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Aircraft Performance Program Part 3: Brief guide Programs APP02, APP03



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THE PREPARATION OF THIS DATA ITEM

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Chairman	
Mr K.J. Balkwill	— Independent
Members	
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Mr T. Bartup	— BAE SYSTEMS, Regional Aircraft, Woodford
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Dr P. Render	— University of Loughborough
Mr P. Renze*	— Raytheon Aircraft Company, Wichita, Kansas, USA
Mr D.N. Sinton	— Independent
Mr G.J.R. Skillen	— Civil Aviation Authority, Safety Regulation Group, Gatwick
Mr G.E. Smith	— Independent
Mr A. Stanbrook	— Independent
Mr R. Storey	— BAE SYSTEMS, Military Aircraft and Aerostructures, Brough
Prof. E. Torenbeek*	— Delft University of Technology, The Netherlands
Mr S. Tsach*	— Israel Aircraft Industries, Jerusalem, Israel
Mr C.J. Turner*	— Boeing, Douglas Products Group, Long Beach, Calif., USA
Mr M. Wilson	— Britten-Norman Ltd, Isle of Wight.

* Corresponding Member.

The construction and subsequent development of the Data Item was undertaken by

Mr A.J. Grundy — under contract to ESDU.

The person with overall responsibility for the work in this subject area was Mr D.J. Mitchell.

AIRCRAFT PERFORMANCE PROGRAM PART 3: BRIEF GUIDE PROGRAMS APP02 AND APP03

CONTENTS

	Page
1. INTRODUCTION	1
2. FLIGHT PERFORMANCE PROGRAM, APP02	1
2.1 Limitations	1
2.2 Program Standard	2
2.3 Program Description	3
2.3.1 System data flow	3
2.3.2 Program structure	3
2.4 Input Data	3
2.4.1 Input formats	3
2.5 Atmosphere Data	7
2.6 Table Format	7
2.6.1 Facilities	7
2.7 Program Output	9
3. INTERPOLATION PROGRAM, APP03	11
4. REFERENCES	11
5. TABLES	12
APPENDIX A – FLIGHT PERFORMANCE PROGRAM, APP02	17
A.1 POINT PERFORMANCE	17
A.1.1 Specific Excess Power and Specific Excess Thrust (Subroutine SEPSET)	17
A.1.2 Sustained and Instantaneous Turn Performance (Subroutine TRNRAT)	18
A.1.3 Ceiling at a Given Rate of Climb (Subroutine CEILING)	19
A.1.4 Steady Cruise Fuel Consumption and Fuel Flow (Subroutine CRUISE)	20
A.1.5 Minimum Flying Speeds MINSPEED (Subroutine MINSPD)	21
A.1.6 Minimum Drag Speed (Subroutine MINDRG)	21
A.1.7 Maximum Level Speed (Subroutine MAXSPD)	21
A.2 PATH PERFORMANCE (Subroutine PATHS)	22
A.2.1 Level Acceleration and Deceleration	23
A.2.2 Climb and Descent	24
A.2.3 Cruise and Loiter	25

A.3	OTHER MAJOR CALCULATION ROUTINES	26
A.3.1	Lift, Drag and Pitching Moment Balances and Engine Forces (Subroutine FORCES)	26
A.3.2	Atmosphere Data (Subroutine ATMOS) and Speed Conversion (Subroutine CONSPD)	27
A.3.3	Real Earth Corrections (Subroutine OBLATE)	28
A.3.4	Check Aircraft Limitations (Subroutine LIMITS)	29

AIRCRAFT PERFORMANCE PROGRAM

PART 3: BRIEF GUIDE

PROGRAMS APP02 and APP03

1. INTRODUCTION

(Note: In this Data Item, data options and facilities which are not available in the current release of the program are presented in *italic script*.)

The facilities and the main calculation modules of the programs that make up the ESDU Aircraft Performance Program are described briefly in this Data Item. For more detailed information on the input and output variables and for examples of the input and output formats see Parts 4, 5 and 6 (References 9, 10 and 11). These programs are as follows

- APP02, the Flight Performance Program,
- APP03, the Interpolation Program.

2. FLIGHT PERFORMANCE PROGRAM, APP02

Program APP02 contains the '**point performance**' and '**path performance**' routines and the time histories of the aircraft performance parameters. Some of the major lower-level routines below these performance calculations are available for use in isolation.

The program uses SI units internally, and converts all data to SI on input. The user has the option to input data in a wide range of units (particularly to allow, for example, for speed in knots or km/hr and height in feet or metres). Output is in units compatible with the user input.

The program accepts both untrimmed and trimmed aerodynamic data. Routines are provided for trimming both conventional tailed and foreplane designs.

2.1 Limitations

The program does not include any capability to estimate installed engine data or aerodynamic coefficients.

Propeller powered aircraft are not specifically treated yet, but if the engine data are expressed as installed thrust, and the aerodynamic coefficients include engine slipstream effects, the program can be used.

The equations used normally assume that the earth is flat and non-rotating; the effects of the Earth's curvature and apparent variations of acceleration due to gravity with latitude, height and aircraft heading may be added, these effects are taken from Reference 34. It is also assumed that the ratio of specific heat capacities for air, γ , is a constant 1.4; this value is used when speeds are converted and kinetic pressure is calculated. For real gas effects found when interpreting pitot-static data at high Mach numbers, see Reference 39 (Mach numbers between 2 and 4) and Reference 52 (Mach numbers greater than 4).

Pressure height is limited to the range between -1000 m (-3281 ft) and the maximum height defined for the atmosphere in use. For the built-in International Standard Atmosphere (Reference 30) the maximum pressure height is 80 000 m (262 467 ft), this limit also applies to any user atmosphere definition (see References 31 and 32).

Issued June 2000 – 20 pages
With Amendments A to D, October 2013 – 29 pages
This page Amendment C and D

2.2 Program Standard

This release contains “Point Performance” and “Path Performance” using trimmed or untrimmed aerodynamic data with installed engine performance. The modules available in this release are listed below and are identified by the Keyword or Symbolic Name used in the data input, see ESDU 00034 and 00035 (References 9 and 10).

Performance Estimation Modules,

Point Performance

SEP	Specific Excess Power [†] .
SET	Specific Excess Thrust [†] .
SUSTAIN	Turn Rate defined by “thrust equal to drag” – ‘Sustained Turn’ [†] .
SUSTAIN+	Turn Rate defined by the more critical of “thrust equal to drag” and the lift limit (INSTANT) [†] .
INSTANT	Turn rate defined by the lift limit – ‘Instantaneous Turn’ [†] .
MAXSPEED	Maximum level flight speed.
CEILING	Ceiling at a given SEP or rate of climb [†] .
CEILING+	Ceiling defined by the more critical of the given SEP or rate of climb and the lift limit [†] .
MINDRAG	Minimum drag speed.
MINSPEED	Minimum flying speed defined by the lift limit.
CRUISE1	Cruise fuel used per unit distance at a given speed [†] .
CRUISE2	Cruising speed and fuel used per unit distance at a given engine power setting.
CRUISE3	<i>Cruise-climb fuel per unit distance at a given speed.</i> [†]
LOITER1	Cruise fuel flow at a given speed [†] .
LOITER2	Cruising speed and fuel flow at a given engine power setting.
LOITER3	<i>Cruise-climb fuel flow at a given speed.</i> [†]
ENVELOPE	<i>Contour of constant specific excess power.</i>

Path Performance, time histories for;

ACCEL	Level acceleration.
DECEL	Level deceleration
CLIMB1	Given power, given speed, find climb angle
CLIMB2	Given power, given initial speed, given climb angle, find speed
CLIMB3	Given speed, given climb angle, find power required
CRUISE1	Given speed, find power required for "T = D"
CRUISE2	Given power, given initial speed, find speed.
CRUISE3	<i>Cruise-climb. Given speed, find power required for "T = D"</i>
LOITER1	Given speed, find power required for "T = D"
LOITER2	Given power, given initial speed, find speed
LOITER3	<i>Cruise-climb. Given speed, find power required for "T = D"</i>
DESCENT1	Given power, given speed, find descent angle
DESCENT2	Given power, given initial speed, given descent angle, find speed
DESCENT3	Given speed, given descent angle, find power required
RADAR_DESC	Optical Radar Descent
DRIFT_DOWN	<i>Drift down descent after engine failure</i>
PULLOUT	<i>Pullout from a dive descent</i>
LOOP	<i>Loop</i>
TURN	<i>Speed and height changes in a turn</i>

This page Amendments B and D

Notes

Where lift limits are used they may be expressed as lift coefficient and/or angle of attack for buffet onset, usable lift or maximum lift, see ESDU 00035 (Reference 10).

- † The modules marked[†] can also be used to search for the speed to give optimum performance, with the further options,
- to factor the optimum speed and find the performance at this factored speed,
 - to factor the performance parameter and find the higher speed at which the factored optimum performance occurs.

Utilities Modules,

ATMOS	Evaluate atmospheric properties.
AIRSPEED	Convert any speed (except indicated speed) to all the other definitions.

2.3 Program Description

2.3.1 System data flow

The input data, with any comments produced during data input, form the first part of the output file. The performance predictions are added to the output file which then contains all the input data plus the results.

2.3.2 Program structure

ESDU 00038 (Reference 13) presents an overview of the system, Jackson Charts showing the overall structure and a logical description of the coding of the Flight Performance Program (APP02). Appendix A in the present Data Item presents general descriptions (including the outline of the method of solution) of the important utility routines, the main top-level performance routines, and includes ESDU Data Item references.

2.4 Input Data

Input data are described by the data Keywords and Symbolic Names listed in Parts 4 and 5 (References 9 and 10). The units used for input items are listed here in Table 5.1.

The user can specify input data either as a constant value, a range or list of values (to form a data permutation or combination), or as tabular data varying with a range of possible variables. For example, engine power setting could be either constant or vary with time (say) to represent a slam acceleration. Engine thrust and fuel flow can be input for up to five sets of jet engine or propeller-engine combinations having different performance per engine in each set (see examples in Section 2.3.2 of ESDU 00035 (Reference 10)). It is assumed that the engine data are fully installed (*i.e.* the data have been corrected, for example, for intake spillage, base drag and aerodynamic interferences) but provision is made for additional thrust factors, and incremental aerodynamic effects which can be functions of engine dependent variables.

2.4.1 Input formats

All numeric input uses a keyword or symbolic name followed by the data value and units (if the input quantity has units which are known to the program), *e.g.* MASS 23000 kg. These data are supplemented by keywords defining calculation and other options. Keyword input must follow the rules listed here.

- (a) Keywords may be input in any mixture of upper case and lower case (**letters 'O' or 'o' are always**

used in keywords not the number zero) and followed by at least one space.

- (b) The value and its units must be separated by at least one space. The values may consist of up to 20 characters; including the sign, leading zero, decimal point and exponent (when using the FORTRAN format, *e.g.* -0.1234E-04).
- (c) All input associated with a particular keyword must be on the same line (maximum line length 100 characters). No continuation character is provided, but additional cases could be input as a follow-on case after the END_CASE keyword.
- (d) Blank lines are permitted (but will be removed during data input).
- (e) Comment lines (starting with '!') or following data input and separated by at least one space or tab from the input, may appear anywhere in the data file.
- (f) The units **must** be input in the correct upper and lower case letters.
- (g) The input units declared with a table input do not have to be the same as those used in the table file.
- (h) Most keywords may be input in any order and may be repeated to change the value of an input.
- (i) For keywords that have units that are not known to the program (*e.g.* RATING12, ENGVAR3, FLAP *etc.*), no units name is input. These variables may be given a synonym (introduced by '=') in the data input. This synonym will be used on the output. There should be at least one space before the '=' sign and no spaces after the '=' sign or in the rest of the synonym.

The synonyms given to the miscellaneous variables, VARIABLE and ENGVAR families, may also be used as variable names in tables in place of the keyword (*e.g.* input, VARIABLE3 1.6 =SHP; then use SHP as a table variable which will be given the value 1.6). To be used as a table variable, a synonym must not be the name of any of the standard variable names in Table 5.2. A synonym can be allocated to a different miscellaneous variable when it is used in a new set of input case data; the synonym is not tied to any particular miscellaneous variable; this provides flexibility in the definition and use of the tables.

Input values may be specified in any of the following six formats.

- (1) Single constant value, *e.g.*

SWING	13.45 sqm
CLOWING	-0.78

- (2) A list of values separated by spaces or commas; the calculation is done at each of these values in turn, *e.g.*

Splay1	1.56 5.67 -0.89, 5.89 deg
VARIABLE1	13476, 35890, 45, -16.76
HP	14000 16000 12000 18000 19000 19500 ft

The three variables will produce a permutation of $4*4*6 = 96$ cases.

- (3) A family of lists for several variables with the same number of values for each variable, and with each list starting with @. This family then forms a combination of cases, *e.g.*

DELTAT	@ 1,	2,	3,	4	C
HP	@ 10,	20,	30,	40	m
Primary1	@ 100	200	300	400	

This is equivalent to the first case input of,

DELTAT	1 C
HP	10 m
Primary1	100

the second case using the values,

DELTAT	2 C
HP	20 m
Primary1	200

and so on until the last (fourth) case uses,

DELTAT	4 C
HP	40 m
Primary1	400

- (4) A range of values starting from an initial value (X_1), with a constant, signed, increment (DeltaX) and finishing at a final value (X_f). The format is X_1 (DeltaX) X_f . The calculation is then done at each of these values in turn, *e.g.*

DELTAT	-15 (5) +25 C
HG	40000 (-5000) 0 ft

The first input is equivalent to the input, DELTAT -15, -10, -5, 0, 5, 10, 15, 20, 25 C

The two variables will produce a permutation of $9 \times 9 = 81$ cases.

- (5) A family of ranges for several variables with the same number of values for each variable, and with each range starting with @. This family then forms a combination of cases, *e.g.*

DELTAT	@ 1 (1) 4 C
HP	@ 10 (10) 40 m
Primary1	@ 100 (100) 400

This is equivalent to the first case input of,

DELTAT	1 C
HP	10 m
Primary1	100

the second case using the values,

DELTAT	2 C
HP	20 m
Primary1	200

and so on until the last (fourth) case uses,

DELTAT	4 C
HP	40 m
Primary1	400

- (6) As a table, with the additional option to specify a positive factor (Fact) and a signed increment

This page Amendment C

(Delta) to the data on the table. The format is: TAB(table_name)<op1> Fact <op2> Delta (the operators can be: <op1> * or /, <op2> + or -). These factors and increments can be,

- Constants,
- Special factor and increment variables: MODTAB1 to MODTABO, see ESDU 00035 (Reference 10),
- A mixture of a constant and a MODTAB variable.

For example,

```
XGMAIN1    TAB(XENGINE) lb
XDMAIN1    TAB(XDENGINE)+100 N
CLWING     TAB(CL)*0.99 -0.02
```

```
! MODTAB1 is a variable factor on fuel flow
MODTAB1    TAB(Factor1) #
FEMAIN1    TAB(FuelFlow)*MODTAB1 lb/hr
FEMAIN2    TAB(FuelFlow)*MODTAB1 + 100 lb/hr
```

```
! MODTAB5 is a variable gross thrust increment, with synonym DelXG
MODTAB5    TAB(DeltaXG) N =DelXG
XGMAIN1    TAB(Thrust) +DelXG N
XGMAIN2    TAB(Thrust)*0.95 +MODTAB5 N
```

Notes.

- (1) All cases

The input units declared with the table input do not have to be the same as those used in the table file. The case data file units are used to define the units to be used for output. The units on the table file(s) define the units of the dependent variable(s) (Section 3 and ESDU 00035 (Reference 11)). So if the output of (say) thrust is required in SI units but the engine data are in Imperial Units, the use of Newtons on the case data input will produce the output thrust in Newtons.

- (2) Constant increment

The input units declared with the table input are used to define the units of any increment applied.

- (3) Using MODTAB variables

- Factors. The dependent data in the MODTAB tables must be non-dimensional.
- Increments. The units of the dependent data in the MODTAB tables must imply the same SI units as those of the table to which the increment is applied.

The MODTAB tables can also be modified by further **constant** factors and increments, *e.g.*

```
! MODTAB5 is a variable gross thrust increment
MODTAB5    TAB(DeltaXG)*1.05 N
XGMAIN1    TAB(Thrust) +MODTAB5 N
```

Note: MODTAB tables can also be used to modify Special Speeds, see ESDU 00035 (Reference 10).

This page Amendments C and D

Options (2), (3), (4) and (5) (above) can be used to define permutations and combinations on two or more variables. The order of input of the variables determines the order in which the permutation is expanded. If a permutation and a combination are used together, the combination is processed first (for the first set of values of the permutation), then repeated for each expansion of the permutation.

2.5 Atmosphere Data

The International Standard Atmosphere (ISA, Reference 30) is built into the program. The data for a selection of special atmospheres (*e.g.* World Wide Maximum, Arctic Minimum) are also stored in the program. These atmospheres may be accessed using the appropriate keyword, see ESDU 00035 (Reference 10).

Some of these definitions are for 'design' atmospheres which do not necessarily represent vertically stable conditions (and in such cases represent conditions that would not be met by an aircraft climbing through the atmosphere) but are the envelopes of the extreme temperatures found around the world.

The non-standard atmospheres are shown in Figure 1 for pressure heights up to 20000 m (65617 ft) (the greatest height common to all the definitions) and are as follows.

- World-Wide Maximum (WWMAX) and World-Wide Minimum (WWMIN) (Reference 3). The UK military extreme temperature 'design' limits.
- Mean Tropical (TROPMEAN) (Reference 4).
A stable standard atmosphere for use in tropical conditions. This atmosphere starts at ISA+15 C at sea level and falls to within about 5 C of World-Wide Minimum.
- Tropical Maximum (TROPMAX) and Arctic Minimum (ARCTMIN) (Reference 31).
The civil aircraft extreme temperature 'design' limits.
- 15 deg North Mean Reference (N15MEAN) (Reference 32).
A typical, yearly average temperature profile, very similar to Mean Tropical. This atmosphere has a small temperature inversion around 2500 m (8200 ft).

2.6 Table Format

Input data which are required to be tables of values (*e.g.* engine thrust, drag coefficient, design diving speed) are presented in one of the two formats described in ESDU 00035 (Reference 10). The names of the variables available for tables are listed in Table 5.2.

2.6.1 Facilities

(a) **Table Filenames:** Tables are stored in files having the same name (1 to 10 characters) as the table, with the file extension **.TAB**. The table names must conform to the lowest common standard of computer operating system conventions for file names. The name is limited to 10 characters which may not include spaces or the symbols '(', ')', and '!'. These table files are kept in the sub-directory or folder defined by the **TABLEDIR** keyword, or the local directory or folder if this keyword is omitted.

(b) **Table Formats:**

Type 1: The table contains keywords to identify the data items.

Type 2: Fixed format table.