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UPDATE OF AIRCRAFT PROFILE DATA FOR THE INTEGRATED NOISE MODEL COMPUTER PROGRAM

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16. Abstract

This report provides aircraft takeoff and landing profiles, aircraft aerodynamic performance coefficients and engine performance coefficients for the aircraft data base (Database 9) in the Integrated Noise Model (INM) computer program. Flight profiles and coefficients are provided for 92 aircraft, covering a wide range of civil transport aircraft types, and selected general aviation and military aircraft. Appendix A lists the aircraft flight profiles; Appendix B lists the aerodynamic and engine coefficients.

The aerodynamic and engine coefficients, upon which the profiles are based, are in the format specified in Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) 1845. To the extent possible, the coefficients and flight profiles are based upon the reference conditions specified in SAE AIR 1845.

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METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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UPDATE OF AIRCRAFT PROFILE DATA FOR THE INTEGRATED NOISE MODEL COMPUTER PROGRAM

1.0 INTRODUCTION

This report presents a comprehensive set of aircraft takeoff and landing profiles that is intended to update the aircraft data base contained in the Federal Aviation Administration (FAA) Integrated Noise Model (INM) computer program for the prediction of noise on the ground around airports due to aircraft operations. In addition to the aircraft profiles, which are developed for specific operating weight and flight operational procedure assumptions, aerodynamic coefficient data are also presented for each aircraft. These data can be used to calculate profiles for aircraft weights and operating conditions other than those assumed in this report.

Flight profile and aerodynamic coefficient data are provided for a wide range of civil transport aircraft types, including those in most common use in the United States. Data for selected general aviation and military aircraft are also provided.

The aerodynamic coefficients, upon which the profiles are based, are in the format specified in Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) 1845 [1][1]. In addition, to the extent possible, the coefficient data and flight profiles are based upon the reference conditions specified in SAE AIR 1845.

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[1] References are listed together at the end of the report text.

2.0 AIRCRAFT PROFILE AND PERFORMANCE PRESENTATION

The aircraft included in this study are listed in Tables 1, 2 and 3. Takeoff and landing profiles for these aircraft are presented in Appendix A, while the aerodynamic coefficients are given in Appendix B. In the tables and appendices, aircraft are identified by a number which is that assigned to the aircraft in INM Version 3, Database 9.

2.1 Aircraft Listings

In Table 1, aircraft are grouped by category, and are identified by aircraft number, manufacturer, aircraft type and engine[2]. In addition to listing the aircraft type and engine, the FAR Part 36 noise certification classification is also given in Table 1. The table also indicates the aircraft within each type category that is representative of the total subgroup. This aircraft should be selected when no other detailed description other than type category and noise classification is known.

Table 2 lists the aircraft weights used in computing the takeoff and landing profiles[3]. Table 3 lists the maximum takeoff and landing weights assumed for each aircraft, and the static engine thrust or power. In Tables 2 and 3, the aircraft are listed in the same order as in Table 1, although the type category is not repeated.

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[2] A listing of aircraft in order of INM numbers is given in the beginning of Appendix A.

[3] Maximum certificated takeoff and landing weights often vary for aircraft within a given type. Representative maximum weights, generally corresponding to the highest certificated weights, have been selected for the computations.

TABLE 1

LIST OF AIRCRAFT BY TYPE CATEGORY

Aircraft Type Category	A/C No.	Manufacturer	Aircraft	Engine	FAR Part 36 Classif	Repres A/C (1)	Perform. Data Sources (2)
4-engine, turbofan, wide body	3	Boeing	B747-100	JT9D-7QN	2		C
	2	Boeing	B747-200	JT9D-7	2	*	C
	4	Boeing	B747SP	JT9D-7	2		C
	83	Boeing	B747-200	JT9D-7A	3		A
	5	Boeing	B747-200	JT9D-7Q	3	**	A
	84	Boeing	B747-400	PW4056	3		A
4-engine, turbofan, narrow body	9	Boeing	B707-320B	JT3D-7	1	*	C
	16	Boeing	B707-320B	JT3D-7QN	2	**	C
	11	Boeing	B720B	JT3D-3	1		C
	12	McDonn Douglas	DC8-50	JT3D-3B	1		C
	13	McDonn Douglas	DC8-60	JT3D-7	1		C
	17	McDonn Douglas	DC8-60	JT8D-7QN	1		C
	14	McDonn Douglas	DC8-70	CFM56-2C-5	3		C,F
	15	Br Aerospace	BAE146-200	ALF502R-5	3	*	B
	88	Br Aerospace	BAE146-300	ALF502R-5	3		B
3-engine, turbofan, wide body	19	McDonn Douglas	DC10-10	CF6-6D	3		C
	20	McDonn Douglas	DC10-30	CF6-50C2	3	**	A
	21	McDonn Douglas	DC10-40	JT9D-20	3		C
	22	Lockheed	L1011	RB211-22B	3		C
	23	Lockheed	L1011-500	RB211-224B	3		C
3-engine, turbofan, narrow body	25	Boeing	B727-100	JT8D-7	1		C
	28	Boeing	B727-100	JT8D-7QN	2		C
	27	Boeing	B727-200	JT8D-9	2		C
	26	Boeing	B727-200	JT8D-15	2	**	C
	29	Boeing	B727-200	JT8D-15QN	2		C
	30	Boeing	B727-200	JT8D-17	2		C
	93	Valsan	B727-200	JT8D-17,217	3	*	B
	94	Valsan	B727-100	JT8D-7,219	3		B
2-engine, turbofan wide body	32	Boeing	B767-200	CF6-80A	3		A
	33	Boeing	B767-200	JT9D-7R4D	3	**	A
	87	Boeing	B767-300	PW4060	3		A
	31	Airbus	A300B4-200	CF6-50C2	3		B
	34	Airbus	A310-300	CF6-80C2A2	3		B
	97	Airbus	A320-211	CFM56-5A-1	3		B

TABLE 1 (CONT'D)

LIST OF AIRCRAFT BY TYPE CATEGORY

Aircraft Type Category	A/C No.	Manufacturer	Aircraft	Engine	FAR Part 36 Classif	Repres A/C (1)	Perform. Data Sources (2)
2-engine, turbofan narrow body	42	Boeing	B737	JT8D-9	1		C
	45	Boeing	B737	JT8D-9QN	2		C
	47	Boeing	B737-200	JT8D-17	2		C
	35	Boeing	B737-300	CFM56-3B-1	3		A
	36	Boeing	B737-300	CFM56-3B-2	3	*	A
	85	Boeing	B737-400	CFM56-3C-1	3		A
	86	Boeing	B737-500	CFM56-3B-1	3		A
	51	Boeing	B757-200	RB211-535E4	3		A
	52	Boeing	B757-200	PW2037	3	*	A
	41	McDonn Douglas	DC9-10	JT8D-7	1		C
	44	McDonn Douglas	DC9-10	JT8D-7QN	2		C
	40	McDonn Douglas	DC9-30	JT8D-9	1		C
	43	McDonn Douglas	DC9-30	JT8D-9QN	2	**	C
	46	McDonn Douglas	DC9-50	JT8D-17	2		C
	48	McDonn Douglas	MD-81	JT8D-209	3		A
	49	McDonn Douglas	MD-82	JT8D-217A	3	*	A
	50	McDonn Douglas	MD-83	JT8D-219	3		A
	89	Fokker	F100	TAY 620-15	3		A
	90	Fokker	F100	TAY 650-15	3		A
2-engine, turbojet narrow body	37	Br Aerospace	BAC111	SPEY MK511-14	2		F
	38	Fokker	F28-2000	RB183MK555	2		A
	39	Fokker	F28-4000	RB183MK555	2	**	A
supersonic transport	18	Br/French	CONCORDE	OLY593	1	**	F
general aviation turbojet & turbofan	53	Comp. Fleet	1985 BUSINESS JET		1	*	F
	55	Gates	LEAR 25	CJ610-8	1		E,F
	54	Gates	LEAR 36	TFE731-2	3	**	E,F
	59	Gulfstream	GIIB	SPEY MK511-8	2		E,F
	96	Gulfstream	GIV	TAY 611	3		E,F
	98	Dassault	FALCON 20	CF700-2D-2	2		E,F
	57	Cessna	CIT 2	JT15D-4	3	*	E,F
	95	Cessna	CIT 3	TFE731-3-100S	3	*	E,F
	60	Mitsubishi	MU300-10	JT15D-4	3		E,F
	58	Canadair	CL600	ALF502L	3		E,F
	61	Canadair	CL601	CF34-3A	3		E,F
	62	Israel A/C	ASTRA 1125	TFE731-3A	3		E,F
4-engine turboprop weight> 50,000 lbs	63	Lockheed	L188C	ALL 501-D13	1	**	E,F
	Also see A/C No. 81, Lockheed C-130H and A/C No. 82, Lockheed C-130E						

TABLE 1 (CONT'D)

LIST OF AIRCRAFT BY TYPE CATEGORY

Aircraft Type Category	A/C No.	Manufacturer	Aircraft	Engine	FAR Part 36 Classif	Repres A/C (1)	Perform. Data Sources (2)
4-engine turboorop weight< 50,000 lbs	65	DeHavilland	DASH 7	PT6A-50	3	**	E,F
2-engine turboprop weight >38,000 lbs	66	Convair	CV580	ALL 501-D15	1	**	F
	67	Br Aerospace	HS748	DART MK532-2	3		F
2-engine turboprop weight >12,500 lbs <38,000 lbs	64	DeHavilland	DASH 8-100	PW121	3	**	B
	99	DeHavilland	DASH 8-300	PW123	3		B
	68	Shorts	SD330	PT6A-45AR	3		E,F
	72	Saab	SF340B	CT7-9B	3		E,F
2-engine turboprop weight <12,500 lbs	69	DeHavilland	DASH 6	PT6A-27	1		F
	73	Cessna	CONQUEST II	TPE331-8	1	**	E
4-engine, piston weight >12,500 lbs	70	McDonn Douglas	DC6	R2800-CB17	1	**	F
2-engine, piston weight >12,500 lbs	71	McDonn Douglas	DC3	R1820-86	1	**	E,F
2-engine, piston weight <12,500 lbs	76	Beech	BARON 58P	TS10-520-L	1	**	E
1-engine, piston	77	Comp. Fleet	1985 1-ENG COMP		1	**	F
	74	Small A/C	1985 1-ENG VP PROP		1		E
	75	Small A/C	1985 1-ENG FP PROP		1		E
4-engine, turbofan military tanker	78	Boeing	KC135A	J57-P-59W	1		D
	92	Boeing	KC135B	JT3D-7	1		D
	91	Boeing	KC135R	CFM56-2B-1	1	**	D
4-engine, turboprop military transport	82	Lockheed	C-130E	T56-A-7	1		E,F
	81	Lockheed	C-130H	T56-A-15	3	**	E,F
2-engine, afterburner turbojet, military	79	McDonn Douglas	F-4C	J79-GE-15	1	**	D
1-engine, turbojet military attack	80	LTV	A-7D,E	TF-41-A-1	1	**	D

Notes - (1) Representative aircraft:
- ** Typical aircraft for type category
- * Typical aircraft for noise certification stage within type category

(2) Major aircraft data sources:
- A Provided by the aircraft manaufacturer as SAE AIR 1845 coefficients
- B Provided by the aircraft manufacturer in detailed performance tables and charts
- C Provided in Aircraft Noise Definition Documents [6 to 11]
- D U.S. Air Force flight manuals
- E Civil aircraft flight manuals or certification reports
- F AAAI project files

TABLE 2

LIST OF AIRCRAFT
WITH LANDING WEIGHTS AND TAKEOFF WEIGHTS BY STAGE LENGTH

A/C No.	Manufacturer	Aircraft	Engine	Landing Weight (klbs)	Takeoff Weight in Kilopounds for Stage Lengths in Nautical Miles: 0 to 500 nm	500 to 1000 nm	1000 to 1500nm	1500 to 2500 nm	2500 to 3500 nm	3500 to 4500 nm	4500 nm or more
3	Boeing	B747-100	JT9D-7QN	507.6	475	495	520	550	625	635	
2	Boeing	B747-200	JT9D-7	507.6	525	545	565	610	665	725	775
4	Boeing	B747SP	JT9D-7	427.5	400	422	443	475	518	560	625
83	Boeing	B747-200	JT9D-7A	507.6	475	500	520	560	610	675	725
5	Boeing	B747-200	JT9D-7Q	567.0	525	545	565	610	665	725	775
84	Boeing	B747-400	PW4056	567.0	571	593	614	663	723	788	843
9	Boeing	B707-320B	JT3D-7	222.3	214	228	240	260	286	312	330
16	Boeing	B707-320B	JT3D-7QN	222.3	214	228	240	260	286	312	330
11	Boeing	B720B	JT3D-3	157.5	165	175	185	200	210		
12	McDonn Douglas	DC8-50	JT3D-3B	216.0	185	195	210	230	255	275	
13	McDonn Douglas	DC8-60	JT3D-7	247.5	220	230	245	265	290	305	325
17	McDonn Douglas	DC8-60	JT8D-7QN	247.5	220	230	245	265	290	305	325
14	McDonn Douglas	DC8-70	CFM56-2C-5	232.2	220	230	245	265	290	305	325
15	Br Aerospace	BAE146-200	ALF502R-5	72.9	76	84	91				
88	Br Aerospace	BAE146-300	ALF502R-5	76.1	80	88	96				
19	McDonn Douglas	DC10-10	CF6-6D	327.2	325	340	360	390	420	450	
20	McDonn Douglas	DC10-30	CF6-50C2	362.7	375	390	405	436	476	517	561
21	McDonn Douglas	DC10-40	JT9D-20	362.7	364	379	393	423	462	502	544
22	Lockheed	L1011	RB211-22B	322.2	330	340	355	370	400	430	
23	Lockheed	L1011-500	RB211-224B	331.2	345	355	370	385	413	441	470
25	Boeing	B727-100	JT8D-7	128.3	136	143	150	158			
28	Boeing	B727-100	JT8D-7QN	128.3	136	143	150	158			
27	Boeing	B727-200	JT8D-9	152.1	156	168	180	191			
26	Boeing	B727-200	JT8D-15	152.1	156	164	175	189	204		
29	Boeing	B727-200	JT8D-15QN	152.1	156	164	175	189	204		
30	Boeing	B727-200	JT8D-17	152.1	157	169	180	189			
93	Valsan	B727-200	JT8D-17,217	147.6	156	164	175	189	204		
94	Valsan	B727-100	JT8D-7,219	128.3	136	143	150	158			
32	Boeing	B767-200	CF6-80A	243.0	227	236	245	261	282	303	316
33	Boeing	B767-200	JT9D-7R4D	243.0	229	238	247	264	285	307	317
87	Boeing	B767-300	PW4060	288.0	265	276	286	306	330	356	368
31	Airbus	A300B4-200	CF6-50C2	265.9	262	280	295	324	357		
34	Airbus	A310-300	CF6-80C2A2	244.1	232	246	261	276	302	327	
97	Airbus	A320-211	CFM56-5A-1	128.0	126	137	149	160			

TABLE 2 (CONT'D)

LIST OF AIRCRAFT
WITH LANDING WEIGHTS AND TAKEOFF WEIGHTS BY STAGE LENGTH

A/C No.	Manufacturer	Aircraft	Engine	Landing Weight (klbs)	Takeoff Weight in Kilopounds for Stage Lengths in Nautical Miles: 0 to 500 nm	500 to 1000 nm	1000 to 1500nm	1500 to 2500 nm	2500 to 3500 nm	3500 to 4500 nm	4500 nm or more
42	Boeing	B737	JT8D-9	88.2	82	85	92	100			
45	Boeing	B737	JT8D-9QN	88.2	82	85	92	100			
47	Boeing	B737-200	JT8D-17	96.3	90	95	100	105			
35	Boeing	B737-300	CFM56-3B-1	102.6	96	102	108	119			
36	Boeing	B737-300	CFM56-3B-2	102.6	98	105	111	122			
85	Boeing	B737-400	CFM56-3C-1	111.6	107	115	121	133			
86	Boeing	B737-500	CFM56-3B-1	99.9	98	105	111	122			
51	Boeing	B757-200	RB211-535E4	178.2	167	173	180	193	209		
52	Boeing	B757-200	PW2037	178.2	165	171	178	190	206	222	
41	McDonn Douglas	DC9-10	JT8D-7	73.5	70	78	85				
44	McDonn Douglas	DC9-10	JT8D-7QN	73.5	70	78	85				
40	McDonn Douglas	DC9-30	JT8D-9	91.8	94	103	112				
43	McDonn Douglas	DC9-30	JT8D-9QN	91.8	94	103	112				
46	McDonn Douglas	DC9-50	JT8D-17	99.0	100	107	115				
48	McDonn Douglas	MD-81	JT8D-209	115.2	115	126	137				
49	McDonn Douglas	MD-82	JT8D-217A	117.0	117	124	132	148			
50	McDonn Douglas	MD-83	JT8D-219	125.6	125	133	141	158			
89	Fokker	F100	TAY 620-15	77.0	78	86	93				
90	Fokker	F100	TAY 650-15	79.2	80	88	96				
37	Br Aerospace	BAC111	SPEY MK511-14	73.8	74	79	85				
38	Fokker	F28-2000	RB183MK555	53.1	58	64					
39	Fokker	F28-4000	RB183MK555	57.6	61	66	73				
18	Br/French	CONCORDE	OLY593	220.5	340	340	375	375	400	400	
53	Comp. Fleet	1985 BUSINESS JET		14.6	19.2						
55	Gates	LEAR 25	CJ610-8	12.2	15.0						
54	Gates	LEAR 36	TFE731-2	13.8	18.3						
59	Gulfstream	GIIB	SPEY MK511-8	52.7	65.5						
96	Gulfstream	GIV	TAY 611	58.5	71.7						
98	Dassault	FALCON 20	CF700-2D-2	24.6	28.7						
57	Cessna	CIT 2	JT15D-4	12.6	14.7						
95	Cessna	CIT 3	TFE731-3-100S	15.3	20.0						
60	Mitsubishi	MU300-10	JT15D-4	11.9	14.1						
58	Canadair	CL600	ALF502L	29.7	36.0						
61	Canadair	CL601	CF34-3A	32.4	43.1						
62	Israel A/C	ASTRA 1125	TFE731-3A	18.6	23.5						
63	Lockheed	L188C	ALL 501-D13	88.3	93	102	115				

TABLE 2 (CONT'D)

LIST OF AIRCRAFT
WITH LANDING WEIGHTS AND TAKEOFF WEIGHTS BY STAGE LENGTH

A/C No.	Manufacturer	Aircraft	Engine	Landing Weight (klbs)	Takeoff Weight in Kilopounds for Stage Lengths in Nautical Miles: 0 to 500 nm	500 to 1000 nm	1000 to 1500nm	1500 to 2500 nm	2500 to 3500 nm	3500 to 4500 nm	4500 nm or more
65	DeHavilland	DASH 7	PT6A-50	35.1	39						
66	Convair	CV580	ALL 501-D15	46.8	49	54	58				
67	Br Aerospace	HS748	DART MK532-2	38.7	46.5						
64	DeHavilland	DASH 8-100	PW121	30.5	31						
99	DeHavilland	DASH 8-300	PW123	37.8	38.7						
68	Shorts	SD330	PT6A-45AR	20.3	21.8						
72	Saab	SF340B	CT7-9B	23.9	24.5	27.3					
69	DeHavilland	DASH 6	PT6A-27	11.1	12.5						
73	Cessna	CONQUEST II	TPE331-8	8.4	9.9						
70	McDonn Douglas	DC6	R2800-CB17	85.5	85	95	105				
71	McDonn Douglas	DC3	R1820-86	22.1	24	26	28				
76	Beech	BARON 58P	TS10-520-L	5.5	5.5						
77	Comp. Fleet	1985 1-ENG COMP		2.2	2.4						
74	Small A/C	1985 1-ENG VP PROP		2.7	3.0						
75	Small A/C	1985 1-ENG FP PROP		2.0	2.2						
78	Boeing	KC135A	J57-P-59W	205.0	285						
92	Boeing	KC135B	JT3D-7	205.0	285						
91	Boeing	KC135R	CFM56-2B-1	220.0	308						
82	Lockheed	C-130E	T56-A-7	117.0	132	155					
81	Lockheed	C-130H	T56-A-15	121.5	132	155					
79	McDonn Douglas	F-4C	J79-GE-15	40.0	52	52					
80	LTV	A-7D,E	TF-41-A-1	33.0	36	42					

TABLE 3

MAXIMUM AIRCRAFT WEIGHTS AND ENGINE THRUSTS

A/C No.	Manufacturer	Aircraft	Engine	Maximum Takeoff Weight (klbs)	Maximum Landing Weight (klbs)	Static Engine Thrust/ Horsepower (klbs/HP)
3	Boeing	B747-100	JT9D-7QN	733.0	564.0	45.5 klbs
2	Boeing	B747-200	JT9D-7	770.0	564.0	45.5
4	Boeing	B747SP	JT9D-7	702.0	475.0	45.5
83	Boeing	B747-200	JT9D-7A	785.0	564.0	46.3
5	Boeing	B747-200	JT9D-7Q	800.0	630.0	53.0
84	Boeing	B747-400	PW4056	870.0	630.0	56.8
9	Boeing	B707-320B	JT3D-7	334.0	247.0	19.0 klbs
16	Boeing	B707-320B	JT3D-7QN	334.0	247.0	19.0
11	Boeing	B720B	JT3D-3	234.0	175.0	18.0
12	McDonn Douglas	DC8-50	JT3D-3B	325.0	240.0	18.0
13	McDonn Douglas	DC8-60	JT3D-7	355.0	275.0	19.0
17	McDonn Douglas	DC8-60	JT8D-7QN	355.0	275.0	19.0
14	McDonn Douglas	DC8-70	CFM56-2C-5	355.0	258.0	22.0
15	Br Aerospace	BAE146-200	ALF502R-5	93.0	81.0	7.0
88	Br Aerospace	BAE146-300	ALF502R-5	97.5	84.5	7.0
19	McDonn Douglas	DC10-10	CF6-6D	455.0	363.5	40.0 klbs
20	McDonn Douglas	DC10-30	CF6-50C2	572.0	403.0	53.2
21	McDonn Douglas	DC10-40	JT9D-20	555.0	403.0	49.4
22	Lockheed	L1011	RB211-22B	430.0	358.0	42.0
23	Lockheed	L1011-500	RB211-224B	510.0	368.0	50.0
25	Boeing	B727-100	JT8D-7	169.5	142.5	14.0 klbs
28	Boeing	B727-100	JT8D-7QN	169.5	142.5	14.0
27	Boeing	B727-200	JT8D-9	190.0	160.0	14.5
26	Boeing	B727-200	JT8D-15	208.0	169.0	15.5
29	Boeing	B727-200	JT8D-15QN	208.0	169.0	15.5
30	Boeing	B727-200	JT8D-17	208.0	169.0	16.0
93	Valsan	B727-200	JT8D-17,217	208.0	164.0	16.0 20.9
94	Valsan	B727-100	JT8D-7,219	169.5	142.5	14.0 21.7
32	Boeing	B767-200	CF6-80A	302.0	270.0	48.0 klbs
33	Boeing	B767-200	JT9D-7R4D	351.0	270.0	48.0
87	Boeing	B767-300	PW4060	407.0	320.0	60.0
31	Airbus	A300B4-200	CF6-50C2	364.0	295.0	52.5
34	Airbus	A310-300	CF6-80C2A2	331.0	271.0	53.5
97	Airbus	A320-211	CFM56-5A-1	162.0	142.0	25.0

TABLE 3 (CONT'D)

MAXIMUM AIRCRAFT WEIGHTS AND ENGINE THRUSTS

A/C No.	Manufacturer	Aircraft	Engine	Maximum Takeoff Weight (klbs)	Maximum Landing Weight (klbs)	Static Engine Thrust/ Horsepower (klbs/HP)
42	Boeing	B737	JT8D-9	109.0	98.0	14.5 klbs
45	Boeing	B737	JT8D-9QN	109.0	98.0	14.5
47	Boeing	B737-200	JT8D-17	124.5	107.0	16.0
35	Boeing	B737-300	CFM56-3B-1	135.5	114.0	20.0
36	Boeing	B737-300	CFM56-3B-2	139.0	114.0	22.0
85	Boeing	B737-400	CFM56-3C-1	150.0	124.0	23.5
86	Boeing	B737-500	CFM56-3B-1	138.5	111.0	20.0
51	Boeing	B757-200	RB211-535E4	220.0	198.0	40.1
52	Boeing	B757-200	PW2037	240.0	198.0	38.3
41	McDonn Douglas	DC9-10	JT8D-7	90.7	81.7	14.0
44	McDonn Douglas	DC9-10	JT8D-7QN	90.7	81.7	14.0
40	McDonn Douglas	DC9-30	JT8D-9	114.0	102.0	14.5
43	McDonn Douglas	DC9-30	JT8D-9QN	114.0	102.0	14.5
46	McDonn Douglas	DC9-50	JT8D-17	121.0	110.0	16.0
48	McDonn Douglas	MD-81	JT8D-209	140.0	128.0	19.3
49	McDonn Douglas	MD-82	JT8D-217A	149.5	130.0	20.9
50	McDonn Douglas	MD-83	JT8D-219	160.0	139.5	21.7
89	Fokker	F100	TAY 620-15	95.0	85.5	13.9
90	Fokker	F100	TAY 650-15	98.0	88.0	15.1
37	Br Aerospace	BAC111	SPEY MK511-14	89.6	82.0	11.4 klbs
38	Fokker	F28-2000	RB183MK555	65.0	59.0	9.9
39	Fokker	F28-4000	RB183MK555	71.0	64.0	9.9
18	Br/French	CONCORDE	OLY593	400.0	245.0	38.1 klbs
53	Comp. Fleet	1985 BUSINESS JET		19.2	16.2	3.6 klbs
55	Gates	LEAR 25	CJ610-8	15.0	13.5	3.0
54	Gates	LEAR 36	TFE731-2	18.3	15.3	3.5
59	Gulfstream	GIIB	SPEY MK511-8	65.5	58.5	11.4
96	Gulfstream	GIV	TAY 611	71.7	58.5	13.9
98	Dassault	FALCON 20	CF700-2D-2	28.7	27.3	4.5
57	Cessna	CIT 2	JT15D-4	14.7	14.0	2.5
95	Cessna	CIT 3	TFE731-3-100S	20.0	17.0	3.7
60	Mitsubishi	MU300-10	JT15D-4	14.1	13.2	2.5
58	Canadair	CL600	ALF502L	36.0	33.0	7.5
61	Canadair	CL601	CF34-3A	43.1	36.0	9.2
62	Israel A/C	ASTRA 1125	TFE731-3A	23.5	20.7	3.7
63	Lockheed	L188C	ALL 501-D13	116.0	98.1	3750 HP
65	DeHavilland	DASH 7	PT6A-50	41.0	39.0	1174 HP

TABLE 3 (CONT'D)

MAXIMUM AIRCRAFT WEIGHTS AND ENGINE THRUSTS

A/C No.	Manufacturer	Aircraft	Engine	Maximum Takeoff Weight (klbs)	Maximum Landing Weight (klbs)	Static Engine Thrust/ Horsepower (klbs/HP)
66	Convair	CV580	ALL 501-D15	58.0	52.0	3750 HP
67	Br Aerospace	HS748	DART MK532-2	46.5	43.0	2280
64	DeHavilland	DASH 8-100	PW121	34.5	33.9	1950 HP
99	DeHavilland	DASH 8-300	PW123	43.0	42.0	2142
68	Shorts	SD330	PT6A-45AR	22.9	22.6	1254
72	Saab	SF340B	CT7-9B	27.3	26.5	1750
69	DeHavilland	DASH 6	PT6A-27	12.5	12.3	652 HP
73	Cessna	CONQUEST II	TPE331-8	9.9	9.4	636
70	McDonn Douglas	DC6	R2800-CB17	106.0	95.0	2500 HP
71	McDonn Douglas	DC3	R1820-86	28.0	24.5	1425 HP
76	Beech	BARON 58P	TS10-520-L	6.1	6.1	310 HP
77	Comp. Fleet	1985 1-ENG COMP		2.4	2.4	165 HP
74	Small A/C	1985 1-ENG VP PROP		3.0	3.0	260
75	Small A/C	1985 1-ENG FP PROP		2.2	2.2	150
78	Boeing	KC135A	J57-P-59W	300.0	228.0	11.8 klbs
92	Boeing	KC135B	JT3D-7	300.0	228.0	19.0
91	Boeing	KC135R	CFM56-2B-1	324.0	244.0	22.0
82	Lockheed	C-130E	T56-A-7	155.0	130.0	4050 HP
81	Lockheed	C-130H	T56-A-15	155.0	135.0	4680 HP
79	McDonn Douglas	F-4C	J79-GE-15	52.0	40.0	10.9 klbs
80	LTV	A-7D,E	TF-41-A-1	42.0	37.1	14.5 klbs

2.2 Aircraft Takeoff Profiles

For all of the civil jet powered transport aircraft, and some of the propeller powered transport aircraft, more than one takeoff profile is provided, with a profile assigned to a particular stage length to be flown (as identified in Table 2). The takeoff weight increases with the stage length, and consequently the takeoff performance of the aircraft changes since climb gradients decrease with increasing weight. For most of the other aircraft, a single takeoff profile is provided. This profile is based on the maximum aircraft gross takeoff weight.

Tables 4-A and 4-B show a typical takeoff profile listing. The tables describe the profile and also provide other information about the aircraft and aircraft performance which is listed at the bottom of the table.

Each profile is broken into a series of segments which correspond to changes in flight altitude, engine thrust, flap configuration or speed. These segments are listed in Table 4-A. The individual segments are then connected to form the complete profile which is described by a series of points as listed in Table 4-B and shown in Figure 1.

For each point, the horizontal distance from brake release in feet, altitude in feet, true airspeed in knots, and normalized thrust for each engine is given. The thrust is given in terms of the referred net thrust in pounds, or alternatively, the percentage of referred net thrust, with the unit chosen to match the parameter used in presenting the INM noise data.

TABLE 4-A

SAMPLE LISTING OF AIRCRAFT TAKEOFF PROFILE SEGMENTS

TAKEOFF SEGMENTS DATA (HEADWIND = 8 KT) 06-19-1991 15:36:56

AIRCRAFT ID NUMBER	AIRCRAFT AND ENGINE NAMES	AIRCRAFT CATEGORY
029	B727-200/JT8D-15QN	JCOM

AIRCRAFT WEIGHT	STAGE NUMBER	NUMBER OF ENGINES
156000	1	3

SEG. NO.	TYPE	FLAP	START ALT (FT)	END ALT (FT)	CALIBRATED START SPEED (KCAS)	END SPEED	SEG. LNGTH (FT)	THRST (LB)	R/C (FPM)	GRAD
1	TKOFF	5	0	0	16	162	5460	13462	0	0.00000
2	CLIMB	5	0	1000	162	162	6052	13572	2725	0.16523
3	ACCEL	5	1000	1136	162	170	1616	13643	1363	0.08017
4	ACCEL	2	1136	1553	170	200	5558	13525	1363	0.07149
5	ACCEL	ZERO	1553	1637	200	210	1695	12121	1000	0.04711
6	CLIMB	ZERO	1637	3000	210	210	9380	12161	3198	0.14530
7	ACCEL	ZERO	3000	3371	210	250	8606	12064	1000	0.04098
8	CLIMB	ZERO	3371	5500	250	250	16938	11925	3399	0.12570
9	CLIMB	ZERO	5500	7500	250	250	18310	11765	3048	0.10923
10	CLIMB	ZERO	7500	10000	250	250	27968	11335	2583	0.08939

SEG. NO.	TYPE	FLAP	THRUST TYPE	VALUE
1	TKOFF	5	MAX TKOFF	
2	CLIMB	5	MAX TKOFF	
3	ACCEL	5	MAX TKOFF	
4	ACCEL	2	MAX TKOFF	
5	ACCEL	ZERO	MAX CLIMB	
6	CLIMB	ZERO	MAX CLIMB	
7	ACCEL	ZERO	MAX CLIMB	
8	CLIMB	ZERO	MAX CLIMB	
9	CLIMB	ZERO	MAX CLIMB	
10	CLIMB	ZERO	MAX CLIMB	

TABLE 4-B

SAMPLE AIRCRAFT TAKEOFF PROFILE LISTING

TAKEOFF PROFILE DATA (HEADWIND = 8 KT) 06-19-1991 15:37:01

AIRCRAFT ID NUMBER	AIRCRAFT AND ENGINE NAMES	AIRCRAFT CATEGORY
029	B727-200/JT8D-15QN	JCOM

	DISTANCE FROM BRAKE RELEASE (FT)	HEIGHT (FT)	SPEED (KTAS)	THRUST (LB)
POINT 1	0	0	16	14694
POINT 2	5460	0	162	13462
POINT 3	11513	1000	164	13667
POINT 4	13129	1136	173	13619
POINT 5	18687	1553	205	13430
POINT 6	19687	1603	211	12154
POINT 7	20381	1637	215	12088
POINT 8	29761	3000	220	12209
POINT 9	38368	3371	263	11919
POINT 10	55306	5500	271	11871
POINT 11	73616	7500	280	11607
POINT 12	101584	10000	291	0

THRUST FOR LEVEL FLIGHT	GRADIENT AT TAKE-OFF POWER	TAKE-OFF THRUST	GRADIENT AT CLIMB POWER
5136	0.165232	13572	0.127656

CLIMB THRUST	GRADIENT AT FAR36 CUTBACK	THRUST FOR ENGINE OUT LEVEL FLIGHT	VZF (KCAS)
12547	0.046069	7705	210

NUMBER OF ENGINES	RATED THRUST LB	AIRCRAFT WEIGHT (LB)	STAGE NUMBER
3	15500	156000	1

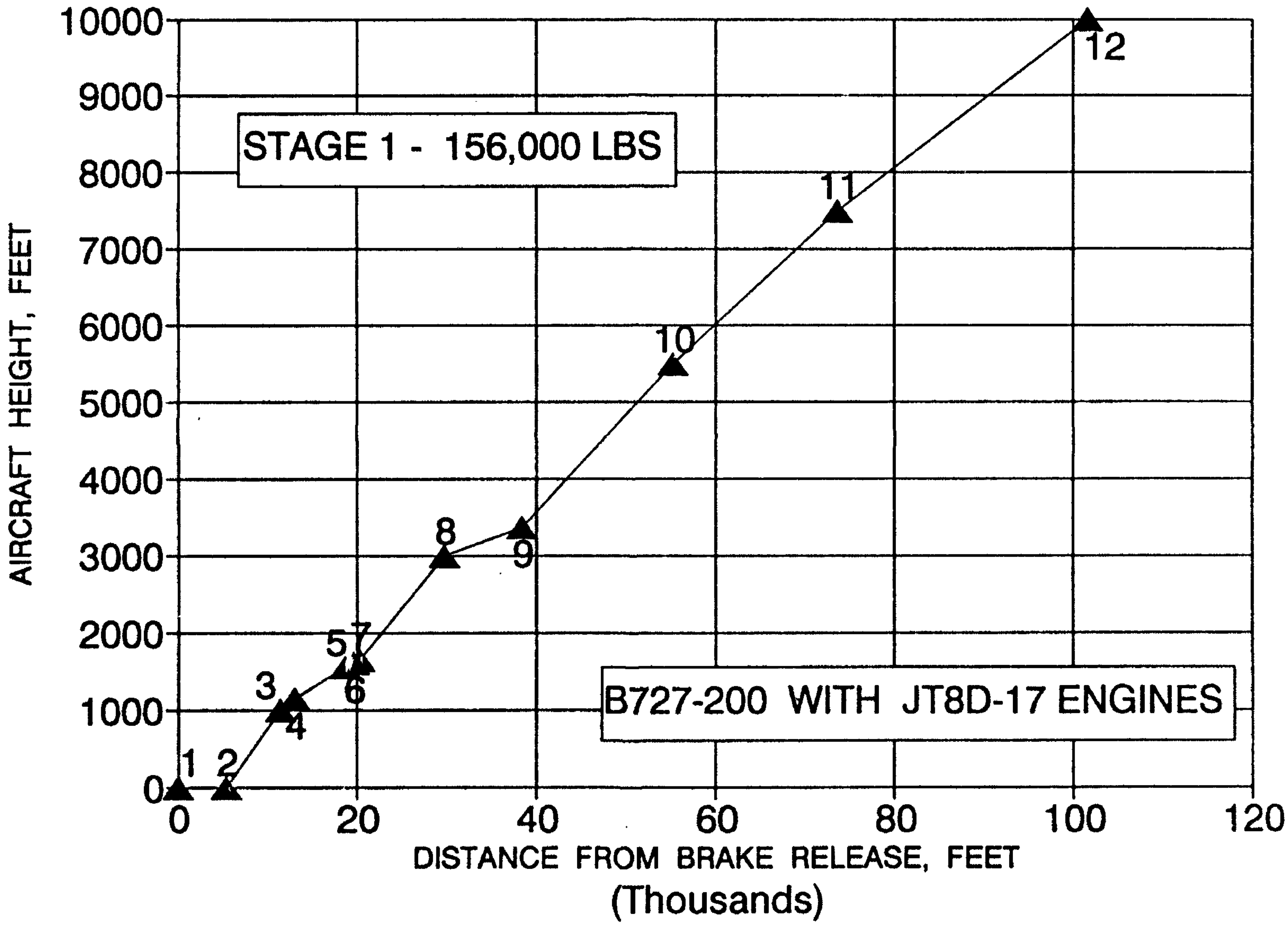

FIGURE 1. SAMPLE TAKEOFF PROFILE

In addition to the takeoff profile description, each profile printout, shown in the lower portion of Table 3-B, provides other information calculated for the conditions given below:

(a) Thrust for level flight - calculated at 1,000 feet altitude, takeoff flaps, and initial climb speed (V2 + 10 knots CAS for most aircraft);

(b) Gradient at takeoff power - average gradient for the initial climb to 1,000 feet altitude;

(c) Takeoff thrust - calculated at liftoff point (zero altitude and V2 + 10 knots CAS);

(d) Gradient at climb power - calculated as the average for a climb from 2,000 to 3,000 feet, takeoff flaps and initial climb speed (usually V2 + 10 knots CAS);

(e) Climb thrust - maximum climb thrust calculated at 1,000 feet, takeoff flaps and initial climb speed (usually V2 + 10 knots CAS);

(f) Gradient at FAR Part 36 cutback - calculated at 1,100 feet (representing the average for a climb from 1,000 to 1,200 feet), takeoff flap, initial climb speed, 8 kt headwind and with the thrust required for FAR Part 36 engine-out criterion with zero wind;

(g) Thrust for engine out level flight - calculated at 1,000 feet altitude, takeoff flaps, and initial climb speed. The thrusts given are those that, in the event of loss of power of one engine, the aircraft could still maintain level flight, with the provision that the climb gradient for the FAR Part 36 thrust is at least 4 percent. Note that a FAR Part 36 thrust and a level flight thrust have been calculated for all the aircraft, even for those which the noise regulations do not apply;

(h) VZF (minimum clean configuration climb speed) - speed given in knots CAS;

(i) Rated thrust - nominal static engine thrust or power (bare engine).

As noted earlier, multiple profiles are provided for the jet transport aircraft. Figure 2 shows a typical set of profiles for different stage weights.

2.3 Landing Profiles

One landing profile has been computed for each aircraft, based on the weight listed in Table 2. This weight is approximately 90 percent of the maximum landing weight for the aircraft. Table 5 shows a typical landing profile listing. Again, the profile is described by a series of points. And, for each point the distance from the runway threshold in feet, altitude in feet, true airspeed in knots and normalized thrust are given. All of the profiles are calculated from a starting altitude of 6,000 feet. With only a few exceptions (for smaller propeller aircraft), the profiles assume a three degree descent path, with the path broken into five segments.

2.4 Aircraft Performance Coefficients

Table 6 shows a sample listing of the aerodynamic and engine performance characteristics for an aircraft. The table lists the coefficients used in computing various takeoff and landing profile segments. The upper portion of the table lists those used for computing takeoff profiles. Immediately below are listed the coefficients applicable to landing profiles. The lower part of the table lists the coefficients for calculating engine thrust.

The coefficients and the equations in which they are used are specified in SAE AIR 1845. They are also described in Section 3 of this report for convenience.

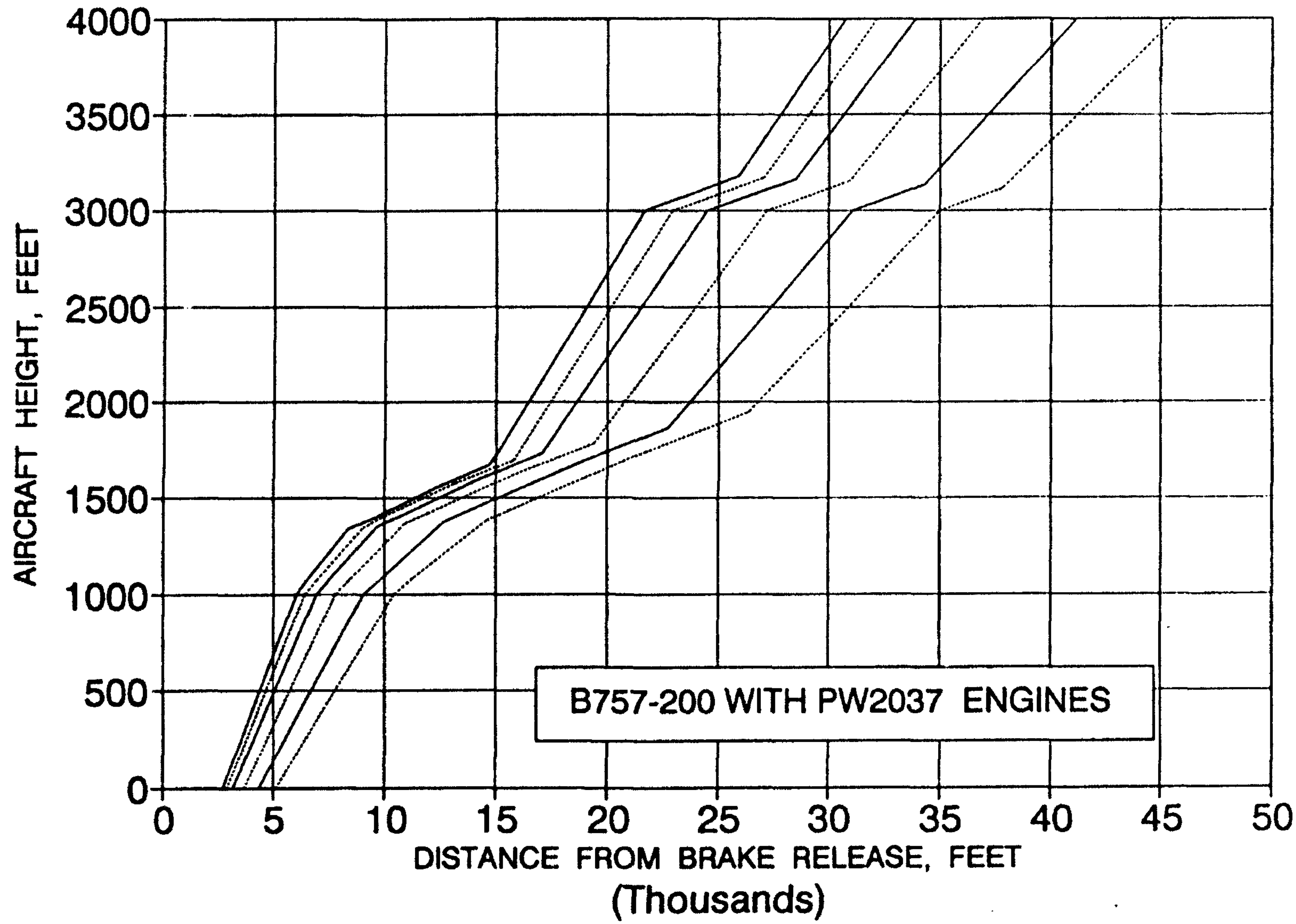

FIGURE 2. A SET OF TAKEOFF PROFILES

TABLE 5

SAMPLE LANDING PROFILE LISTING

APPROACH PROFILE DATA (HEADWIND = 8 KT) 02-15-1992 12:44:11

AIRCRAFT ID NUMBER	AIRCRAFT AND ENGINE NAMES	AIRCRAFT CATEGORY
029	B727-200/JT8D-15QN	JCOM

	DISTANCE FROM RW THRESHOLD (FT)	HEIGHT (FT)	SPEED (KTAS)	THRUST (LB)	FLAPS
POINT 1	113533	6000	273	809	ZERO
POINT 2	56289	3000	167	2495	5
POINT 3	27668	1500	153	3144	D 25
POINT 4	18127	1000	150	4855	D 30
POINT 5	-954	0	148	4682	D 30
POINT 6	-1302	0	140	9300	
POINT 7	-4430	0	30	1550	

NUMBER OF ENGINES	RATED THRUST LB	AIRCRAFT WEIGHT (LB)	GLIDE SLOPE
3	15500	152100	3.00

TABLE 6

SAMPLE LISTING OF AIRCRAFT PERFORMANCE COEFFICIENTS

Name: B727-200/JT8D-15QN
ID: A/C Number 029
AC Type: JCOM 3 ENGINES
Rated Power: 15500 LB

	TOFLAP	B	C	RT
1	25	0.739100E-02	0.365969E+00	0.1178280
2	20	0.771200E-02	0.376653E+00	0.1088970
3	15	0.807800E-02	0.387088E+00	0.1006310
4	5	0.906200E-02	0.409200E+00	0.0949260
5	2	0.000000E+00	0.000000E+00	0.0857000
6	ZERO	0.000000E+00	0.000000E+00	0.0636000

	APPFLAP	D	R
1	D 40	0.372094E+00	0.184387E+00
2	D 30	0.378419E+00	0.143164E+00
3	D 25	0.383689E+00	0.109535E+00
4	U 25	0.000000E+00	0.109535E+00
5	U 15	0.000000E+00	0.899690E-01

REFERRED THRUST COEFFICIENTS:

	E	F	Ga	Gb	H
1 MAX T/O	0.148298E+05	-.846009E+01	0.233373E+00	-.291450E-04	0.000000E+00
2 MAX CLIMB	0.134210E+05	-.765638E+01	0.211202E+00	-.263762E-04	0.000000E+00
3 GEN. THRUST	-.147737E+05	-.509534E+01	0.000000E+00	0.000000E+00	0.000000E+00

K1a	K1b	K2	K3
0.177173E+05	0.000000E+00	-.184507E+04	0.000000E+00

2.5 Reference Conditions for Aerodynamic and Engine Coefficients

SAE AIR 1845 specifies the following reference conditions for the calculation of airplane aerodynamic and engine data for the calculation of aircraft noise:

(a) Wind: 4 m/s (8 knots) headwind, constant with height above ground
(b) Runway elevation: mean sea level
(c) Runway gradient: none
(d) Air temperature: 15 degrees C (59 degrees F)
(e) Takeoff gross weight: 85 percent of maximum takeoff gross weight
(f) Landing gross weight: 90 percent of maximum landing weight
(g) Number of engines supplying thrust: all

In addition, the variations in atmospheric pressure, density and temperature with altitude are assumed to follow the International Standard Atmosphere (ISA) [2,3].

The above reference conditions correspond approximately to long-term average conditions existing at several major airports around the world.

In principle, the profiles given in this report can be recalculated to fit other atmospheric, airport elevation and aircraft weight conditions using the aerodynamic and engine coefficients provided in this report in conjunction with the SAE AIR 1845 performance equations. One limitation in such applications to non-ISA atmospheric conditions is that engine coefficients given in this report may not provide accurate estimates of engine thrust for non-ISA temperature conditions.

Whenever possible, aerodynamic and engine coefficients were developed in accordance with the SAE AIR 1845 recommendations given above. However, for many older aircraft, performance information over a range of weights and operating conditions was not available. In such cases, coefficients were developed from the best information available. In particular, coefficients for many business jet and propeller aircraft were developed from noise certification information which is based upon takeoff and landing performance at maximum gross weights and an ISA + 10 degree Centigrade atmosphere.

2.6 Reference Conditions for Aircraft Profiles

All takeoff and landing profiles have been calculated for the same recommended reference conditions (International Standard Atmosphere) and assume an 8 knot headwind.

3.0 TECHNICAL BACKGROUND DISCUSSION

3.1 Project Background

As noted earlier, the aircraft profiles presented in this report are based upon the procedures, algorithms and assumptions described in SAE AIR 1845. Many of the profiles in the current INM data base were based on an analytical approach developed by Bolt Beranek and Newman Inc. (BBN) in earlier studies [4,5]. The basic analytic approach and equations are generally similar in either case. And, for similar assumptions regarding aircraft weight, flight procedures and reference atmospheric conditions, the resulting profiles for jet aircraft calculated in accordance with SAE AIR 1845 will be little different from those developed in the BBN studies. The most noticeable difference in assumptions is that the SAE AIR 1845 procedures are based upon an 8 knot headwind, while the BBN procedures assumed no wind conditions.

SAE AIR 1845 requires the derivation of the aerodynamic coefficients from aircraft performance at weights of 85 percent of maximum takeoff weight, and 90 percent of maximum landing weight. The coefficients employed in the earlier BBN studies may not have been derived from performance information at these weights, and hence may differ slightly because of differences in weight assumptions.

3.2 Flight Profile Equations

The development of flight profiles uses basic simplified equations of fixed-wing aircraft performance. Each profile is broken down into a series of segments. By assuming constant conditions for the relevant basic parameters in each segment, the path traveled by the aircraft is described by a straight line between the beginning and end points of the segment. Certain simplifying assumptions are made to ease the calculations and integrate the effect of many of the minute changes in aircraft performance that occur during takeoffs and landings.

The aircraft flight path is divided into segments, each corresponding to one of the following procedures:

(a) Takeoff ground roll;
(b) Climb at a constant speed, aircraft configuration and engine thrust;
(c) Acceleration in flight at a constant aircraft configuration and thrust;
(d) Descent at a constant aircraft configuration and speed;
(e) Deceleration to a stop on the runway upon landing.

The first four procedures are defined in SAE AIR 1845, while deceleration on landing is not.[4]

3.2.1 Takeoff Ground Roll

During takeoff, it is assumed that the airplane uses a specified takeoff-rated thrust to accelerate along the runway until liftoff. Following liftoff, the airspeed is assumed to be constant throughout the initial part of the climbout. The landing gear, if retractable, are assumed to be retracted shortly after liftoff.

The actual takeoff ground-roll is approximated by an equivalent distance along the runway, s_g, from the start of takeoff roll to the point where a straight line extension of the initial landing gear-retracted climb flight path intersects the runway. The equivalent takeoff-roll distance is:

$$s_g = B\theta_{am}(W/\delta_{am})^2/[N(Fn/\delta_{am})] \tag{1}$$

[4] The equations and much of the discussion in the following subsections have been extracted directly from SAE AIR 1845.

where

B is a coefficient appropriate to a specific airplane/flap-deflection combination, and varies only with the takeoff flap/slat setting.

W is the airplane gross weight at brake release.

N is the number of engines supplying thrust.

F_n is the net thrust calculated for the airspeed and engine power settings used during initial climbout.

δ_{am} and Θ_{am} represent the ratios of the ambient air pressure and temperature to the standard-day sea level values, respectively.

3.2.2 Climb

The initial climb airspeed is determined from:

$$V_c = C\sqrt{W} \qquad (2)$$

where

C is a coefficient appropriate to the takeoff flap/slat setting.

W is the brake release gross weight.

When the airplane climbs with a given configuration, flap setting, and calibrated airspeed into an 8-knot headwind, the average geometric climb angle γ is determined from

$$\gamma = \arcsin(1.01\{[N(F_n/\delta_{am})_{avg}/(W/\delta_{am})_{avg}] - R\}) \qquad (3)$$

where

the factor of 1.01 accounts for the increased climb gradient associated with the 8-knot headwind and the acceleration inherent in climbing at a reference equivalent airspeed of 160 knots.

and

R is the non-dimensional ratio of the airplane's drag coefficient to lift coefficient for a given flap setting and airplane configuration. The landing gear is assumed to be retracted.

The distance along the ground track, s_c, that the airplane traverses, while climbing at angle γ to a specified increment in pressure altitude, Δh, above the runway elevation is calculated from

$$s_c = \Delta h / \tan_\gamma \tag{4}$$

For the profiles given in this report climb segments at airspeeds below 200 KCAS are calculated in accordance with equation (3). At higher climb speeds, the following is used [5]:

$$\gamma = \arcsin\ (0.95\ \{[N(F_n/\delta_{am})_{avg}/(W/\delta_{am})_{avg}] - R\}) \tag{5}$$

The average corrected net thrust is determined at the average pressure altitude for the segment. The values of the net thrust and the ratio R are determined for the calibrated airspeed and airplane configuration appropriate for the segment.

In equation (5), the constant in the argument of the arcsin is smaller than that in equation (3) because the effects of acceleration associated with climb at a constant calibrated

[5] SAE AIR 1845 does not make this distinction in choice of equations with airspeed, but selects the equation based on whether the segment is before or after acceleration has occurred.

airspeed and the 8 knot headwind assumption are less at the higher airspeeds.

3.2.3 Acceleration

The horizontal distance, s_a, traversed while accelerating from an initial true airspeed, V_{ta}, to a final airspeed, V_{tb}, and while climbing at a specified average rate-of-climb, V_{tz}, is calculated from:

$$s_a = \frac{(1/2g)\ (0.95)\ (V_{tb}^2 - V_{ta}^2)}{[N(F_n/\delta_{am})_{avg}/(W/\delta_{am})_{avg}] - R_{avg} - (V_{tz}/V_{tavg})} \tag{6}$$

where

g is acceleration caused by gravity for free fall at mean sea level, 32.17 ft/sec^2 (9.807 m/sec^2).

The non-dimensional factor of 0.95 represents the effect of climbing into an 8 knot headwind on the ground-track distance.

and

$(F_n/\delta_{am})_{avg}$, $(W/\delta_{am})_{avg}$, R_{avg}, and V_{tavg} are averages of the values applicable to the conditions and heights at true airspeeds V_{ta} and V_{tb}.

At the beginning of the acceleration, the airplane's pressure altitude is known because it is the same as that at the end of the previous segment. Thus, the values for δ_{am} and σ_{am} are also known at the beginning of the acceleration segment. The pressure altitude, and hence δ_{am} and σ_{am}, at the end of the acceleration segment is unknown. As a consequence, it is necessary to estimate the pressure altitude at the end of the acceleration segment in order to supply corresponding estimates for δ_{am} and

σ_{am}. The calculated height gain is then compared against the estimated height gain to determine if further iteration is needed to improve the accuracy of the calculation.

The gain in height, Δh, relative to the height at the beginning of the acceleration, is calculated from

$$\Delta h = (s_a V_{tz}/V_{tavg})/0.95 \tag{7}$$

The calculated height gain is compared with the estimated height gain, and iteration is employed using the calculated height gain as a replacement for the initially estimated height gain. For the profiles given in this report, reiteration is employed until the calculated height gain is within one foot of the estimated height gain.

3.2.4 Landing Descent

The landing approach airspeed, V_{CA}, is assumed to be 10 knots more than the reference approach airspeed. This assumption allows the approach airspeed to be related to the gross landing weight by:

$$V_{CA} = D\sqrt{W} \tag{8}$$

where the coefficient D is to be evaluated at a landing flap setting.

The equation used to relate glide slope descent angle to airplane and engine parameters is:

$$\gamma = \arcsin(1.03\{[N(F_n/\delta_{am})_{avg}/(W/\delta_{am})_{avg}] - R\}) \tag{9}$$

Equation (9) can be solved for the average net thrust to yield

$$((F_n/\delta_{am})_{avg}) = (1/N)(W/\delta_{am})_{avg}\{R + [(\sin\gamma)/1.03]\} \tag{10}$$

During landing approach, the geometric glide slope descent angle is assumed to be constant at -3 degrees for jet-powered, and multi-engine propeller aircraft, and at -5 degrees for single-engine propeller aircraft.

For the landing profiles given in this report, the engine thrusts that are calculated at points along the landing profile assume a stabilized speed, glide slope and aircraft configuration.

3.2.5 Landing Stop Distance

The landing stop distance is calculated from the published FAR landing field length at maximum landing weight. For 90 percent of the maximum landing weight, the stop distance is estimated as 0.90 times the FAR landing field length at maximum landing weight.

For those aircraft having reverse thrust capabilities, the reverse thrust values are taken as:

Jet aircraft - 60 percent of maximum thrust
Propeller aircraft - 40 percent of maximum thrust

3.3 Engine Thrust Equations

The net thrust is one of the quantities that must be specified at each end of a flight segment. It represents the component of the engine gross thrust that is available for propulsion. It is determined by either the net thrust available when operating at a specified engine rating, or by the net thrust available when a thrust setting parameter (such as the engine pressure ratio (EPR) or engine low pressure rotor speed (N_1)) is set to a particular value. The equations used in this study follow those defined in SAE AIR 1845, except that second order expressions are allowed to account for the variation of thrust with altitude. The equations used are:

For turbojet and turbofan engines, corrected net thrust is defined by:

$$(F_n/\delta_{am}) = E + FV_c + G_a h + G_b h^2 + HT_{am} \tag{11}$$

where

F_n is the net thrust per engine;

δ_{am} is the ratio of the ambient air pressure at the airplane to the standard air pressure at mean sea level, (101.325 kPa or 1013.25 mb for air pressure in kilopascals or millibars);

V_c is the calibrated airspeed;

h is the pressure altitude (height) above sea level at which the airplane is operating;

T_{am} is the ambient air temperature in which the airplane is operating; and

E, F, G_a, G_b and H are constants or coefficients which are determined for a particular engine at rated takeoff and climb thrust.

When the engines are being operated at thrusts other than rated thrust, the thrust developed is a function of the thrust-setting parameter. The expression for net thrust has the following form when engine pressure ratio (EPR) is used to set thrust:

$$(F_n/\delta_{am}) = E + FV_c + Gh + HT_{am} + K_{1a}(EPR) + K_{1b}\ (EPR)^2 \tag{12}$$

where E, F, G, H, K_{1a} and K_{1b} are constants or coefficients which are used to relate the engine pressure ratio to net thrust per engine for a particular engine.

When the engine rotational speed is the parameter used to set thrust (e.g., the rotational speed of the low-pressure compressor), then the expression for net thrust is:

$$(F_n/\delta_{am}) = E + FV_c + Gh + HT_{am} + K_2(N_1/\sqrt{\theta_T}) + K_3\ (N_1/\sqrt{\theta_T})^2 \qquad (13)$$

where:

N_1 is the engine's low pressure rotor speed;

$N_1/\sqrt{\theta_T}$ is the corrected low pressure rotor speed;

θ_T is the ratio of the absolute total air temperature at the engine inlet to the absolute standard air temperature at mean sea level, (288.15 degrees K for air temperature in kelvins). θ_T is closely approximated by $\theta\cdot(1 + 0.2M^2)$;

K_2 and K_3 are derived from installed engine data encompassing the referred shaft speeds of interest; and

M is the aircraft Mach number.

For propeller driven airplanes, corrected net thrust per engine is calculated by:

$$(F_n/\delta_{am}) = (\tilde{n}P_p/V_t)/\delta_{am} \qquad (14)$$

where:

$\tilde{n}$ is the propeller efficiency for a particular propeller installation and is a function of propeller rotational speed and airplane flight speed;

V_t is true flight speed; and

P_p is installed net propulsive power.

For computations with V_t in knots and P_p in horsepower, Equation 14 becomes:

$$(F_n/\delta_{am}) = (325.87\tilde{n}P_p/V_t)/\delta_{am} \tag{15}$$

For the purposes of this study, ñ, the propeller efficiency, was assumed to be a constant (either 0.85 or 0.9). P_p in horsepower was also assumed to be a constant value.

3.4 Calculation Notes

In computing the values of atmospheric pressure, temperature and density ratios for use in the equations given in Sections 3.2 and 3.3, second order regression equations were fitted to the published ratios for the International Standard Atmosphere over the altitude range from sea level to 10,000 feet. The following expressions were used:

Pressure ratio

$$\delta = 1 - (3.5975845 \times 10^{-5})h + (4.762008 \times 10^{-10})h^2 \tag{16}$$

Temperature ratio

$$\theta = 1 - (6.87680 \times 10^{-6})h - (1.09529 \times 10^{-13})h^2 \tag{17}$$

Density ratio

$$\sigma = 1 - (2.9191335 \times 10-5)h + 3.04613 \times 10^{-10})h^2 \tag{18}$$

where h is the aircraft height in feet above sea level.

4.0 FLIGHT PROFILE ASSUMPTIONS

4.1 Takeoff Procedures

An aircraft may be flown in a variety of ways, and takeoffs can follow alternative paths depending upon choices of flap and power settings, rate of climb, speed, and acceleration. For the present study, sets of profiles have been developed using a combination of recommended and practiced procedures.

4.1.1 FAA Recommended Procedure for Civil Jet Aircraft

The current FAA recommended takeoff procedure, designed to reduce the noise impact for all civil jet aircraft in excess of 75,000 pounds takeoff weight, is given in FAA Advisory Circular AC 91-53 [6]. This procedure is depicted in Figure 3 and can be summarized as:

(a) Takeoff and climb at an air speed of V_2+10 to 20 knots until attaining an altitude of 1000 feet above the airport elevation.

(b) Upon attaining this height, accelerate to zero flap minimum safe maneuvering speed while retracting flaps on schedule and reduce thrust. Thrust for high by-pass engines should be reduced to normal climb thrust, while thrust for low by-pass engines should be reduced below normal climb thrust, but not below the minimum thrust as specified under paragraph 25.121(c) of FAR Part 25; "Final Takeoff Engine Out Climb Gradient."

(c) Continue climb, at reduced thrust, and at the zero flap minimum safe maneuvering speed to 3,000 feet above the airport elevation.

(d) Upon attaining 3,000 feet, smoothly initiate a normal climb profile.

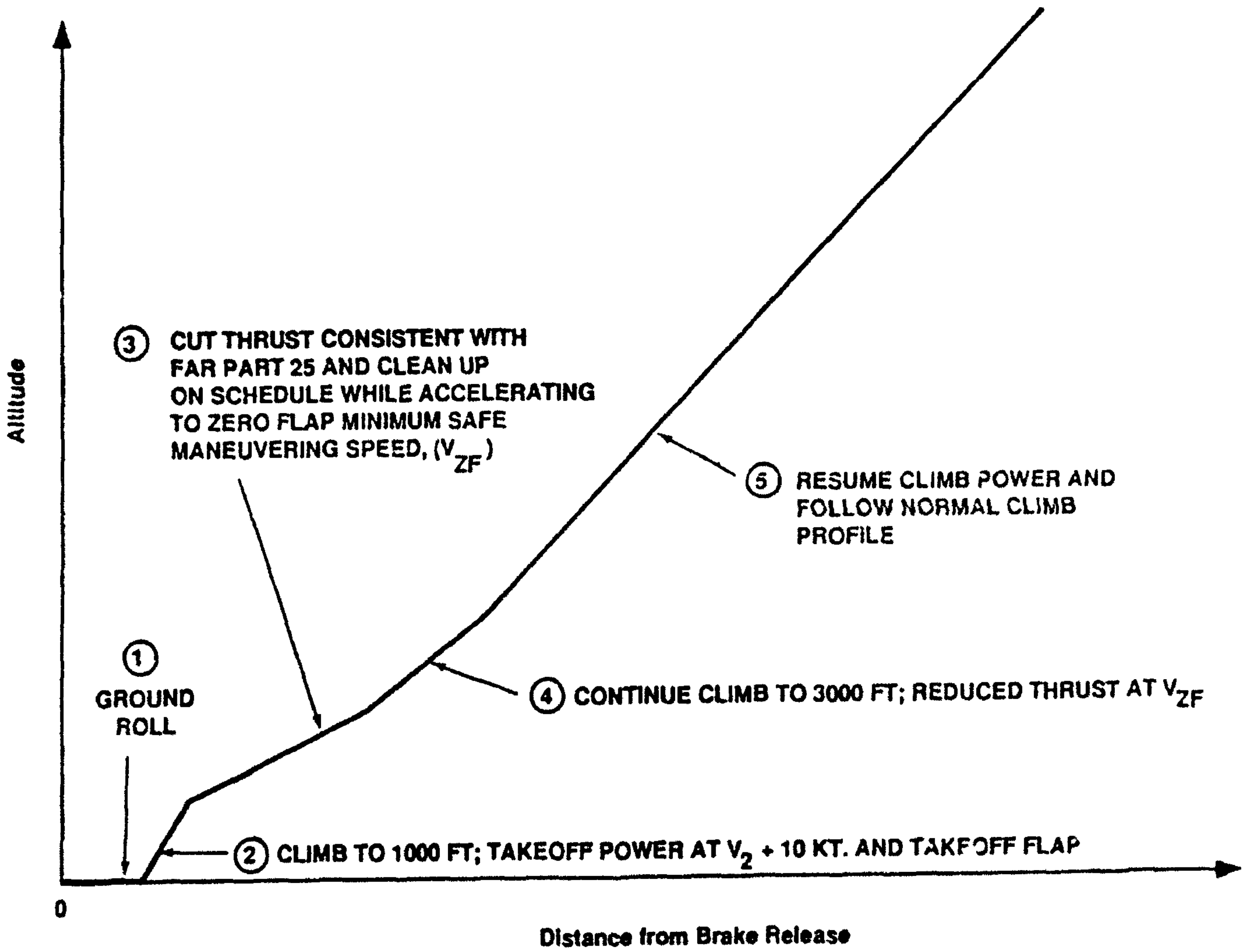

FIGURE 3. FAA AC91-53 NOISE ABATEMENT DEPARTURE PROFILE

4.1.2 BBN Report 4594 Procedures

In applying this basic FAA recommended procedure to develop the takeoff profiles given in Ref 5, a representation of the FAA procedure was employed, as shown in Figure 4 and summarized as follows:

1) Takeoff and climb at V_2+10 knots and takeoff flap to 1000 feet altitude.
2) Accelerate 10 knots at a rate of climb which is 2/3 that calculated for the initial climb.
3) Instantaneously retract the flaps to an intermediate position, and also instantaneously cut the thrust to climb thrust or reduced climb thrust. Then accelerate to zero flap minimum safe maneuvering speed. The rate climb is adjusted as necessary to maintain a reasonable acceleration, but is not less than 500 feet per minute.
4) Upon achieving zero flap minimum safe maneuvering speed, instantaneously retract flaps to clean configuration and climb at constant speed to 3000 feet altitude, or accelerate to an interim climb speed and then climb at that speed to 3000 feet altitude.
5) Upon achieving 3000 feet altitude, instantaneously increase thrust to maximum climb, if it had been reduced to a lesser value for noise abatement, and then accelerate to 250 knots, using a rate of climb typically matched to the initial value chosen under paragraph 2.
7) Upon achieving 250 knots, climb out to 10,000 feet. For the purpose of the calculation, this part of the profile was completed in three segments: to 5,500 feet altitude; 5,500 feet to 7,500 feet altitude; and 7,500 feet to 10,000 feet altitude.

Finally, in recognition that the thrust cannot be changed instantaneously, and so the noise will not change

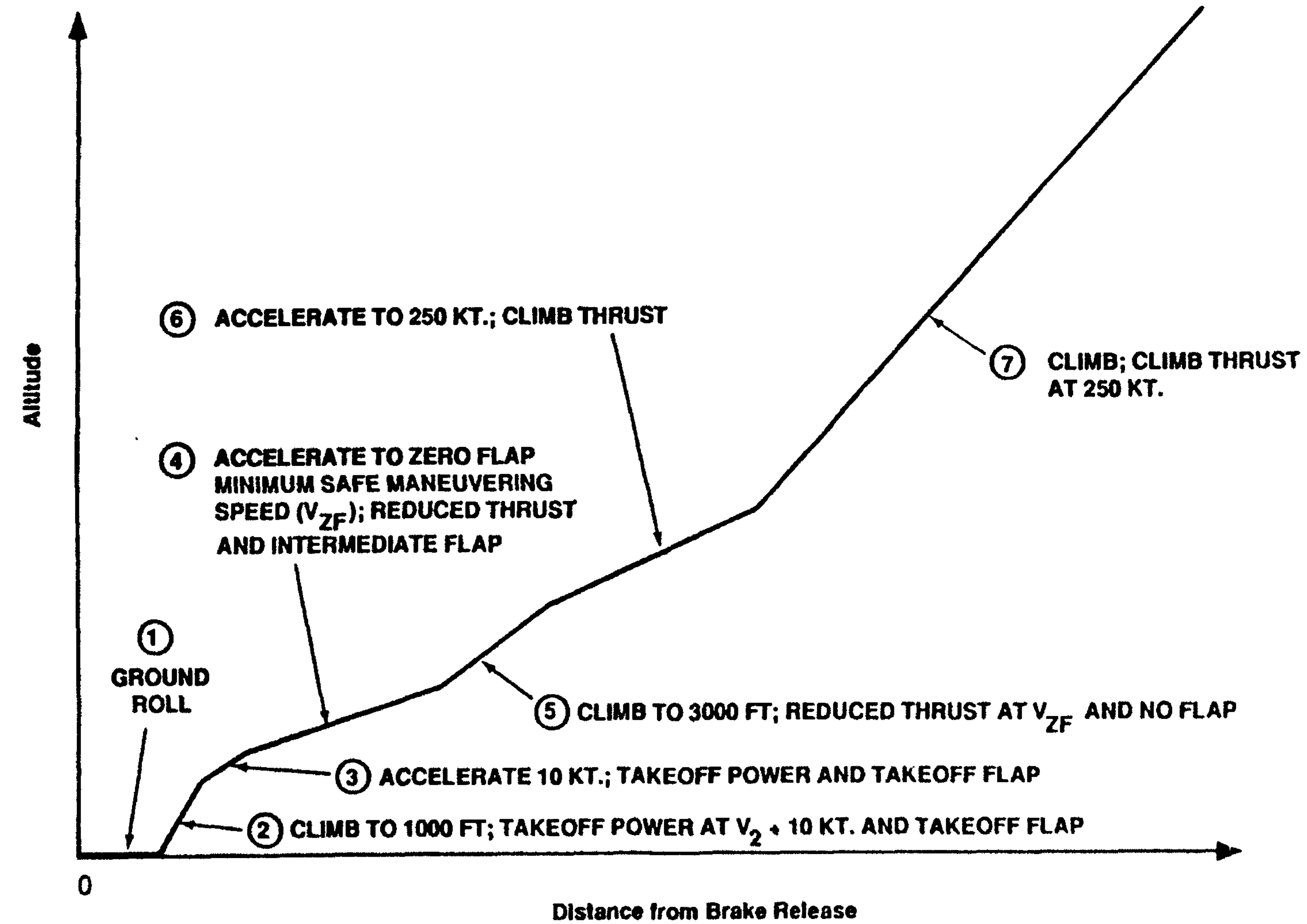

FIGURE 4. REFERENCE 3 DEPARTURE PROFILE

instantaneously, a transition segment of 1,000 feet ground distance was inserted at each thrust change.

4.1.3 Comparisons of Procedures for Jet Transport Aircraft

Comparisons of the profiles given in Ref 5 for major civil jet transport aircraft (notably B727, B737, B747, DC9, DC10 and L1011 aircraft) with flight profiles actually flown at the Seattle-Tacoma Airport [7] showed that the flown profiles were generally significantly higher than the calculated profiles, particularly at distances beyond 3 n. miles (18,000 feet) from brake release[6]. A probable reason for such differences is that the pilots did not reduce thrust as much as specified by FAA AC 91-53. As a result of these comparisons, INM profiles for the DC9, B737 and B727 were revised to be in better agreement with the observed flight profiles. Figures 5 and 6 compare the profiles for a B727-200 as given in Ref 5 and as currently incorporated in INM Version 3.9, Data Base 9. Figure 5 shows the profile as a function of aircraft height versus distance from brake release while Figure 6 plots engine thrust versus distance.

4.1.4 Current Profiles for Jet Transport Aircraft

For the profiles of jet transport aircraft developed in this project, the takeoff procedure used in Ref 5, and outlined above in Section 4.1.2, has been followed, with two major changes or exceptions:

(a) The initial thrust cutback (instituted at intermediate or clean flap configuration) is to **maximum** climb power, not to the minimum thrust that might be allowed under FAA AC 91-53.

(b) Whenever possible (i.e. whenever information is available), takeoff flap settings, flap retraction and thrust reduction

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[6] The differences in takeoff profiles were generally greatest for the low bypass ratio powered (narrow body) aircraft.

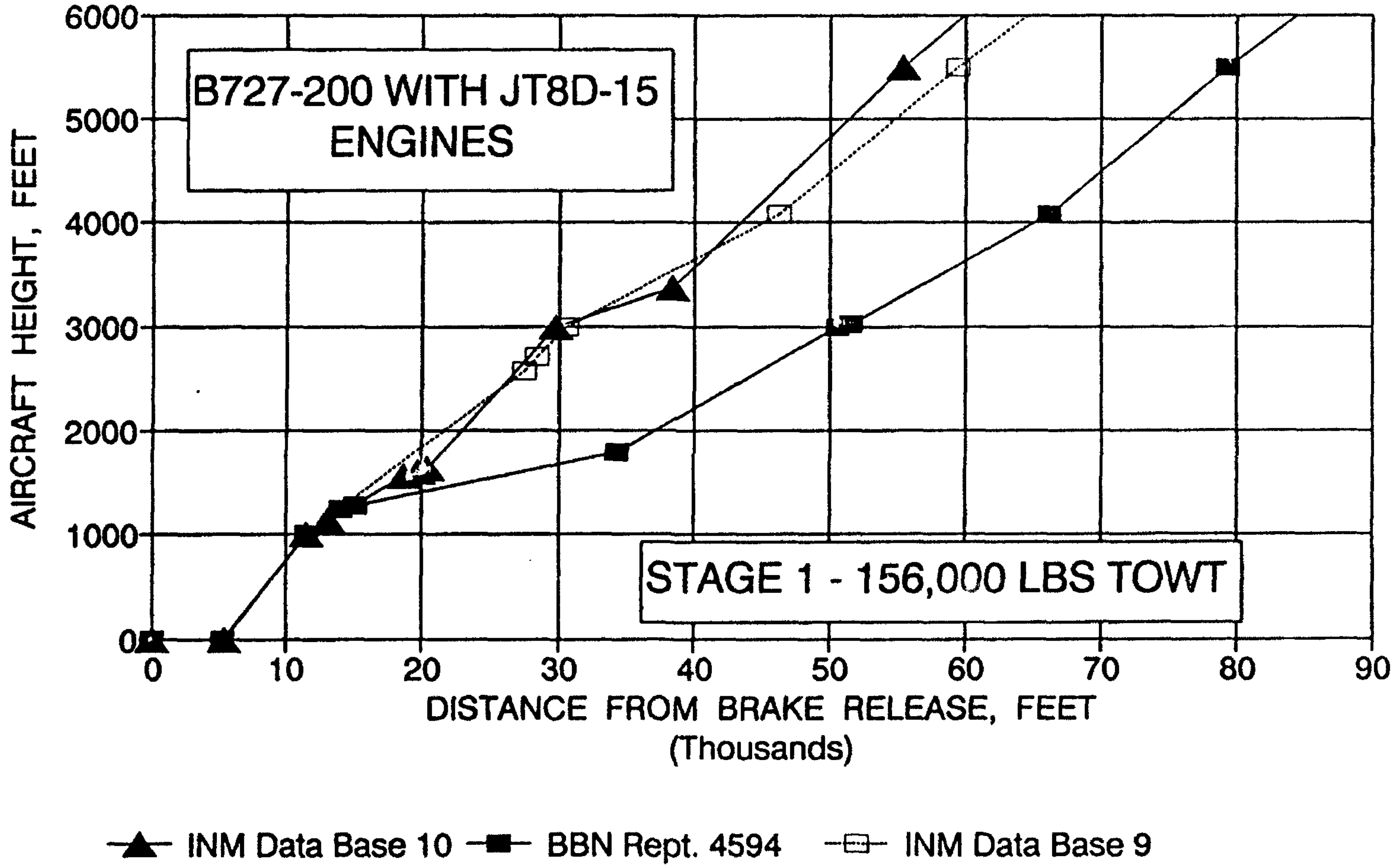

FIGURE 5. COMPARISON OF PROFILES
(HEIGHT VS DISTANCE)

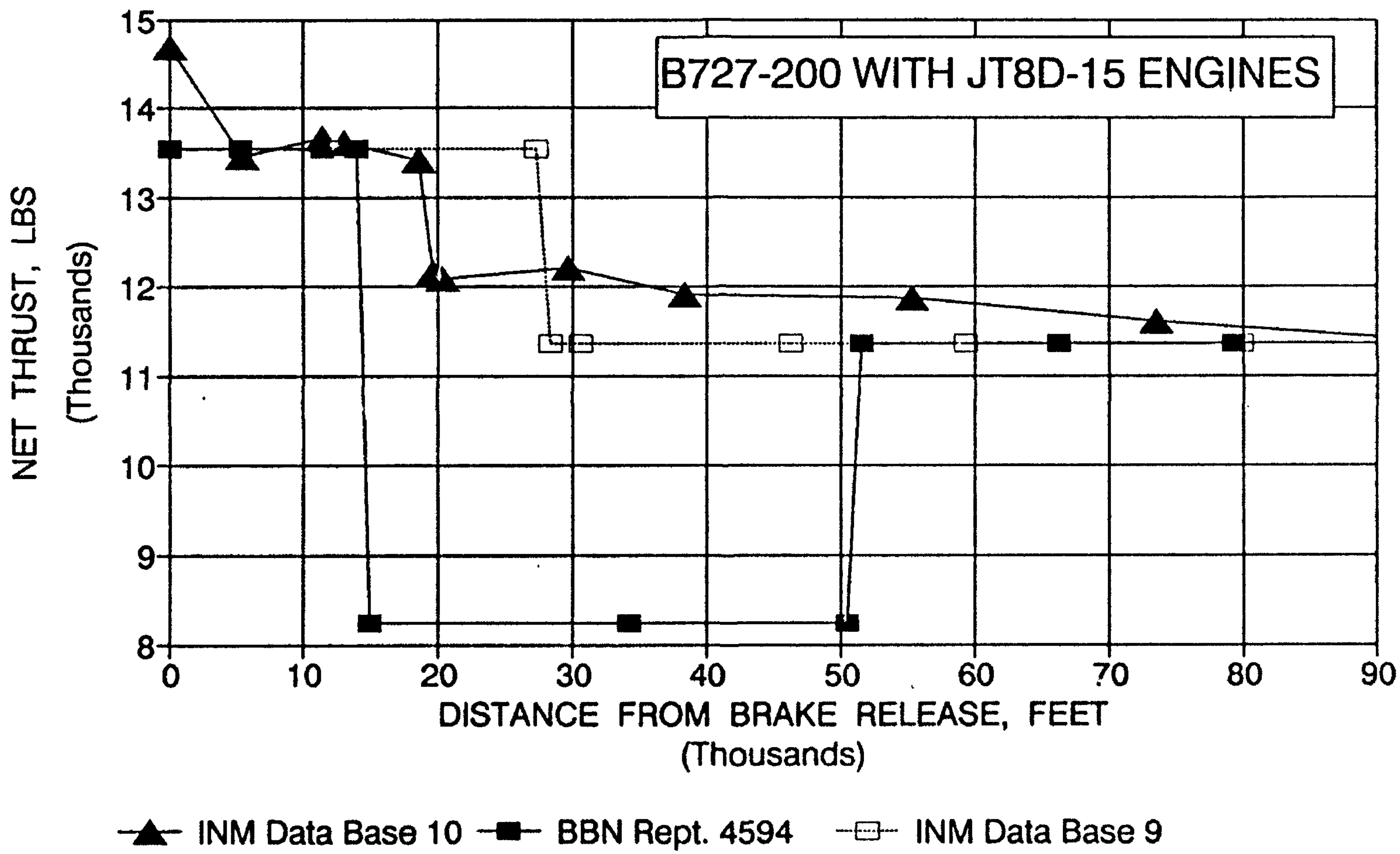

FIGURE 6. COMPARISON OF PROFILES
(THRUST VS DISTANCE)

schedules are based upon information supplied by one or more airlines or the aircraft manufacturer.

Figures 5 and 6 compare a profile developed in this study (INM Data Base 10) with previous profiles (see Section 4.1.3).

In reviewing the transport aircraft profiles developed in this study, several factors should be kept in mind:

(a) Not all airlines follow the same takeoff procedures. For example, airlines may differ in their choice of takeoff flap setting (in addition to any choices in takeoff flaps that may be dictated by local airport conditions);

(b) For most (if not all) of the newer aircraft, takeoff thrust settings are determined by consideration of aircraft takeoff weight, runway length, and airport temperature and atmospheric pressure. The net effect is that many takeoffs are made at less than maximum takeoff thrust in order to conserve engine life and fuel.

4.1.5 Business Jet Takeoff Profiles

All business jet profiles are based upon an approximation of the NBAA (National Business Aircraft Association) noise abatement departure procedures. The major elements of the procedure as used in this study are:

(a) Take off at maximum power and a speed of V_2+10 and immediately climb while accelerating to a speed of V_2+25 knots;

(b) Climb at a constant speed of V_2+25 knots to an height of 1,500 feet;

(c) Retract flaps, accelerate to a speed of V_2+50 knots, and reduce to climb power;

(d) Climb to 3,000 feet;

(e) Upon attaining 3,000 feet, accelerate to 250 knots and continue climb to 10,000 feet.

It should be noted that some business aircraft may use special noise abatement procedures which differ from that outlined above.

4.1.6 Other Aircraft Takeoff Profiles

For aircraft other than the major civil jet and business jet aircraft, the takeoff flight profiles were determined by reference to a variety of sources including manufacturers' data, past measurement programs, noise certification documentation and owner's manuals. The takeoff profiles for the military aircraft were based directly on information provided by the USAF and the aircraft manufacturers.

4.2 Landing Procedures

As noted earlier, the landing profiles assume a constant angle descent from 6,000 feet altitude. The descent angle is 3 degrees for all aircraft except for the smaller propeller aircraft where a 5 degree angle has been assumed. The profile is broken into five segments, with the points defining the segments calculated as follows:

(a) Point 1 - 6,000 feet altitude, zero flaps, gear up, terminal airspeed (taken as 250 knots CAS for jet aircraft);
(b) Point 2 - 3,000 feet altitude, intermediate flaps, gear up, intermediate flap extension speed;
(c) Point 3 - 1,500 feet altitude, approach flaps, gear down, approach flap extension speed;
(d) Point 4 - 1,000 feet altitude, final landing flaps, gear down, final landing speed (typically Vref + 10 knots);
(e) Point 5 - touchdown at zero altitude, final landing flaps and final landing speed;
(f) Point 6 - maximum thrust reverse thrust point. This point is chosen as 10 percent of the distance between touchdown and full stop. Reverse thrust values are taken as 60

percent of the static engine thrust for jet aircraft, and 40 percent of the static power for propeller aircraft;

(g) Point 7 - nominal stop distance from runway threshold. The stop distance is calculated from the published FAR landing distance. The thrust is that for "idle thrust", taken as 10 percent of the rated engine static thrust.

As noted earlier, the thrust values are calculated assuming stabilized aircraft speeds at each point. This results in some over-estimation of engine thrust values at points 2 and 3. The thrust calculations also do not take into account the power needed for internal aircraft systems (air conditioning and anti-icing, for example), hence may under-estimate the engine thrusts at point 1.

Although airline approach procedures may be similar for the same type of aircraft, there is often quite large variability in actual approach flight paths at distances beyond 3 to 4 n. miles (18,000 to 24,000 feet) from touchdown because of variations in the type of procedure flown (visual versus ILS or other instrument approaches), air traffic restrictions and weather. In view of these factors, the simplified approach profile adopted in this study appears to be a reasonable selection for noise modeling purposes.

For many jet transport aircraft, one can choose among several different landing flap settings. The flap settings selected for the profiles in this study were selected on the basis of information provided by airlines or the aircraft manufacturer.

5.0 SOURCES OF DATA

5.1 General

The calculation of takeoff and landing profiles requires two kinds of information, often provided by different sources:

(a) Aircraft performance information, which defines the aircraft performance capabilities and limitations. This performance is expressed through the equations and aerodynamic coefficients defined by SAE AIR 1845. The performance information usually is provided by the aircraft manufacturer either directly, or indirectly, as extracted from performance information generated by the manufacturer;

(b) Information on how the aircraft is flown, i.e., typical operating procedures. This information may often be provided by the aircraft manufacturer. However, major users of an aircraft may operate the aircraft somewhat differently than suggested by the manufacturer. And, in practice, airport limitations, noise abatement considerations, local airport geographic features, weather and air traffic requirements may often dictate variations in operating procedures from airport to airport and from time to time.

5.2 Aircraft and Engine Performance Information

The aircraft and engine performance information for calculating the aerodynamic and engine coefficients comes from a variety of sources. For many newer aircraft, the airframe manufacturers have provided substantial performance information, either directly in the form of coefficients supplied in accordance with SAE AIR 1845, or in the form of detailed performance charts from which the coefficients could be derived with considerable accuracy. For older aircraft, the performance information needed to develop the coefficients is less complete and often is fragmentary. In these instances, the coefficients have been developed from whatever information that can be found, or inferred by comparison with other aircraft of comparable characteristics.

The last column in Table 1 identifies the major sources of the data used to compute the performance information given in Appendix B for each aircraft. These sources are classified as follows:

(A) Information provided by the aircraft manufacturer directly in the form of SAE AIR 1845 coefficients;
(B) Information provided by the aircraft manufacturer in the form of detailed performance tables and charts;
(C) Information provided in the Aircraft Noise Definition Reports prepared by the manufacturers for the FAA [8 to 13];
(D) U.S. Air Force aircraft flight manuals;
(E) Civil aircraft flight manuals or noise certification reports;
(F) AAAI project files.

In addition to the above, a number of more general sources was used to identify aircraft and engine models, aircraft weights and landing stop distances. These sources include various issues of the following publications:

(1) "Jane's All the World's Aircraft";
(2) FAA Advisory Circular 36-1, "Noise Levels for U.S. Certificated and Foreign Aircraft";
(3) "Commercial Aircraft of the World", "Commuter Aircraft Directory", and "Corporate and Utility Aircraft Buyer's Guide", Flight International;
(4) "Aerospace Specification Tables", Aviation Week & Space Technology.

5.3 Aircraft Operating Weights

As noted earlier, SAE AIR 1845 recommends the calculation of aerodynamic coefficients based on performance of the aircraft at 85 percent of maximum gross takeoff weight, and 90 percent of maximum gross landing weight. These recommendations were followed for those aircraft (which include all newer aircraft) for which performance information was available over a range of weights. For older aircraft for which limited performance information was available, these guidelines could not be consistently followed. For those cases where coefficients may have been developed from noise certification test data, the coefficients are based on the aircraft performance at or near maximum takeoff and landing weights.

The takeoff weights for the civil transport aircraft operating over different stage lengths are based upon the following:

(a) The weights given in INM data base version 9 have been used with few changes;
(b) For newer aircraft, the manufacturer's information has been used whenever supplied;
(c) For other aircraft, the weights were based upon comparisons with aircraft of comparable range capabilities.

5.4 Takeoff and Landing Operational Procedures

As discussed in Section 4, there is not complete uniformity in the way aircraft are operated, and many variations in procedures are possible. These variations may or may not result in noticeable differences in the noise received on the ground during takeoff and landing operations. The profiles for civil jet transport aircraft presented in this report are believed to be reasonably representative of the way many aircraft are operated. They do not, however, take into account any airport runway, topographical or noise abatement limitations. In addition to the guidance provided by FAA Advisory Circular AC 91-53 [6], and FAA

Report DOT/FAA/EE-82/10 [7], information provided by aircraft manufacturers and several major U.S. airlines has been used. The several airlines contacted during this project were particularly helpful in furnishing extracts from pilot's training handbooks and in responding to further inquiries regarding specific climb power settings and flap retraction and extension speed schedules.

REFERENCES

1. Society of Automotive Engineers Aerospace Information Report 1845, "Procedure for the Calculation of Airplane Noise in the Vicinity of Airports", March 1986.

2. International Civil Aviation Organization, "Manual of the ICAO Standard Atmosphere", Document 7488/2, 2nd Ed., 1964.

3. National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, United States Air Force, "U.S. Standard Atmosphere, 1976", U.S. Government Printing Office NOAA-S/T 76-1562, October 1976.

4. Galloway, W.J., Mills, J.F. and Hays, A.P., "Data Base for Predicting Noise from Civil Aircraft: Flight Profile Prediction," BBN Report No. 2746R, Project 11150, submitted to the U.S. Environmental Protection Agency, March 1976.

5. Potter, R.C., Mills, J.F., "Aircraft Flight Profiles for Use in Aircraft Noise Prediction Models", BBN Report 4594 (draft), January 1981.

6. U.S. Department of Transportation, Federal Aviation Administration, "Noise Abatement Departure Profile", Advisory Circular AC 91-53, October 1978.

7. Flathers, G.W., "A comparison of FAA Integrated Noise Model Flight Profiles with Profiles Observed at Seattle-Tacoma Airport", DOT Report DOT/FAA/EE-82/10, December 1981.

8. Boeing Commercial Airplane Company, "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 707," Report No. FAA-EQ-73-7, 2, AD A013177, December 1973.

9. Boeing Commercial Airplane Company, "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 727," Report No. FAA-EQ-73-7, 3, AD A013177, December 1973.

10. Boeing Commercial Airplane Company, "Aircraft Noise Definition, Individual Aircraft Technical Data, Model 737," Report No. FAA-EQ-73-7, 4, AD A014964, December 1973.

11. Douglas Aircraft Company, McDonnell Douglas Corporation, "Aircraft Noise Definition, Phase I, Analysis of Existing Data for the DC-8, DC-9 and DC-10 Aircraft," Report No. FAA-EQ-73-5, AD A016278, August 1973.

12. Douglas Aircraft Company, McDonnell Douglas Corporation, "Aircraft Noise Definition, Phase II, Analysis of Flyover-Noise Data for the DC-8-61 Aircraft," Report No. FAA-EQ-74-5, AD A019759, August 1974.

13. Lockheed California Company, Lockheed Aircraft Corporation, "Commercial Aircraft Noise Definition L-1011 Tristar," Report No. FAA-EQ-73-6, AD A012371, September 1974.