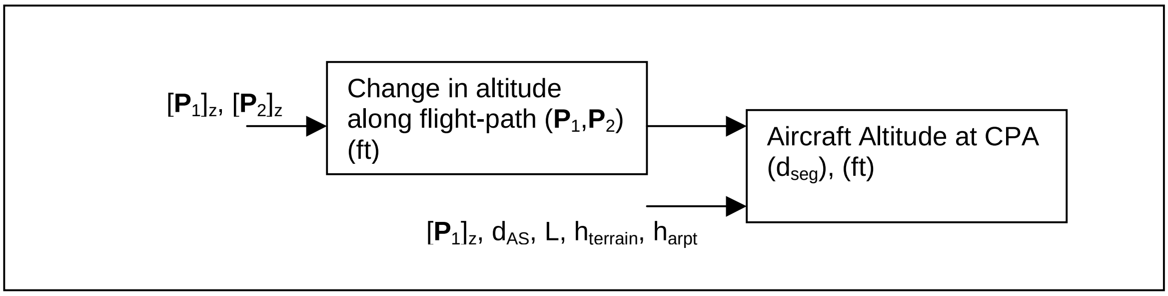


Figure A.10. System of equation flow chart for the calculation of interpolated speed

A small error in the interpolated speed at a point on the flight path (δAS_{seg}) is given by;

$$\delta AS_{seg} = \frac{\partial AS_{seg}}{\partial AS_{P1}}\delta AS_{P} + \frac{\partial AS_{seg}}{\partial d_{AS}}\delta d_{AS} + \frac{\partial AS_{seg}}{\partial L}\delta L + \frac{\partial AS_{seg}}{\partial \Delta AS}\ \frac{\partial \Delta AS}{\partial AS_{P1}}\delta AS_{P1} + \frac{\partial \Delta AS}{\partial AS_{P2}}\delta AS_{P2}\ |$$

Altitude Interpolation



Figuren A.11. System of equation flow chart for the calculation of interpolated altitude

A small error in Interpolated Altitude (δd_{seg}) is given by;

$$\delta d_{seg} = \frac{\partial d_{seg}}{\partial[\mathbf{P}_1]_z}\delta[\mathbf{P}_1]_z + \frac{\partial d_{seg}}{\partial d_{AS}}\delta d_{AS} + \frac{\partial d_{seg}}{\partial L}\delta L + \frac{\partial d_{seg}}{\partial h_{terrain}}\delta h_{terrain} + \frac{\partial d_{seg}}{\partial h_{airport}}\delta h_{airport}$$

$$+ \frac{\partial d_{seg}}{\partial(\mathbf{P}_1\mathbf{P}_2)_z}\ \frac{\partial(\mathbf{P}_1\mathbf{P}_2)_z}{\partial[\mathbf{P}_1]_z}\delta[\mathbf{P}_1]_z + \frac{\partial(\mathbf{P}_1\mathbf{P}_2)_z}{\partial[\mathbf{P}_2]_z}\delta[\mathbf{P}_2]_z\ |$$

Engine Power Level Interpolation

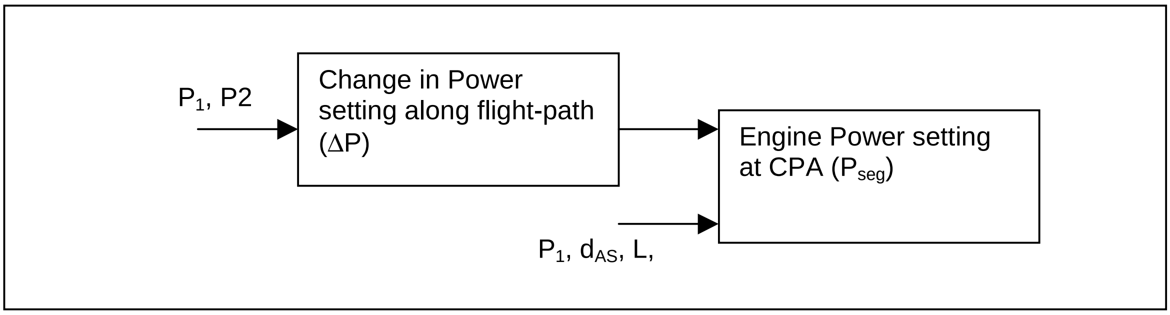


Figure A.12. System of equations flow chart for the calculation of interpolated engine power

A small error in Interpolated Engine Power Setting (δP_{seg}) at a point on the flight path is given by;

$$\delta P_{seg} = \frac{\partial P_{seg}}{\partial P_1}\delta P_1 + \frac{\partial P_{seg}}{\partial d_{AS}}\delta d_{AS} + \frac{\partial P_{seg}}{\partial L}\delta L + \frac{\partial P_{seg}}{\partial \Delta P}\ \frac{\partial \Delta P}{\partial P_1}\delta P_1 + \frac{\partial \Delta P}{\partial P_2}\delta P_2 \ |$$

Noise Level Interpolation

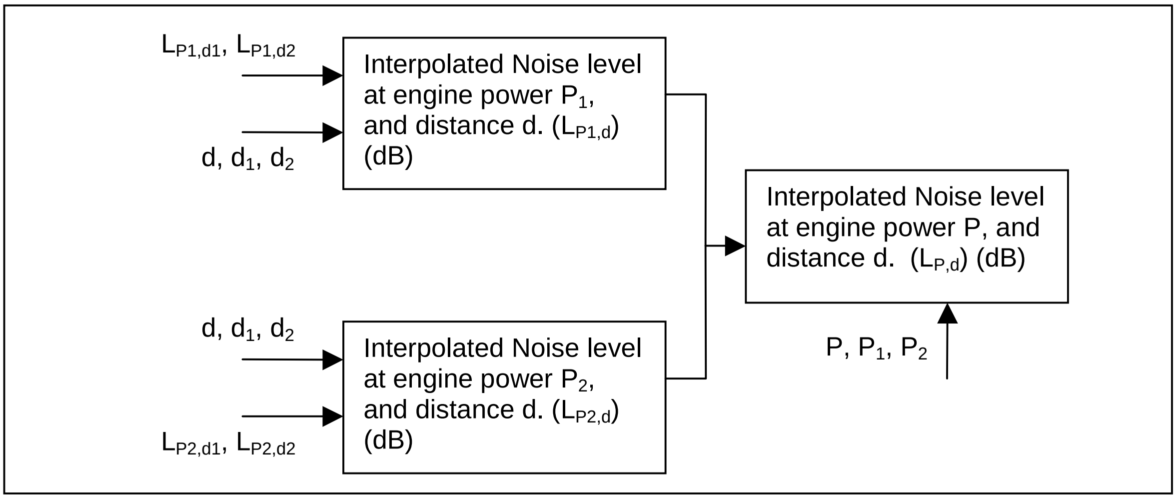


Figure A.13. System of equations flow chart for the calculation of interpolated noise level

A small error in Interpolated Power level ($\delta L_{P,d}$) at a point on the flight path is given by;

$$\delta L_{P,d} = \frac{\partial L_{P,d}}{\partial P_1}\delta P_1 + \frac{\partial L_{P,d}}{\partial P_2}\delta P_2 + \frac{\partial L_{P,d}}{\partial P}\delta P + \frac{\partial L_{P,d}}{\partial L_{P1,d}}\delta L_{P1,d} + \frac{\partial L_{P,d}}{\partial L_{P2,d}}\delta L_{P2,}$$

where the small error in Noise level at engine power P_1 and P_2 ($\delta L_{P1,}d$ and $\delta L_{P2,d}$ respectively) are given by;

$$\delta L_{P1,d} = \frac{\partial L_{P1,d}}{\partial L_{P1,d1}}\delta L_{P1,d1} + \frac{\partial L_{P1,d}}{\partial L_{P1,d2}}\delta L_{P1,d2} + \frac{\partial L_{P1,d}}{\partial d}\delta d + \frac{\partial L_{P1,d}}{\partial d_1}\delta d_1 + \frac{\partial L_{P1,d}}{\partial d_2}\delta d_2$$

$$\delta L_{P2,d} = \frac{\partial L_{P2,d}}{\partial L_{P2,d1}}\delta L_{P2,d1} + \frac{\partial L_{P2,d}}{\partial L_{P2,d2}}\delta L_{P1,d2} + \frac{\partial L_{P2,d}}{\partial d}\delta d + \frac{\partial L_{P2,d}}{\partial d_1}\delta d_1 + \frac{\partial L_{P2,d}}{\partial d_2}\delta d_2$$

Acoustic Impedance Adjustment

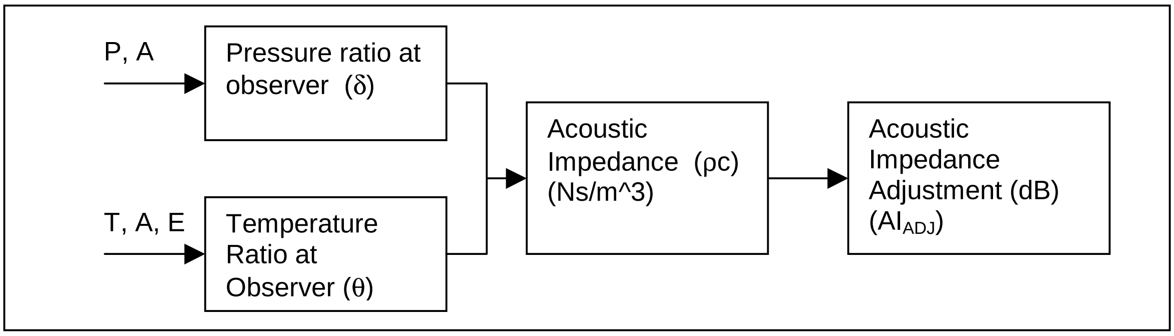


Figure A.14. System of equations flow chart for the calculation of the Acoustic Impedance Adjustment

A small error in Acoustic Impedance Adjustment (δAI_{ADJ}) is given by;

$$\delta AI_{ADJ} = \frac{\partial AI_{ADJ}}{\partial \rho c} \quad \frac{\partial \rho c}{\partial \delta} \quad \frac{\partial \delta}{\partial P}\delta P + \frac{\partial \delta}{\partial A} + \delta A \quad + \frac{\partial \rho c}{\partial \theta} \quad \frac{\partial \theta}{\partial T}\delta T + \frac{\partial \theta}{\partial A}\delta A + \frac{\partial \theta}{\partial E}\delta E \quad |$$

Noise Fraction Adjustment for Flight segments

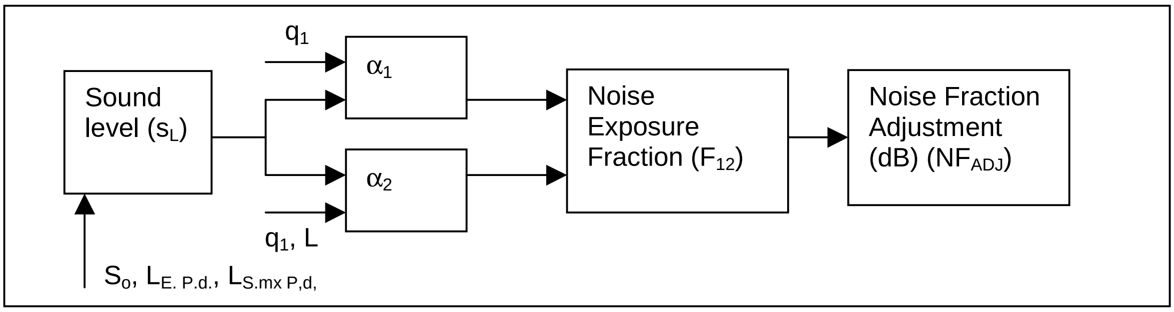


Figure A.15. System of equations flow chart for the calculation of the noise fraction adjustment for flight segment.

A small error in the Noise Fraction Adjustment (δNF_{ADJ}) for Flight Segments is given by;

$$\delta NF_{ADJ} = \frac{\partial NF_{ADJ}}{\partial F_{12}} \quad \frac{\partial F_{12}}{\partial \alpha_1}\delta\alpha_1 + \frac{\partial F_{12}}{\partial \alpha_2}\delta\alpha_2 \; |$$

Where the small error of $\delta\alpha_1$ and $\delta\alpha_2$ is given as;

$$\delta\alpha_1 = \frac{\partial\alpha_1}{\partial q_1}\delta q_1 + \frac{\partial\alpha_1}{\partial S_L}\frac{\partial S_L}{\partial S_0}\delta S_0 + \frac{\partial S_L}{\partial L_{E.P,\,d}}\delta L_{E.P,\,d} + \frac{\partial S_L}{\partial L_{Smx.P,\,d}}\delta L_{Smx.P,\,d}\,\Big|$$

$$\delta\alpha_2 = \frac{\partial\alpha_2}{\partial L}\delta L + \frac{\partial\alpha_2}{\partial q_1}\delta q_1 + \frac{\partial\alpha_2}{\partial S_L}\frac{\partial S_L}{\partial S_0}\delta S_0 + \frac{\partial S_L}{\partial L_{E.P,\,d}}\delta L_{E.P,\,d} + \frac{\partial S_L}{\partial L_{Smx.P,\,d}}\delta L_{Smx.P,\,d}\,\Big|$$

Noise Fraction Adjustment for Behind Start-of-Takeoff-Roll

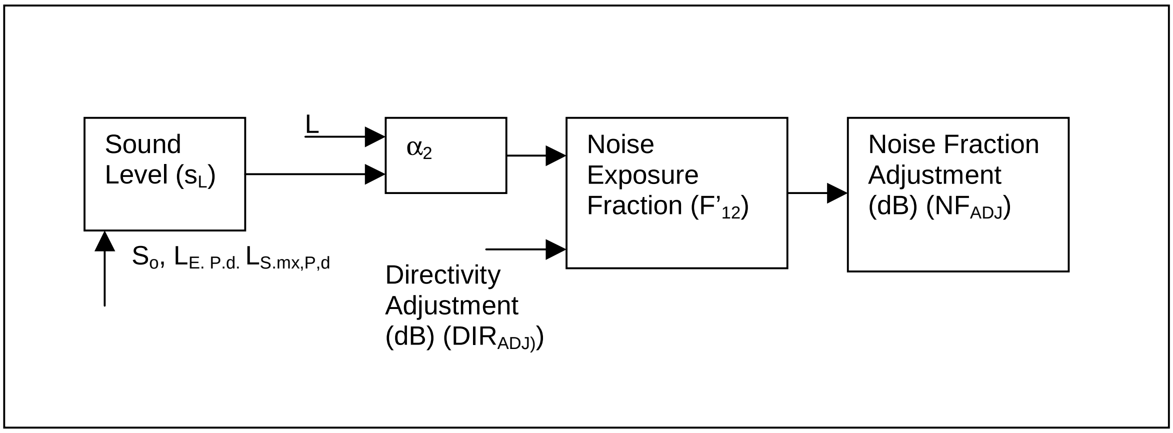


Figure A.16. System of equations flow chart for the calculation of the noise fraction adjustment when the observer is behind start-of-take-off-roll

A small error in the Noise fraction Adjustment (δNF_{ADJ}) for Behind start-of-Takeoff Roll is given by;

$$\delta NF_{ADJ} = \frac{\partial NF_{ADJ}}{\partial F'_{12}}\frac{\partial F'_{12}}{\partial\alpha_2}\delta\alpha_2 + \frac{\partial F'_{12}}{\partial DIR_{ADJ}}\delta DIR_{ADJ}\,\Big|$$

where

$$\delta\alpha_2 = \frac{\partial\alpha_2}{\partial L}\delta L + \frac{\partial\alpha_2}{\partial S_L}\frac{\partial S_L}{\partial S_0}\delta S_0 + \frac{\partial S_L}{\partial L_{E.P,\,d}}\delta L_{E.P,\,d} + \frac{\partial S_L}{\partial L_{Smx.P,\,d}}\delta L_{Smx.P,\,d}\,\Big|$$

Speed Adjustment

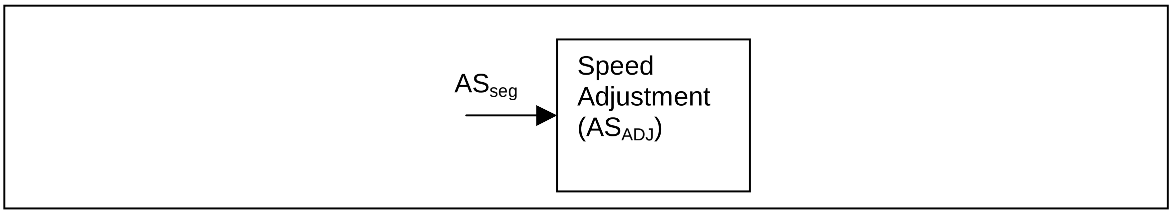


Figure A.17. System of equations flow chart for the calculation of the speed adjustment

A small error in Speed Adjustment (δAS_{ADJ}) is given by;

$$\delta AS_{ADJ} = \frac{\partial AS_{ADJ}}{\partial AS_{seg}} \delta AS_{seg}$$

Lateral Attenuation Adjustment

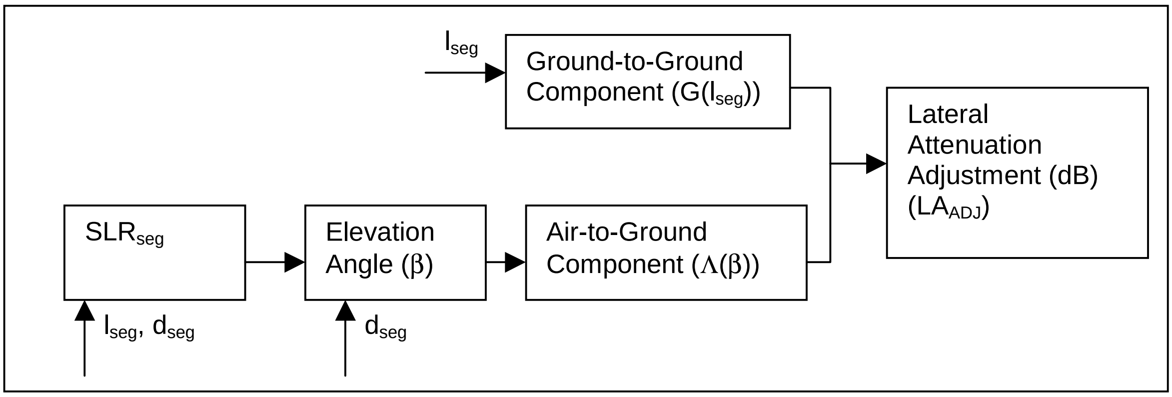


Figure A.18. System of equations flow chart for the calculation of Lateral Attenuation adjustmet

A small error in Lateral Attenuation Adjustment (δLA_{ADJ}) is given as;

$$\delta LA_{ADJ} = \frac{\partial LA_{ADJ}}{\partial G\left(l_{seg}\right)} \frac{\partial G\left(l_{seg}\right)}{\partial l_{seg}} \delta l_{seg}$$

$$+ \frac{\partial LA_{ADJ}}{\partial \Lambda(\beta)} \frac{\partial \Lambda(\beta)}{\partial \beta} \frac{\partial \beta}{\partial d_{seg}} \delta d_{seg} + \frac{\partial \beta}{\partial SLR_{seg}} \frac{\partial SLR_{seg}}{\partial d_{seg}} \delta d_{seg} + \frac{\partial SLR_{seg}}{\partial l_{seg}} \delta l_{seg} \quad |$$

The same equation is used to calculate the error for NOISEMAP aircraft, using different differential terms.

Ground-Based Directivity Adjustment

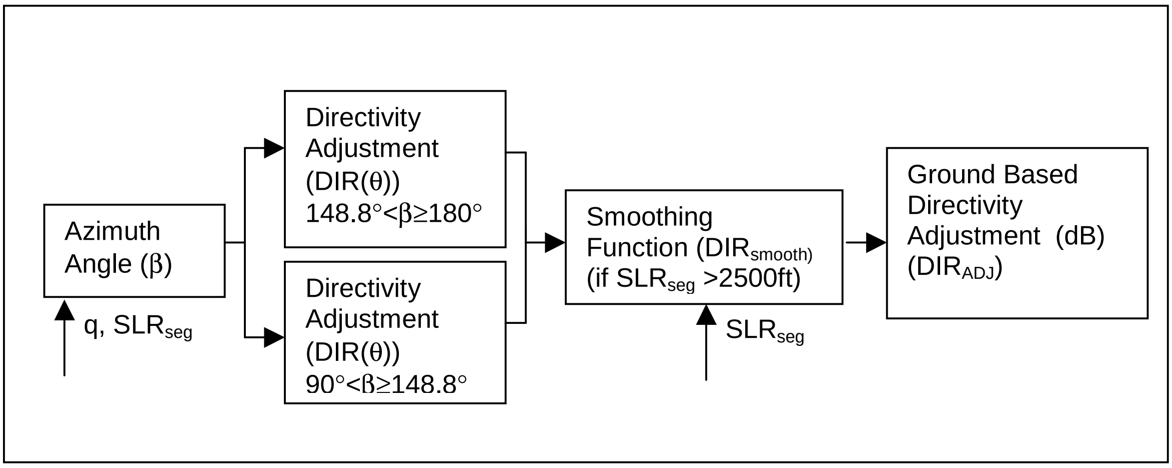


Figure A.19. System of equations flow chart for the calculation of the gound based directivity adjustment

The error in Ground-based directivity adjustment is calculated using the full INM equation and calculating for datum conditions, and then recalculating at the same conditions but with a small error included.

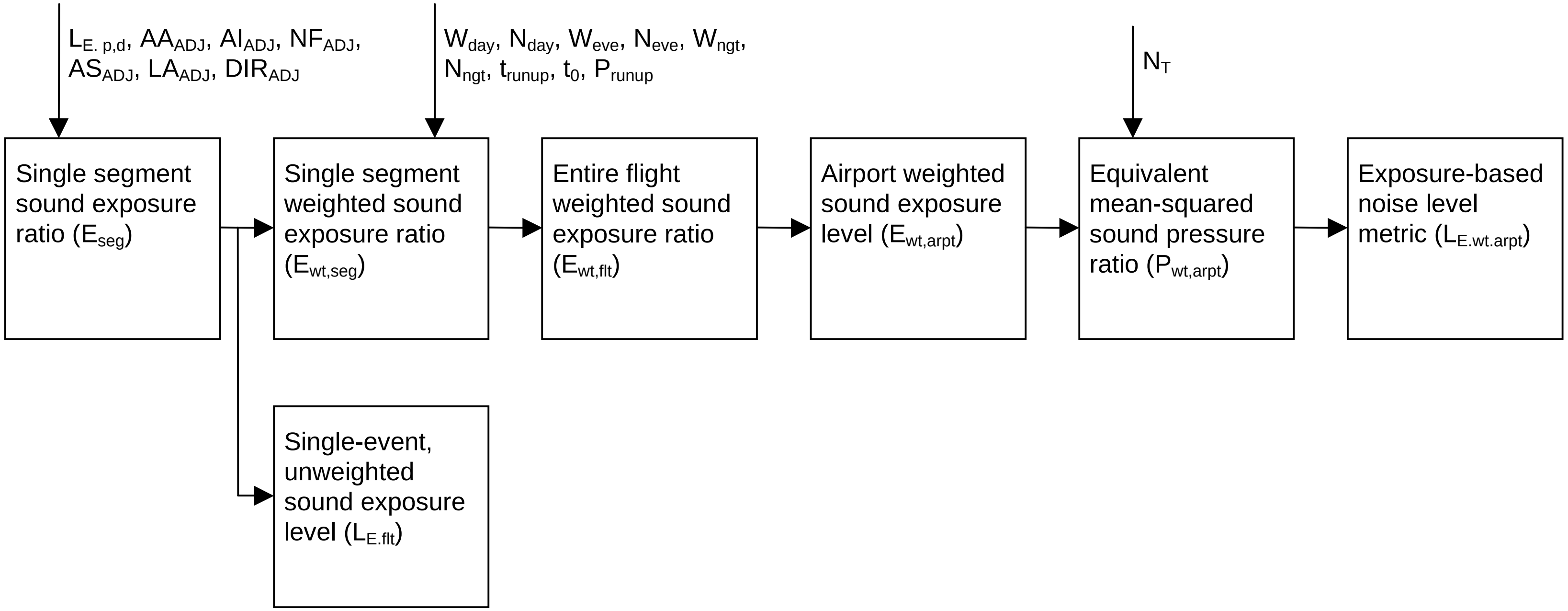


Figure A.16. System of equations flow chart for the calculation of Exposure Based noise level metric

A small error in Exposure-based noise level metric ($L_{E.wt.arpt}$) for Flight operations is given as;

$$\delta L_{E.wt.arpt} = \frac{\partial L_{E.wt.arpt}}{\partial P_{wt.arpt}} \frac{\partial P_{wt.arpt}}{\partial N_T} \delta N_T + \frac{\partial P_{wt.arpt}}{\partial E_{wt.arpt}} \frac{\partial E_{wt.arpt}}{\partial E_{wt.flt}} \frac{\partial E_{wt.flt}}{\partial E_{wt.seg}} \delta E_{wt.seg} \qquad |$$

where the small error in single segment weighted sound exposure ratio ($E_{wt.seg}$) is given by;

$$\delta E_{wt.seg} = \frac{\partial E_{wt.seg}}{\partial W_{day}} \delta W_{day} + \frac{\partial E_{wt.seg}}{\partial N_{day}} \delta N_{day} + \frac{\partial E_{wt.seg}}{\partial W_{eve}} \delta W_{eve} + \frac{\partial E_{wt.seg}}{\partial N_{eve}} \delta N_{eve} + \\ \frac{\partial E_{wt.seg}}{\partial W_{ngt}} \delta W_{ngt} + \frac{\partial E_{wt.seg}}{\partial N_{ngt}} \delta N_{ngt} + \frac{\partial E_{wt.seg}}{\partial E_{seg}} \delta E_{seg}$$

where the small error in Single segment sound exposure ratio (E_{seg}) is given as;

$$\delta E_{seg} = \frac{\partial E_{seg}}{\partial L_{E.P,\,d}} \delta L_{EP,\,d} + \frac{\partial E_{seg}}{\partial AA_{ADJ}} \delta AA_{ADJ} + \frac{\partial E_{seg}}{\partial AI_{ADJ}} \delta AI_{ADJ} + \\ \frac{\partial E_{seg}}{\partial NF_{ADJ}} \delta NF_{ADJ} + \frac{\partial E_{seg}}{\partial AS_{ADJ}} \delta AS_{ADJ} + \frac{\partial E_{seg}}{\partial LA_{ADJ}} \delta LA_{ADJ} + \frac{\partial E_{seg}}{\partial DIR_{ADJ}} \delta DIR_{ADJ}$$

A small error in Exposure-based noise level metric ($L_{E.wt.arpt}$) for Runup Operations is given using a similar equation as above, with the following equations altered to include a number of additional terms;

$$\delta P_{runup} = \frac{\partial P_{runup}}{\partial L_{Smx.P,\,d}} \delta L_{Smx.P,\,d} + \frac{\partial P_{runup}}{\partial AA_{ADJ}} \delta AA_{ADJ} + \frac{\partial P_{runup}}{\partial AI_{ADJ}} \delta AI_{ADJ} \\ + \frac{\partial P_{runupg}}{\partial LA_{ADJ}} \delta LA_{ADJ} + \frac{\partial P_{runup}}{\partial DIR_{ADJ}} \delta DIR_{ADJ}$$

$$\delta E_{wt.runup} = \frac{\partial E_{wt.runup}}{\partial W_{day}} \delta W_{day} + \frac{\partial E_{wt.runup}}{\partial N_{day}} \delta N_{day} + \frac{\partial E_{wt.runup}}{\partial W_{eve}} \delta W_{eve} + \frac{\partial E_{wt.runup}}{\partial N_{eve}} \delta N_{eve} + \\ \frac{\partial E_{wt.runup}}{\partial W_{ngt}} \delta W_{ngt} + \frac{\partial E_{wt.runup}}{\partial N_{ngt}} \delta N_{ngt} + \frac{\partial E_{wt.runup}}{\partial P_{runup}} \delta P_{runup} \\ + \frac{\partial E_{wt.runup}}{\partial t_{runup}} \delta t_{runup} + \frac{\partial E_{wt.runup}}{\partial t_0} \delta t_0$$

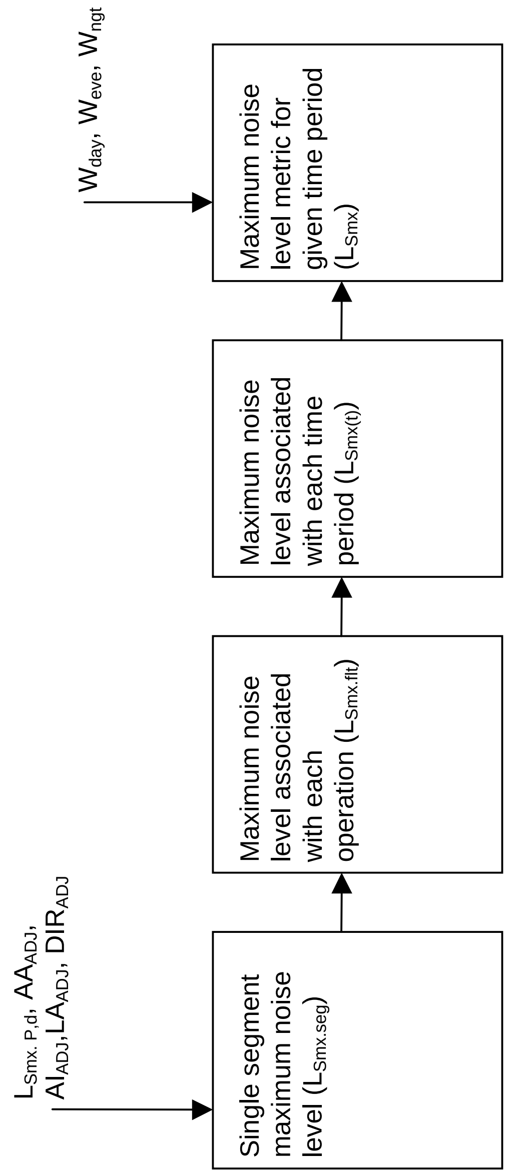


Figure A.17. System of equations flow chart for the calculation of maximum noise level metric

A small error in maximum noise level due to a single flight-path segment ($L_{Smx.\,seg}$) is given as;

$$\delta L_{Smx.seg} = \frac{\partial L_{Smx.seg}}{\partial L_{Smx.P,\,d}}\,\delta L_{Sma.P,\,d} + \frac{\partial L_{Smx.seg}}{\partial AA_{ADJ}}\,\delta AA_{ADJ} + \frac{\partial L_{Smx.seg}}{\partial AI_{ADJ}}\,\delta AI_{ADJ} + \frac{\partial L_{Smx.seg}}{\partial LA_{ADJ}}\,\delta LA_{ADJ} + \frac{\partial L_{Smx.seg}}{\partial DIR_{ADJ}}\,\delta DIR_{ADJ}$$

This page is intentionally blank

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient B	33.624	32.569	41.285	26.704	29.335	31.073	51.039	33.882	30.958	34.003	34.719	38.204	39.589
Coefficient C	6.138	6.841	7.635	3.673	4.531	6.736	11.377	4.302	5.121	5.304	5.642	4.700	6.120
Coefficient E	-40.1	-39.74	-49.33	-30.60	-34.11	-38.13	-63.12	-38.56	-36.34	-39.68	-40.71	-43.31	-46.21
Coefficient F	6.482	7.164	8.052	3.901	4.778	7.058	12.088	4.632	5.390	5.684	5.998	5.110	6.623
Coefficient Ga	-0.007	0.007	-0.006	-0.004	-0.003	0.002	-0.006	0.001	-0.012	-0.008	-0.006	-0.005	-0.006
Coefficient Gb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Airport Elevation	0.025	0.037	0.033	0.021	0.024	0.031	0.041	0.033	0.017	0.024	0.027	0.031	0.031
Airport Pressure	-52.22	-79.39	-69.27	-44.17	-51.13	-66.63	-87.94	-70.68	-35.32	-51.83	-56.67	-65.23	-65.81
Airport Temp	3.805	3.686	4.673	3.025	3.323	3.516	5.765	3.835	3.506	3.846	3.929	4.322	4.475
Aircraft Weight	70.317	68.559	86.388	55.244	60.936	65.514	107.78	69.915	64.476	70.658	72.259	78.758	82.239
Head-wind	-3.934	-3.817	-4.308	-3.209	-3.326	-3.819	-5.655	-3.845	-3.468	-4.150	-4.004	-4.291	-4.776
Elevation E1	-0.343	-0.323	-0.417	-0.228	-0.247	-0.322	-0.711	-0.329	-0.269	-0.380	-0.356	-0.410	-0.503
Elevation E2	0.515	0.485	0.625	0.342	0.370	0.483	1.067	0.494	0.403	0.570	0.535	0.615	0.755
Runway Length	-0.172	-0.162	-0.208	-0.114	-0.123	-0.161	-0.356	-0.165	-0.134	-0.190	-0.178	-0.205	-0.252

Table B.1. Error in ground track disance (ft) for the takeoff segment, due to a 1% error in each of the input

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310 - 300	A319 - 131	A320 - 232	A330 - 301	A340 - 211
Coefficient E	175.43	235.35	536.7	370.92	604.75	796.73	407.2	493.37	494.60	214.79	247.11	613.86	298.55
Coefficient F	0	0	0	0	0	0	0	0	0	0	0	0	0
Coefficient Ga	0.031	-0.04	0.067	0.052	0.062	-0.046	0.042	-0.019	0.169	0.041	0.036	0.073	0.04
Coefficient Gb	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Elevation	0.031	-0.04	0.067	0.052	0.062	-0.046	0.042	-0.019	0.169	0.041	0.036	0.073	0.04
Airport Pressure	-65.026	85.345	-142.52	-110.62	-131.663	96.855	-89.026	39.376	-360.27	-86.574	-76.468	-155.691	-84.784

Table B.2. Error in intial thrust (lb.) for the takeoff segment, due to a 1% error in each of the input varaibles

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient C	-28.356	-42.428	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793
Coefficient E	175.43	235.35	536.7	370.92	604.75	796.73	407.2	493.37	494.6	214.79	247.11	613.86	298.55
Coefficient F	-28.356	-42.428	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793
Coefficient Ga	0.031	-0.04	0.067	0.052	0.062	-0.046	0.042	-0.019	0.169	0.041	0.036	0.073	0.04
Coefficient Gb	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Elevation	0.031	-0.04	0.067	0.052	0.062	-0.046	0.042	-0.019	0.169	0.041	0.036	0.073	0.04
Airport Pressure	-65.026	85.345	-142.56	-110.64	-131.67	96.855	-89.03	39.376	-360.27	-86.574	-76.468	-155.70	-84.784
Airport Temp	3.786	3.668	4.649	3.012	3.309	3.498	5.725	3.817	3.491	3.825	3.909	4.299	4.446
Aircraft Weight	-14.178	-21.214	-43.801	-23.643	-42.357	-73.734	-38.989	-29.665	-36.682	-15.384	-18.203	-36.211	-21.396

Table B.3. Error in final thrust (lb.) for the takeoff segment, due to a 1% error in each of the input variables

Aircraft/ Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient C	1.448	1.445	1.613	1.412	1.491	1.382	1.524	1.49	1.508	1.391	1.467	1.505	1.406
Aircraft Weight	0.724	0.723	0.807	0.706	0.746	0.691	0.762	0.745	0.754	0.696	0.734	0.752	0.703

Table B.4. Error in final calibrated airspeed (knot) for the takeoff segment, due to a 1% error in each of the input varaibles

This page is intentionally blank

Aircraft / Variable	**717-200**	**737-700**	**747-400**	**757-200**	**767-400ER**	**777-200**	**L1011**	**A300 B4**	**A310-300**	**A319-131**	**A320-232**	**A330-301**	**A340-211**
Coefficient R	-0.046	-0.045	-0.049	-0.046	-0.048	-0.049	-0.055	-0.055	-0.06	-0.044	-0.043	-0.039	-0.045
Coefficient E	0.216	0.239	0.22	0.265	0.248	0.246	0.215	0.22	0.251	0.194	0.213	0.195	0.178
Coefficient F	-0.035	-0.043	-0.036	-0.034	-0.035	-0.046	-0.041	-0.026	-0.037	-0.028	-0.031	-0.023	-0.026
Coefficient Ga	0.001	0.002	0.001	0.001	0.001	-0.001	0.001	0	0.003	0.001	0.001	0.001	0.001
Coefficient Gb	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Elevation	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Pressure	0.103	0.112	0.127	0.155	0.161	0.23	0.128	0.211	0.039	0.09	0.118	0.124	0.104
Aircraft Weight	-0.182	-0.198	-0.185	-0.233	-0.214	-0.2	-0.175	-0.193	-0.217	-0.168	-0.183	-0.173	-0.154
Final Altitude	-0.002	-0.002	-0.002	-0.003	-0.003	-0.004	-0.002	-0.004	-0.001	-0.002	-0.002	-0.002	-0.002
CAS	-0.035	-0.043	-0.036	-0.034	-0.035	-0.046	-0.041	-0.026	-0.037	-0.028	-0.031	-0.023	-0.026
Head-wind	0.008	0.009	0.007	0.011	0.009	0.009	0.007	0.008	0.009	0.007	0.008	0.007	0.006

Table C.1. Error in climb angle (degree) for the first climb segment, due to a 1% error in each of the input

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient R	14.977	11.617	15.854	8.267	10.625	13.02	22.873	17.422	14.685	16.989	13.276	13.04	22.627
Coefficient E	-69.658	-61.961	-71.078	-47.53	-54.996	-65.362	-88.986	-69.232	-61.607	-75.038	-65.45	-65.027	-89.007
Coefficient F	11.26	11.17	11.602	6.059	7.704	12.098	17.041	8.326	9.138	10.749	9.643	7.672	12.758
Coefficient Ga	-0.473	-0.411	-0.345	-0.259	-0.219	0.145	-0.356	0.101	-0.822	-0.554	-0.371	-0.302	-0.463
Coefficient Gb	0	0	0	0	0	0	0	0	0.009	-0.002	0.002	0.001	0.004
Airport Elevation	-0.547	-0.487	-0.548	-0.398	-0.448	-0.494	-0.624	-0.54	-0.473	-0.602	-0.533	-0.557	-0.688
Airport Pressure	-33.256	-28.912	-41.157	-27.699	-35.704	-61.25	-52.956	-66.516	-9.519	-34.654	-36.319	-41.464	-52.075
Aircraft Weight	58.871	51.202	59.822	41.73	47.512	53.118	72.303	60.806	53.282	64.844	56.176	57.656	76.709
Final Altitude	42.707	37.967	42.927	31.148	35.122	39.098	48.961	42.747	36.551	46.962	41.691	43.625	53.851
CAS	11.26	12.287	11.602	6.059	7.704	12.098	17.041	8.326	9.138	10.749	9.643	7.672	12.758
Head-wind	-2.521	-2.267	-2.253	-1.944	-2.035	-2.41	-2.7	-2.416	-2.111	-2.877	-2.427	-2.462	-3.225

Table C.2. Error in ground track distance (ft) for the first climb segment, due to a 1% error in each of the input varaibles

Aircraft / Variable	**717-200**	**737-700**	**747-400**	**757-200**	**767-400ER**	**777-200**	**L1011**	**A300 B4**	**A310-300**	**A319-131**	**A320-232**	**A330-301**	**A340-211**
Coefficient E	175.43	235.35	536.7	370.92	604.76	796.73	407.2	493.37	494.60	214.79	247.11	613.86	298.55
Coefficient F	-28.356	-42.427	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793
Coefficient Ga	2.35	3.084	5.15	3.998	4.758	-3.5	3.217	-1.423	13.026	3.128	2.764	5.627	3.065
Coefficient Gb	0	0	0	0	0	0	0.024	0.007	-0.272	0.018	-0.028	-0.034	-0.046
Airport Pressure	-65.026	-85.345	-142.52	-110.64	-131.67	96.855	-90.34	38.987	-345.41	-87.551	-74.961	-153.83	-82.271
Final Altitude	2.35	3.084	5.15	3.998	4.758	-3.5	3.265	-1.409	12.482	3.164	2.709	5.559	2.973
CAS	-28.356	-42.427	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793

Table C.3. Error in final corrected net thrust (lb.) for the first climb segment, due to a 1% error in each of the input variables

This page is intentionally blank

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient R	4.592	2.025	17.848	0.45	8.055	0.069	8.159	7.246	7.842	1.131	1.532	0.61	1.434
Coefficient E	-23.005	-12.86	-71.45	-2.443	-34.491	-0.252	-28.52	-26.04	-30.09	-4.743	-7.177	-2.898	-5.334
Coefficient F	5.535	2.56	13.39	0.354	5.521	0.036	5.994	3.628	5.044	0.846	1.216	0.372	0.937
Coefficient Ga	-0.587	-0.21	-1.196	-0.031	-0.81	-0.003	-0.296	0.103	-1.089	-0.081	-0.095	-0.031	-0.065
Coefficient Gb	0	0	0	0	0	0	-0.003	-0.001	0.03	-0.001	0.001	0	0.001
Initial Altitude	11.068	11.422	11.376	10.375	11.644	10.682	10.569	10.952	10.131	10.099	10.174	10.231	10.135
Airport Elevation	0	0	0	0.001	0	0.001	0	0	0	0	0	0.001	0
Airport Pressure	-10.85	-7.336	-24.93	-11.83	-14.16	-7.923	-9.415	-30.686	-4.186	-3.857	-4.173	-7.321	-5.022
Aircraft Weight	19.548	10.529	44.366	2.133	24.034	0.226	12.94	31.035	25.369	5.715	5.199	2.655	6.235
Airport Temperature	0.289	0.124	-0.129	1.215	0.184	0.904	0.076	-0.059	-0.103	0.106	0.103	0.631	0.103
CAS1	-14.08	-18.77	-55.17	0.154	-24.103	0.017	-47.72	-49.74	-46.55	-9.177	-10.05	0.179	-10.16
CAS 2	25.143	23.319	62.427	21.274	31.59	15.753	52.098	53.095	49.055	12.126	12.853	11.201	13.154
Climb Rate	14.703	8.537	31.524	1.694	17.65	0.156	8.59	21.426	18.029	4.134	3.902	2.03	4.289

Table D.1. Error in final altitude (ft) for the Acceleration segment, due to a 1% error in each of the inpu varaibles

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient B	71.434	18.696	118.42	-8.014	85.006	-10.462	57.997	44.412	44.147	18.213	21.104	9.225	24.544
Coefficient E	-357.79	-118.63	-473.63	43.758	-363.23	38.206	-202.7	-159.93	-169.36	-76.511	-98.863	-43.927	-91.49
Coefficient F	86.114	23.626	88.827	-6.321	58.263	-5.464	42.603	22.272	28.397	13.64	16.754	5.643	16.062
Coefficient Ga	-9.132	-1.943	-7.942	0.504	-8.546	0.433	-2.108	0.608	-6.132	-1.257	-1.31	-0.44	-1.066
Coefficient Gb	0	0	0	0	0	0	-0.019	-0.004	0.168	-0.008	0.015	0.003	0.018
Initial Altitude	8.303	3.419	10.39	-1.131	9.497	-1.076	4.536	5.84	1.249	2.029	3.032	1.56	2.781
Airport Elevation	0.01	0.003	0	0	0.005	0	0	0	0	0.003	0.003	0.001	0.003
Airport Pressure	-238.37	-85.332	-196.27	-7.776	-200.55	3.535	-61.362	-200.9	-29.777	-81.395	-75.211	-38.515	-106.4
Aircraft Weight	302.30	97.244	302.72	7.18	263.13	-6.166	90.081	201.10	142.63	90.551	73.052	33.563	105.73
Airport Temperature	12.655	3.183	0.302	0.372	6.625	0.063	-0.008	-0.159	0.139	4.033	3.369	1.727	4.224
CAS1	-172.12	-163.02	-392.85	-125.54	-241.11	-179.54	-365.99	-342.24	-269.91	-130.36	-129.15	-135.98	-157.08
CAS 2	480.25	241.21	461.54	133.14	404.25	179.81	388.88	370.15	297.04	218.68	202.68	171.01	251.53
Climb Rate	83.804	35.648	151.49	3.152	95.932	-1.87	42.18	99.378	69.472	20.977	17.649	8.309	24.876

Table D.2. Error in ground track distance (ft) for the acceleration segment, due to a 1% error in each of the input

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient E	155.42	219.37	536.7	370.92	459.03	612.98	407.2	493.37	494.60	214.79	247.11	613.858	298.55
Coefficient F	-27.883	-37.463	-84.111	-54.873	-56.732	-87.976	-75.722	-61.608	-73.456	-33.864	-35.036	-71.67	-46.468
Coefficient Ga	2.719	2.872	5.15	3.998	6.92	6.723	3.217	-1.423	13.026	3.128	2.764	5.627	3.065
Coefficient Gb	0	0	0	0	0	0	0.024	0.007	-0.272	0.018	-0.028	-0.034	-0.046
Initial Altitude	2.719	2.872	5.15	3.998	6.92	6.723	3.265	-1.409	12.479	3.164	2.709	5.559	2.973
Airport Pressure	-70.268	-71.197	-141.94	-110.19	-174.59	-177.662	-89.794	38.884	-346.08	-87.063	-74.869	-153.47	-82.29
CAS1	-27.313	-37.879	-88.943	-48.006	-62.195	-82.88	-79.15	-60.135	-74.478	-31.232	-36.947	-73.499	-43.425

Table D.3. Error in initial corrected net thrust (lb.) for the acceleration segment, due to a 1% error in each of the input variables

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient B	1.171	0.523	9.192	0.18	5.102	0.045	2.682	-1.016	9.52	0.359	0.412	0.338	0.423
Coefficient E	149.55	216.05	499.90	369.94	437.18	612.82	397.825	497.02	458.03	213.28	245.18	612.25	296.97
Coefficient F	-43.159	-46.485	-96.817	-48.769	-81.779	-81.737	-80.914	-67.812	-77.061	-40.364	-46.172	-82.053	-54.986
Coefficient Ga	4.868	4.073	11.227	4.31	13.515	6.777	4.639	-2.12	19.811	3.737	3.614	6.391	3.69
Coefficient Gb	0	0	0	0	0	0	0.051	0.016	-0.681	0.026	-0.048	-0.044	-0.067
Initial Altitude	2.822	2.951	5.859	4.148	7.376	6.885	3.474	-1.535	12.298	3.203	2.738	5.677	2.993
Airport Elevation	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Pressure	-73.035	-73.092	-154.78	-114.92	-183.58	-182.77	-93.189	42.958	-342.89	-88.559	-75.598	-157.29	-83.07
Aircraft Weight	4.984	2.72	22.848	0.853	15.224	0.146	4.24	-4.345	30.878	1.814	1.401	1.473	1.837
Airport Temperature	0.074	0.032	-0.067	0.486	0.117	0.583	0.025	0.008	-0.125	0.034	0.028	0.35	0.03
CAS1	-3.588	-4.847	-28.41	0.062	-15.268	0.011	-15.627	6.967	-56.752	-2.913	-2.707	0.099	-2.996
CAS 2	-38.16	-41.123	-71.563	-40.405	-65.265	-71.606	-65.809	-74.736	-23.509	-36.784	-43.037	-76.044	-51.387
Climb Rate	3.749	2.205	16.235	0.677	11.18	0.101	2.815	-3	21.948	1.312	1.051	1.126	1.264

Table D.4. Error in final corrected net thrust (lb.) for the acceleration segment, due to a 1% error in each of the input variables

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient B	0.018	0.006	0.052	0.001	0.027	0	0.02	0.019	0.02	0.003	0.004	0.002	0.004
Coefficient E	-0.088	-0.038	-0.21	-0.005	-0.114	-0.001	-0.07	-0.067	-0.078	-0.013	-0.02	-0.007	-0.015
Coefficient F	0.021	0.008	0.039	0.001	0.018	0	0.015	0.009	0.013	0.002	0.003	0.001	0.003
Coefficient Ga	-0.002	-0.001	-0.004	0	-0.003	0	-0.001	0	-0.003	0	0	0	0
Coefficient Gb	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial Altitude	0.042	0.033	0.033	0.023	0.039	0.023	0.026	0.028	0.026	0.028	0.029	0.026	0.028
Airport Elevation	0	0	0	0	0	0	0	0	0	0	0	0	0
Airport Pressure	-1.337	-1.011	-1.061	-0.767	-1.162	-0.758	-0.849	-0.946	-0.889	-0.948	-0.968	-0.888	-0.94
Aircraft Weight	0.075	0.031	0.129	0.005	0.079	0.001	0.032	0.08	0.066	0.016	0.015	0.007	0.017
Airport Temperature	0.15	0.114	0.113	0.088	0.128	0.087	0.095	0.099	0.1	0.108	0.11	0.101	0.106
CAS1	-0.054	-0.055	-0.161	0	-0.079	0	-0.116	-0.127	-0.12	-0.025	-0.028	0.001	-0.028
CAS 2	2.672	2.042	2.149	1.53	2.323	1.518	1.778	1.868	1.878	1.906	1.946	1.767	1.887
Climb Rate	0.056	0.025	0.092	0.004	0.058	0	0.021	0.055	0.047	0.011	0.011	0.005	0.012

Table D.5.Error in final true airspeed (knot) for the acceleration segment, due to a 1% error in each of the input variables

This page is intentionally blank

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient R	-0.046	-0.045	-0.049	-0.046	-0.048	-0.049	-0.055	-0.055	-0.06	-0.044	-0.043	-0.039	-0.045
Coefficient E	0.2	0.222	0.203	0.245	0.229	0.227	0.199	0.203	0.233	0.18	0.197	0.18	0.165
Coefficient F	-0.032	-0.04	-0.033	-0.031	-0.032	-0.042	-0.038	-0.024	-0.035	-0.026	-0.029	-0.021	-0.024
Coefficient Ga	0.007	0.007	0.005	0.007	0.005	-0.002	0.004	-0.001	0.015	0.007	0.006	0.004	0.004
Coefficient Gb	0	0	0	0	0	0	0	0	-0.001	0	0	0	0
Airport Pressure	0.103	0.112	0.124	0.151	0.155	0.213	0.123	0.196	0.065	0.089	0.119	0.122	0.105
Aircraft Weight	-0.175	-0.189	-0.175	-0.221	-0.201	-0.183	-0.165	-0.178	-0.213	-0.161	-0.174	-0.163	-0.146
Initial Altitude	-0.004	-0.004	-0.004	-0.005	-0.006	-0.008	-0.004	-0.007	-0.002	-0.003	-0.004	-0.004	-0.004
Final Altitude	-0.006	-0.006	-0.007	-0.008	-0.008	-0.012	-0.007	-0.011	-0.004	-0.005	-0.006	-0.007	-0.006
CAS	-0.032	-0.04	-0.033	-0.031	-0.032	-0.042	-0.038	-0.024	-0.035	-0.026	-0.029	-0.021	-0.024
Head- wind	0.007	0.008	0.006	0.01	0.009	0.008	0.006	0.007	0.008	0.007	0.007	0.007	0.006

Table E.1. Error in climb angle (degree) for the second climb segment, due to a 1% error in each of the input variables

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient B	16.931	13.069	18.375	9.404	12.342	16.402	27.042	21.998	15.583	19.11	15.209	15.105	26.423
Coefficient E	-73.223	-64.819	-76.603	-50.277	-59.401	-76.557	-97.82	-81.275	-60.802	-78.482	-69.718	-70.039	-96.645
Coefficient F	11.836	11.685	12.503	6.409	8.321	14.17	18.732	9.774	9.019	11.243	10.271	8.263	13.852
Coefficient Ga	-2.452	-2.124	-1.838	-1.355	-1.168	0.841	-1.932	0.586	-4.003	-2.857	-1.95	-1.605	-2.48
Coefficient Gb	0	0	0	0	0	0	-0.036	-0.007	0.209	-0.041	0.049	0.024	0.093
Airport Pressure	-37.814	-32.718	-46.749	-31.017	-40.23	-71.929	-60.292	-78.488	-16.865	-38.831	-41.918	-47.235	-61.273
Aircraft Weight	63.839	55.257	65.937	45.222	52.248	61.546	81.055	70.923	55.577	70.137	61.348	63.356	85.179
Initial Altitude	-87.99	-78.17	-89.04	-64.425	-72.996	-83.009	-102.02	-90.733	-74.062	-96.589	-86.216	-90.465	-111.80
Final Altitude	136.09	120.80	138.63	100	113.86	132.31	159.57	144.61	112.92	149.09	133.87	140.82	174.35
CAS	11.836	11.685	12.503	6.409	8.321	14.17	18.732	9.774	9.019	11.243	10.271	8.263	13.852
Head-wind	-2.7	-2.422	-2.443	-2.089	-2.21	-2.725	-2.957	-2.735	-2.19	-3.072	-2.616	-2.668	-3.509

Table E.2. Error in ground track distance (ft) for the second climb segment, due to a 1% error in each of the input variables

Aircraft / Variable	717-200	737-700	747-400	757-200	767-400ER	777-200	L1011	A300 B4	A310-300	A319-131	A320-232	A330-301	A340-211
Coefficient E	175.43	235.35	536.7	370.92	604.76	796.73	407.2	493.37	494.60	214.79	247.11	613.86	298.55
Coefficient F	-28.356	-42.428	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793
Coefficient Ga	7.049	9.252	15.45	11.994	14.274	-10.5	9.65	-4.269	39.077	9.384	8.292	16.881	9.195
Coefficient Gb	0	0	0	0	0	0	0.216	0.064	-2.449	0.161	-0.248	-0.306	-0.414
Pressure	-65.026	-85.345	-142.52	-110.64	-131.67	96.855	-92.996	38.198	-315.29	-89.531	-71.907	-150.07	-77.18
Final Altitude	7.049	9.252	15.45	11.994	14.274	-10.5	10.082	-4.141	34.18	9.706	7.795	16.269	8.367
CAS	-28.356	-42.428	-87.602	-47.285	-84.714	-147.47	-77.979	-59.331	-73.364	-30.769	-36.407	-72.423	-42.793

Table E.3. Error in final corrected net thrust for the second climb segment, due to an error in each of the input variables

This page is intentionally blank

F. Output Errors for the Descent Segment

Aircraft / Variable	717-200	737-700	747-400	757-200	L1011	A300 B4	A310-300
Coefficient R	67.549	80.230	194.137	115.711	162.445	162.132	339.328
Pressure	-42.39	-50.954	-122.09	-70.423	-107.86	-94.565	-277.31
Weight	42.386	50.949	122.078	70.417	107.848	94.556	277.283
CAS2	-0.381	-0.467	-0.983	-0.713	-0.799	-1.024	-0.931
Descent Angle	-25.893	-30.130	-74.148	-46.607	-56.180	-69.534	-63.843
Head-wind	1.642	2.142	4.145	3.007	3.355	4.318	3.923
Final Altitude	0.020	0.024	0.057	0.033	0.051	0.044	0.130

Table F.1. Error in final headwind corrected net thrust (lb.) for the descent segment, due to a 1% error in each of the input variables

Aircraft/ Variable	717-200	737-700	747-400	757-200	L1011	A300 B4	A310-300
Initial Altitude	190.811	190.811	190.811	190.811	190.811	190.811	190.811
Final Altitude	-2.481	-2.481	-2.481	-2.481	-2.481	-2.481	-2.481
Descent Angle	-188.68	-188.68	-188.68	-188.68	-188.68	-188.68	-188.68

Table F.2. Error in Ground Track Distance (ft) for the descent segment, due to a 1% error in input variable

This page is internationally blank

G. Output Error for the Landing segment

Aircraft / Variable	717-200	737-700	747-400	757-200	L1011	A300 B4	A310-300
Coefficient D	1.310	1.326	1.555	1.347	1.456	1.400	1.429
Pressure	-0.656	-0.664	-0.778	-0.674	-0.728	-0.701	-0.715
Temp	0.075	0.075	0.088	0.077	0.083	0.080	0.081
Weight	0.655	0.663	0.777	0.674	0.728	0.700	0.715
Elevation	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table G.1. Error in Initial True Airspeed (knot) for the Landing Segment, due to a 1% error in each of the input variables

Aircraft / Variable	717-200	737-700	747-400	757-200	L1011	A300 B4	A310-300
Static Thrust	108	144	340.8	240.6	252	315	321
Percent Thrust	108	144	340.8	240.6	252	315	321

Table G.2. Error in Final Corrected Net Thrust for the Landing segment, due to a 1% error in each of the input variables

This page is internationally blank

Error in Interpolated Speed

Segment	Start of Segment Speed, (knot)	End of Segment Speed, (knot)	Segment Length, (ft)	Distance along flight-path segment from the start to the CPA (d_{AS}), (ft)			
Takeoff	35.0	146.8	3400	500	1000	2000	3000
Acceleration	148.9	187.4	3890	500	1000	2000	3000

Table H.1.1. Input data for Speed Interpolation of the Takeoff and Acceleration segments, for an A320-232 aircraft

Error Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
D_{AS}	0.16	0.33	0.66	0.99
Length	-0.16	-0.33	-0.66	-0.99
AS1	0.30	0.25	0.14	0.04
AS2	0.22	0.43	0.86	1.30

Table H.1.2. Error in Interpolated speed (knot) for a range of d_{AS}, over the takeoff segment of an A320-232 Aircraft, due to a 1% error in the input variables.

Error Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
D_{AS}	0.05	0.1	0.20	0.30
Length	-0.05	-0.1	-0.20	-0.30
AS1	1.30	1.11	0.72	0.34
AS2	0.24	0.48	0.96	1.45

Table H.1.3. Error in Interpolated speed (knot) for a range of d_{AS}, over the acceleration segment of an A320-232 Aircraft, due to a 1% error in the input variables.

Error in Interpolared Engine Power

Segment	Start of Segment Power (lb.)	End of Segment Power (lb.)	Segment Length (ft)	Distance along flight-path segment from the start to the CPA (d_{AS}), (ft)			
Takeoff	24715	21074	3400	500	1000	2000	3000
Acceleration	21348	20414	3890	500	1000	2000	3000

Table H.2.1. Input data for Engine Power Level Interpolation for an A320-232 aircraft

Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
D_{AS}	-5.35	-10.71	-21.42	-32.13
Length	5.35	10.71	21.42	32.13
P1	210.80	174.46	101.77	29.08
P2	30.99	61.98	123.96	185.95

Table H.2.2. Error in Interpolated Engine Power level (lb.) for a range of d_{AS}, over the takeoff segment of an A320-232 Aircraft, due to a 1% error in the input variables

Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
D_{AS}	-1.20	-2.40	-4.80	-7.20
Length	1.20	2.40	4.80	7.20
P1	186.04	158.60	103.72	48.84
P2	26.24	52.48	104.96	157.43

Table H.2.3. Error in Interpolated Engine Power level (lb.) for a range of d_{AS}, over the acceleration segment of an A320-232 Aircraft, due to a 1% error in the input variable

Error in Interpolated Altitude

	Start of Segment Altitude (ft)	End of Segment Altitude (ft)	Segment Length (ft)	Distance along flight-path segment from the start to the CPA (d_{AS}), (ft)			
Climb 1	0	1000	4104	500	1000	2000	4000
Climb 2	1423.5	3000	10873	1000	2000	4000	8000

Table H.3.1. Input data for Altitude Interpolation of the two Climb segments for an A320-232 aircraft

Error Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
d_{AS}	1.22	2.44	4.87	9.75
Length	-1.22	-2.44	-4.87	-9.75
AS1	0.00	0.00	0.00	0.00
AS2	1.22	2.44	4.87	9.75

Table H.3.2. Error in Interpolated Altitude (ft) for a range of d_{AS}, over the first climb segment of an A320-232 Aircraft, due to a 1% error in each of the input variables

Error Variable	**Distance d_{AS}**			
	500	**1000**	**2000**	**3000**
d_{AS}	1.45	2.90	5.80	11.60
Length	-1.45	-2.90	-5.80	-11.60
AS1	12.93	11.62	9.00	3.76
AS2	2.76	5.52	11.04	22.07

Table H.3.3. Error in Interpolated Altitude (ft) for a range of d_{AS}, over the second climb segment of an A320-232 Aircraft,, due to a 1% error in the input variables.

Error in Interpolated Sound Exposure Level

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	-0.06	-0.06	-0.06	-0.06
500	-0.07	-0.07	-0.06	-0.06
800	-0.08	-0.08	-0.07	-0.07
1500	-0.08	-0.08	-0.08	-0.07
3000	-0.09	-0.09	-0.09	-0.08
5000	-0.11	-0.10	-0.10	-0.09
8000	-0.12	-0.12	-0.11	-0.11
13000	-0.14	-0.14	-0.13	-0.13
18000	-0.16	-0.16	-0.15	-0.15

Table H.4.1. Error in Interpolated Departure Sound Exposure Level (dB) for the V2527A Engine due to a 1% error in Distance,

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	0.17	0.11	0.09	0.11
500	0.18	0.12	0.09	0.12
800	0.19	0.13	0.10	0.13
1500	0.19	0.14	0.12	0.15
3000	0.19	0.15	0.13	0.16
5000	0.19	0.16	0.14	0.18
8000	0.19	0.16	0.15	0.19
13000	0.18	0.17	0.16	0.20
18000	0.18	0.18	0.16	0.21

Table H.4.2. Error in Interpolated Departure Sound Exposure Level (dB) for the V2527A Engine, due to a 1% error in Power,

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	0.10	0.31	0.33	-0.14
500	0.12	0.37	0.39	-0.17
800	0.11	0.34	0.36	-0.15
1500	0.09	0.28	0.30	-0.13
3000	0.08	0.26	0.28	-0.12
5000	0.09	0.29	0.32	-0.14
8000	0.08	0.26	0.29	-0.12
13000	0.07	0.22	0.24	-0.10
18000	0.10	0.33	0.37	-0.16

Table.H.4.3. Error in Interpolated Departure Sound Exposure Level (dB) for the V25257A Engine, due to a 1% error in noise level at Power level 1, and Distance 1.

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	0.31	0.11	0.10	0.58
500	0.37	0.13	0.11	0.69
800	0.34	0.12	0.11	0.63
1500	0.28	0.10	0.09	0.53
3000	0.26	0.09	0.08	0.50
5000	0.29	0.10	0.10	0.57
8000	0.26	0.09	0.09	0.51
13000	0.22	0.08	0.07	0.44
18000	0.33	0.12	0.11	0.67

Table.H.4.4. Error in Interpolated departure Sound Exposure Level (dB) for the V25257A Engine, due to a 1% error in noise level at Power level 2, and Distance 1.

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	0.13	0.42	0.45	-0.19
500	0.11	0.34	0.37	-0.16
800	0.11	0.35	0.37	-0.16
1500	0.11	0.37	0.40	-0.17
3000	0.10	0.34	0.37	-0.16
5000	0.08	0.27	0.29	-0.13
8000	0.08	0.26	0.29	-0.12
13000	0.08	0.25	0.28	-0.12
18000	0.03	0.10	0.12	-0.05

Table.H.4.5. Error in Interpolated Departure Sound Exposure Level (dB) for the V25257A Engine, due to a 1% error in noise level at Power level 1, and Distance 2

	Engine Power Level (lb.)			
Distance (ft)	**13000**	**15000**	**19000**	**24000**
300	0.42	0.14	0.13	0.79
500	0.34	0.12	0.11	0.65
800	0.35	0.12	0.11	0.66
1500	0.37	0.13	0.12	0.70
3000	0.34	0.12	0.11	0.66
5000	0.27	0.09	0.09	0.52
8000	0.26	0.09	0.09	0.52
13000	0.25	0.09	0.09	0.51
18000	0.10	0.04	0.04	0.22

Table.H.4.6. Error in Interpolated Sound Exposure Level for the V25257A Engine, due to a 1% error in noise level at Power level 2, and Distance 2..

I. Error in Noise Adjustments and Noise level

Acoustic Impedance Adjustment

Variable	Airport Pressure	Airport Temperature	Observer Elevation	Airport Elevation
Datum Conditions	28.5	65	13	13
Range of Values	28.5	65	13	13
	29	70	100	100
	29.5	75	200	200
	30	80	300	300
	35	85	400	400

Table I.1.1. Datum Conditions and Range of values for Acoustic Impedance Adjustment Error Analysis

Pressure	Airport Pressure	Airport Temperature	Observer Elevation	Airport Elevation
28.5	0.043	-0.003	-1.87E-05	-1.92E-06
29	0.043	-0.003	-1.86E-05	-1.92E-06
29.5	0.043	-0.003	-1.85E-05	-1.92E-06
30	0.043	-0.003	-1.85E-05	-1.92E-06
35	0.043	-0.003	-1.84E-05	-1.92E-06

Table I.1.2. Error in Acoustic Impedance Adjustment (dB) for a range of Airport Pressure (in-Hg) values due to a 1% error in each of the variables

Temperature	Airport Pressure	Airport Temperature	Observer Elevation	Airport Elevation
65	0.043	-0.003	-1.87E-05	-1.92E-06
70	0.043	-0.003	-1.88E-05	-1.90E-06
75	0.043	-0.003	-1.88E-05	-1.88E-06
80	0.043	-0.003	-1.88E-05	-1.87E-06
85	0.043	-0.003	-1.88E-05	-1.85E-06

Table I.1.3. Error in Acoustic Impedance Adjustment (dB) for a range of Airport Temperatures (°F) due to a 1% error in each of the input variables

Observer Elevation	Airport Pressure	Airport Temperature	Observer Elevation	Airport Elevation
13	0.043	-0.003	-1.87E-05	-1.92E-06
100	0.043	-0.003	-1.44E-04	-1.92E-06
200	0.043	-0.003	-2.88E-04	-1.92E-06
300	0.044	-0.003	-4.32E-04	-1.92E-06
400	0.044	-0.003	-5.76E-04	-1.92E-06

Table I.1.4. Error in Acoustic Impedance Adjustment (dB) for a range of Observer Elevation (ft) values due to a 1% error in each of the variables

Airport Elevation	Airport Pressure	Airport Temperature	Observer Elevation	Airport Elevation
13	0.043	-0.003	-1.87E-05	-1.92E-06
100	0.043	-0.003	-1.87E-05	-1.48E-05
200	0.043	-0.003	-1.87E-05	-1.48E-05
300	0.043	-0.003	-1.87E-05	-1.48E-05
400	0.043	-0.003	-1.87E-05	-5.89E-05

Table I.1.5. Error in Acoustic Impedance Adjustment (dB) for a range of Airport Elevation (ft) values due to a 1% error in each of the variables

Noise Fraction Adjustment

Variable	q_1	L	L_e	L_{max}
Datum Conditions	500	500	70	65
Range of Values	500	500	70	65
	1000	1000	75	70
	1500	1500	80	75
	2000	2000	85	80
	2500	2500	90	85

Table I.2.1. Datum Conditions and Range of values for Noise Fraction adjustment Error Analysis

q_1 (ft)	q_1	L	L_e	L_{max}
500	-0.013	0.027	-0.238	0.211
1000	-0.039	0.033	0.077	-0.093
1500	-0.045	0.030	0.227	-0.224
2000	-0.046	0.028	0.283	-0.271
2500	-0.046	0.027	0.309	-0.292

Table I.2.2. Error in Noise fraction adjustment (dB) for a range of $q_1$values due to a 0.5% error in each of the input variables

L (ft)	q_1	L	L_e	L_{max}
500	-0.013	0.027	-0.238	0.211
1000	0.001	0.014	-0.238	0.211
1500	0.003	0.007	-0.180	0.158
2000	0.004	0.005	-0.148	0.130
2500	0.005	0.003	-0.130	0.115

Table I.2.3. Error in Noise fraction adjustment (dB) for a range of Segment Lengths (L) due to a 0.5% error in each of the input variables

L_e (dB)	q_1	L	L_e	L_{max}
70	-0.013	0.027	-0.238	0.211
75	-0.002	0.022	-0.356	0.306
80	0.000	0.022	-0.398	0.323
85	0.000	0.022	-0.425	0.325
90	0.000	0.022	-0.450	0.325

Table I.2.4. Error in Noise fraction adjustment (dB) for a range of NPD noise exposure levels (dB) due to a 0.5% error in each of the input variables

L_{max} (dB)	q_1	L	L_e	L_{max}
65	-0.013	0.027	-0.238	0.211
70	-0.047	0.051	-0.089	0.082
75	-0.139	0.136	-0.026	0.026
80	-0.139	0.136	-0.026	0.026
85	-1.430	1.074	-0.003	0.003

Table I.2.5. Error in Noise fraction adjustment (dB) for a range of NPD Maximum Noise levels (dB) due to a 0.5% error in each of the input variables

Lateral Attenuation Adjustment

	l_{seg} (ft)				
d_{seg} (ft)	**500**	**1000**	**1500**	**2000**	**2500**
0	0.01	0.00	0.00	0.00	0.00
500	0.02	0.03	0.04	0.04	0.04
1000	0.01	0.02	0.02	0.03	0.03
1500	0.01	0.02	0.02	0.02	0.02
2000	0.01	0.02	0.02	0.02	0.02
2500	0.01	0.01	0.02	0.02	0.02

Table I.3.1. Error in Lateral Attenuation Adjustment (dB) for an INM type aircraft, due to a 1% error in l_{seg}

	l_{seg} (ft)				
d_{seg} (ft)	**500**	**1000**	**1500**	**2000**	**2500**
0	0.00	0.00	0.00	0.00	0.00
500	-0.02	-0.02	-0.03	-0.04	-0.04
1000	-0.01	-0.02	-0.02	-0.03	-0.03
1500	-0.01	-0.02	-0.02	-0.02	-0.02
2000	-0.01	-0.02	-0.02	-0.02	-0.02
2500	-0.01	-0.01	-0.02	-0.02	-0.02

Table I.3.2. Error in Lateral Attenuation Adjustment (dB) for an INM type aircraft, due to a 1% error in d_{seg}

Ground-Based Directivity Adjustment

	SLR (ft)						
q (ft)	**250**	**500**	**750**	**1000**	**1500**	**2000**	**2500**
-100	0.02	0.01	0.00	0.00	0.00	0.00	0.00
-150	0.01	0.01	0.01	0.01	0.00	0.00	0.00
-200	-0.09	0.02	0.01	0.01	0.00	0.00	0.00
-250	----	0.01	0.01	0.01	0.01	0.00	0.00
-500	----	----	-0.01	0.01	0.01	0.01	0.01

Table I.4.1. Error in Ground-Based Directivity Adjustment (dB) due to a 1% error in distance of observer to the PCPA (q) on the flight path

	SLR (ft)						
q (ft)	**250**	**500**	**750**	**1000**	**1500**	**2000**	**2500**
-100	-0.02	-0.01	0.00	0.00	0.00	0.00	0.00
-150	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00
-200	0.09	-0.02	-0.01	-0.01	0.00	0.00	0.00
-250	----	-0.01	-0.01	-0.01	-0.01	0.00	0.00
-500	----	----	0.01	-0.01	-0.01	-0.01	-0.01

Table I.4.2 Error in Ground-Based Directivity Adjustment (dB) due to a 1% error in slant range distance from observer to start of takeoff roll (SLR)

Exposure-Based Noise Levle

	Datum Condition	**Error in Exposure–based noise level metric due to a 1% Error in Input**
Sound Exposure Level (dB) (Le)	85	0.85
Atmospheric Absorption adjustment (dB) (Aaadj)	1	0.01
Acoustic Impedance adjustment (dB) (Aiadj)	0.3	0.003
Noise Fraction Adjustment (dB) (Nfadj)	5	5E-02
Aircraft Speed Adjustment (dB) (Asadj)	3	0.03
Lateral Attenuation Adjustment (dB) (Laadj)	4	-0.04
Ground-Based Directivity Adjustment (dB) (DIRadj)	1.5	0.015

Table I.5.1. Example Datum Conditions and Error in exposure-based noise level, due to a 1% error in each of the input variables.

This page is internationally blank

J. Nomenclature

Subscripts 1,mid, and 2, indicate start, middle, and end of segment conditions respectively

A	Aircraft altitude (ft)
AS_{seg}	Aircraft speed at CPA (knot)
AS	Aircraft speed at start of segment (knot)
B	Aircraft Ground Roll flap coefficient
β (Beta)	Elevation angle of aircraft above ground
C	Takeoff flap coefficient
CPA	Closest Point of Approach. The point on the flight-path, which is the closest-point of approach to the observer(ft)
D	Landing flap coefficient
d_{as}	Distance along flight path segment from the start of of the segment to the CPA (ft)
δ (Delta)	Pressure Ratio at aircraft altitude
d_{seg}	Flight path height at the CPA (dB)
E	Engine thrust coefficient or Airport elevation
$E_{wt, arpt}$	Airport weighted sound exposure ratio (dB)
$E_{wt, flt}$	Entire flight weighted sound exposure ratio (dB)
$E_{wt,seg}$	Single segment weighted sound exposure ratio (dB)
E1, E2	Runway ends elevation (ft)
E_{seg}	Single segment sound exposure ratio (dB)
$E_{smx, seg}$	Single segment maximum sound level (dB)
F	Engine thrust coefficient
Ga	Engine thrust coefficient
γ (Gamma)	Climb/ descent angle (degree)
Gb	Engine thrust coefficient
H	Engine thrust coefficient
h	pressure altitude
h_{arpt}	elevation of airport (ft)
$h_{terrain}$	elevation of terrain (ft)
k	Climb coefficient
L	Length of the flight path segment (ft)
$L_{E\ wt, arpt}$	Exposure based noise level metric (dB)
$L_{p,d}$	Interpolated noise level (dB)
$L_{p1,d1}$	Noise level at engine power level1, and distance 1 (dB)
$L_{p1,d2}$	Noise level at engine power level1, and distance 2 (dB)

$L_{p1,d2}$	Noise level at engine power level2, and distance 2 (dB)
$L_{p2,d1}$	Noise level at engine power level2, and distance 1 (dB)
l_{seg}	Sideline distance from the observer to the CPA (ft)
L_{smx}	Max noise level metric for given time period (dB)
$L_{smx, flr}$	Max noise level associated with each operations (dB)
$L_{smx,(t)}$	Max noise level associated with each time period (dB)
N	Number of engines
N_{day}	Number of operations during the day
N_{eve}	Number of operations during the evening
N_{ngt}	Number of operations during the night
P	Airport Pressure (in-Hg_
$P_{wt, arpt}$	Equivalent mean-squared sound pressure ratio (dB)
$P_{\%}$	Percentage of engine static net thrust used
P	Engine power at CPA, Engine power at start of segment, engine power at end of segment (lb.)
P_1, P_2	Engine power at start of segment, engine power at end of segment (lb.)
PCPA	Perpendicular Closest Point of Approach. Point on the flight path or the extended flight path which is the perpendicular closest point of approach to the observer (ft)
q	Distance along the flight path segment from the start of the segment to the PCPA (ft)
R_f	Drag over lift flap coefficient
σ (Sigma)	Density Ratio at aircraft altitude
SLR	Slant Range. Length of the vector from the observer to CPA on the flight path (ft)
T	Airport Temperature (°F)
T_c	Temperature at Aircraft in Celsius (°C)
T_f	Temperature at Aircraft in Fahrenheit (°F)
θ (Theta)	Temperature ratio at Aircraft altitude
V_{cas}	calibrated Airspeed (knot)
V_{tas}	true airspeed (knot)
w	Headwind (knot)
W	Aircraft Weight (lb.)
W_{day}	Day operation weighting
W_{eve}	Evening operation weighting
W_{ngt}	Night operation weighting

References

1 Society of Automotive Engineers, Committee A-21, Aircraft Noise, Procedure for the Computation of Airplane Noise in the Vicinity of Airports, Aerospace Information Report No. 1845, Warrendale, PA: Society of Automotive Engineers Inc., March 1986.

2 Study of Optimisation Procedures for the Decreasing the Impact of Noise Around Airports (SOURDINE), Requirements for Tools- D4, July 1999.

3 Society of Automotive Engineers, Committee A-21, Aircraft Noise, Prediction Method for Lateral Attenuation of Airplane Noise During Takeoff and Landing, Aerospace Information Report No. 1751, Warrendale, PA: Society of Automotive Engineers Inc., March 1986.

4 Study of Optimisation Procedures for the Decreasing the Impact of Noise Around Airports (SOURDINE), Environmental Requirements and Operational Constraints-D1, July 1999.

5 Study of Optimisation Procedures for the Decreasing the Impact of Noise Around Airports (SOURDINE), Study of Key Elements Acting on Noise Impact of Aircraft in Operation-D2, July 1999.

For more information about the
EEC Environmental Studies Business Area
please contact:

Ted Elliff
Environmental Studies Business Area Manager,
EUROCONTROL Experimental Centre
BP15, Centre de Bois des Bordes
91222 BRETIGNY SUR ORGE CEDEX
France

Tel: +33 1 69 88 73 36
Fax: +33 1 69 88 72 11
E-Mail: Ted.Elliff@eurocontrol.int

or visit

http://www.eurocontrol.fr/ba_env/