



Aircraft performance from flight test

Part 2: thrust-drag accounting



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AIRCRAFT PERFORMANCE FROM FLIGHT TEST
PART 2: THRUST-DRAG ACCOUNTING

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AIRCRAFT PERFORMANCE FROM FLIGHT TEST PART 2: THRUST-DRAG ACCOUNTING

1. NOTATION AND DIMENSIONS

		Dimensions
A	cross-sectional area of stream tube	L^2
D	drag	MLT^{-2}
F	absolute stream force, $WU + AP_S$	MLT^{-2}
F_G	gauge stream force, $WU + A(P_S - (P_S)_0)$	MLT^{-2}
F_N	standard net thrust, $(F_G)_9 - (F_G)_0$	MLT^{-2}
F_N^*	modified (standard) net thrust, $F_N - \phi_{Plug} - \phi_{CAB}$	MLT^{-2}
F_N^1	overall net thrust, $(F_G)_{00} - (F_G)_9$	MLT^{-2}
$(F_N)_{Int}$	intrinsic net thrust, $(F_G)_9 - (F_G)_1$	MLT^{-2}
F_{NP}	net propulsive force [†] , $(F_G)_9 - (F_G)_1 - \phi_{Nacelle}$	MLT^{-2}
NPR	nozzle pressure ratio	—
P_S	static pressure	$ML^{-1}T^{-2}$
U	velocity of flow in stream tube	LT^{-1}
W	mass flow rate ($= \rho AU$)	MT^{-1}
α	angle of attack	—
ρ	density of flow (air or exhaust gases)	ML^{-3}
τ	angle of thrust vector in x-z plane	—
ϕ	component force	MLT^{-2}

[†] Other equivalent formulations for net propulsive force are also used within this Data Item.

Subscripts

<i>a</i>	afterbody
<i>c</i>	cowl forebody
<i>CAB</i>	core afterbody
<i>CB</i>	intake centre body
<i>Ref</i>	at reference conditions
<i>J</i>	jet interference
<i>Nacelle</i>	engine nacelle
<i>Plug</i>	nozzle plug
<i>Post</i>	post exit (that is, jet) flow
<i>Pre</i>	pre-entry flow
0	upstream infinity
1 to 9	engine stations (a leading 1, for example, 19, denotes by-pass flow) (1 and 2 also denote stations 1 and 2 on a streamtube)
00	downstream infinity

2. INTRODUCTION

When deriving force and moment coefficients from flight testing (see Reference 1), a comprehensive thrust-drag accounting procedure must be observed. Installed thrust depends on airframe external flow effects; aircraft drag depends on engine intake and exhaust flows. The thrust-drag accounting system must clearly define how all propulsion and airframe related forces are accounted.

It is important to have a consistent, and preferably standardised, structure of definitions for the various components of thrust and drag to ensure no components are counted twice and none are missed. The basic requirements of this 'book-keeping' system are that it allows engine and airframe performance to be considered separately, that it has clear definitions of interfaces between engine and airframe flows, that it must be unambiguous, and practical for experimental and theoretical studies.

The way in which longitudinal forces are divided into thrust and drag components is somewhat arbitrary. However, the definitions of these components need to be sufficiently clear and consistent such that the total longitudinal force on the aircraft is given by the difference between the sum of the thrust components and the sum of the drag components.

For the purpose of this analysis it is assumed that no mixing occurs between the internal and external flows, that is the flows through the engine and around the airframe are entirely separate. Ahead of the engine intake the flows are said to be separated by the surface of the pre-entry streamtube. Behind the nozzle exit it is assumed a similar dividing surface exists, the post-exit streamtube; although turbulent mixing of the flows often occurs in practice.

In order to derive aerodynamic coefficients that are invariant with engine setting it is necessary to select aircraft/propulsion system reference operating conditions (see Reference 1, Section 4.3.2). These are reference flow conditions at the intake and at the nozzle. The intake and nozzle reference conditions do not necessarily need to represent the same aircraft operating conditions. Differences from the reference conditions, that is changes from the reference intake mass flow ratio and nozzle pressure ratio, can be established analytically, from model testing, extended flight testing or, most likely, a combination of these.

Due to the difference in propulsion systems it is impractical to define a single rigorous accounting scheme that applies to all configurations. Therefore, the accounting scheme needs to be tailored to the particular system. This Item considers the installation of turbojet/fan engines mounted in the aircraft fuselage or in wing or fuselage pods. A practical accounting scheme is derived and the more commonly used definitions of propulsion system thrust are discussed.

Further treatment of thrust-drag accounting and thrust and drag definitions can be found in those items listed in the Bibliography. There is no generally accepted standard nomenclature and terminology for thrust definitions and a number of variations can be found in the literature. The nomenclature of this Data Item is generally consistent with that of AGARD AG-237 (see Reference 4). A comparison of the terms used in these reports can be found in Table 9.1.