TAKEOFF2 Manual,

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TAKEOFF2.FOR is a FORTRAN implementation of a modified approach proposed by Krenkel and Salzman to solve for aircraft takeoff. The original methodology solved the aircraft equations of motion parametrically, whereas this program solves through a time-step integration technique. The methodlology was also modified to calculate Balanced Field Length (BFL) for preliminary design purposes. Balanced field length is often, as here, defined as the distance required to make either a One Engine Inoperative (OEI) takeoff (including obstacle passage) or a braked stop when an engine fails at critical engine failure speed.

Krenkel and Salzman assumed thrust vectoring capability and thrust variation with velocity to create the balance of forces equations on the aircraft during its takeoff run. All necessary input parameters can be obtained from the performance parameters necessary for preliminary aircraft design. Some sources for estimating design parameters are located below.

The program is broken into two, each describing different aspects in a takeoff analysis:

1) Normal Takeoff - From stop to liftoff to passage over a 35ft (11m)obstacle.
2) Balance Field Length calculation - Interative solution to find where the engine can fail so that the distance to perform a OEI takeoff is equal to the distance to brake to a stop.

Each section prints out important times, distances and velocities for the takeoff run. For normal takeoff , incremental time distance and velocity data is output as well.

References

Krenkel, A.R., Salzman, A., "Takeoff Performance of Jet-Propelled Conventional and Vectored Thrust STOL Aircraft", *Journal of Aircraft,* Vol. 5, No. 5, 1968, pp. 429.

Roskam, Jan, *Airplane Design Part 1: Preliminary Sizing of Airplanes*, Roskam Aviation and Engineering Corp., Ottawa, KS, 1989.

Torenbeek, Egbert, *Synthesis of Subsonic Airplane Design*, Kluwer Academic Publishers, Norwell, MA, 1982.

Input Format

The input file to the program (TAKEOFF2.IN) was designed to be self-explanatory and to provide a ready reference to some of the input parameters. The twenty five input parameters (two of which control output) are FORTRAN unformatted input, although 15 spaces have been allocated for each input. As will be noticed, each input line contains a description of the input necessary for that line. Note that all input is in english engineering units, as is the output. A sample input file is included below.

Note: File TAKEOFF1.INB is a blank version of the input file.

```
TEST RUN DC9                 (03/10/93) <- Run Title and Information
.002376900     <- Density of air at takeoff (sl/ft^3)
95000.0        <- Weight of aircraft        (lbs)
1000.          <- Wing area of aircraft     (ft^2)
2.000          <- CLmax - max lift coefficient of the aircraft
0.30           <- CLgrd - lift coeff. for ground run takeoff segment
1.6500         <- CLair - lift coeff. for climb takeoff segment
.080           <- CDgrd - drag coeff. for ground run takeoff segment
0.121          <- CDair - drag coeff. for climb takeoff segment
.025           <- MUgrd - rolling friction coefficient *Note 1*
.3             <- MUbrk - braking friction coefficient *Note 2*
0.0            <- LAMBDA - thrust deflection angle, positive up (rad)
1.1            <- K - stall margin *Note 3*
3.             <- TIME between engine failure and braking (sec) *Note4*
35.            <- OBSHT - height of obstacle (ft) (usu 35 or 50 ft)
0.5            <- PLOSS - fraction of power remaining when engine fails
31450.0        29835.0        28475.0        <- 3 thrusts (lbs) *Note 5*
0.             111.6          334.           <- 3 velocities (ft/s)
1.00           <- TSTEP - time step for incremental output (sec) *Note 6*
3.             <- TROT  - time required for rotation
7              <- Integer for output device *Note 7*
```

Note 1: Rolling friction coefficient is typically:

- Dry concrete/Asphalt - 0.02
- Hard turf/Gravel - 0.04
- Short, dry grass - 0.05
- Long grass - 0.10
- Soft Ground - 0.10 to 0.30

Note 2: Braking friction coefficient is typically:
0.20 to 0.40 with good assumptions being, 0.30 or 0.35

Note 3: Takeoff speed is usually defined as Vto = k * Vstall, where k is the stall margin and Vstall is the aircraft stall speed. k is usually defined as 1.1, although 1.2 is also used, (ie. the takeoff speed is 10% to 20% higher than stall speed).

Note 4: This is the time lag between engine failure and the decision to begin braking.
(by MIL-M-007700B this is 3 sec after failure)

Note 5: These three thrusts are used to calculate a quadratic thrust curve for the aircraft engine. Each thrust should correspond to the velocity below it. For cases with unknown thrust curves a constant thrust can be entered for three different velocities.

Note 6: This is the time step between incremental distance and velocity output points. From experience, 0.25, 0.5 or 1.0 second intervals work well. This time step is only for display purposes as the adaptive differential equation solver will often break the internal step size down to maintain solution integrity.

Note 7: Output destination is specified by the following integers:

- 6 - Sends output to the printer
- 7 - Sends output to a file
- 8 - Sends output to the screen

Note 7: This integer number specifies how many data points will be generated for each curve. For instance, 20 as an input will create 20 points between V=0 and V= Vto for normal takeoff.

Output Format

The program was designed to output a variety of data to satisfy many needs. The output data is divided into three sections:

1) Echo the input case data
2) Output normal takeoff data
3) Output OEI BFL takeoff data

Each section, in turn, is divided into three sections: critical times, distances and velocity output. As can be seen, it is a fairly simple task to modify the data for import to a spreadsheet for graphing.

```
                    TEST RUN DC9                 (03/10/93)

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< CASE INPUT DATA >>>>>>>>>>>>>>>>>>>>>>>>>>>>>

     Gravitational accel. (g)=       32.174(ft/s^2)
     Air density at takeoff  =        0.002(sl/ft^3
     Aircraft weight      (W)=    95000.000   (lbs)
     Aircraft wing area   (S)=     1000.000(ft/s^2)
     Max lift coeff   (CLmax)=        2.000(nondim)
     Ground lift coeff(CLgrd)=        0.300(nondim)
     Air lift coeff   (CLair)=        1.650(nondim)
     Ground drag coeff(CDgrd)=        0.080(nondim)
     Air drag coeff   (CDair)=        0.121(nondim)
     Roll frict coeff (MUgrd)=        0.025(nondim)
     Brake frict coeff(MUbrk)=        0.300(nondim)
     Angle of thrust (LAMBDA)=        0.000   (deg)
     Stall margin         (k)=        1.100(ft/s^2)
     Descision time    (TIME)=        3.000   (sec)
     Obstacle height  (OBSHT)=       35.000    (ft)
     EI pwr remaining (PLOSS)=        0.500 (fract)

THRUST =  31450.000 +    -17.263*V +      0.025*V^2

<<<<<<<<<<<<<<<<<<<<<<<<<<<<< NORMAL TAKEOFF DATA >>>>>>>>>>>>>>>>>>>>>>>>>
```

Time (s)	X-Dist (ft)	X-Vel (ft/s)	Y-Dist (ft)	Y-Vel (ft/s)
0.000	0.000	0.000	0.000	0.000
1.000	4.914	9.818	0.000	0.000
2.000	19.615	19.574	0.000	0.000
3.000	44.040	29.266	0.000	0.000
4.000	78.123	38.889	0.000	0.000
5.000	121.794	48.441	0.000	0.000
6.000	174.980	57.918	0.000	0.000
7.000	237.604	67.318	0.000	0.000
8.000	309.588	76.636	0.000	0.000
9.000	390.849	85.871	0.000	0.000
10.000	481.301	95.020	0.000	0.000
11.000	580.858	104.079	0.000	0.000
12.000	689.429	113.047	0.000	0.000
13.000	806.921	121.921	0.000	0.000
14.000	933.239	130.699	0.000	0.000
15.000	1068.286	139.378	0.000	0.000
16.000	1211.962	147.958	0.000	0.000
17.000	1364.167	156.435	0.000	0.000
18.000	1524.798	164.808	0.000	0.000
19.000	1693.749	173.076	0.000	0.000
20.000	1870.914	181.237	0.000	0.000
21.000	2056.187	189.290	0.000	0.000

22.000	2249.458	197.233	0.000	0.000
23.000	2450.617	205.066	0.000	0.000
24.000	2659.553	212.787	0.000	0.000
24.936	2862.368	219.912	0.000	0.000
27.936	3555.614	242.080	0.000	0.000
28.000	3571.035	242.515	0.014	0.434
29.000	3816.719	248.600	4.282	8.473
30.000	4067.677	252.999	17.637	18.539
30.716	4249.870	254.706	35.000	26.859
Time (s)	X-Dist (ft)	X-Vel (ft/s)	Y-Dist (ft)	Y-Vel (ft/s)

<<<<<<<<<<<<<<<<<<<<<<<<<< NORMAL TAKEOFF SUMMARY >>>>>>>>>>>>>>>>>>>>>>

Rotation Velocity	(Vr)=	219.912	(ft/s)
Liftoff Velocity	(Vlo)=	242.079	(ft/s)
Velocity over obs.	(Vobs)=	256.118	(ft/s)
Rotation Distance	(Xr)=	2862.368	(ft)
Liftoff Distance	(Xlo)=	3555.614	(ft)
Distance to obst.	(Xobs)=	4249.870	(ft)
Rotation Time	(Tr)=	24.936	(s)
Liftoff Time	(Tlo)=	27.936	(s)
Time to obst.	(Tobs)=	30.716	(s)
TOTAL TAKEOFF DIST	(Xto)=	4249.870	(ft)
TOTAL TAKEOFF TIME	(Tto)=	30.716	(s)

<<<<<<<<<<<<<<<<<<<<<<<<<< OEI TAKEOFF SUMMARY >>>>>>>>>>>>>>>>>>>>>>

Critical Velocity	(Vcrit) =	203.830	(ft/s)
Decision Velocity	(V1) =	212.327	(ft/s)
Velocity over obs.	(Vobs) =	256.118	(ft/s)
Critical Distance	(Xcrit) =	2418.157	(ft)
Decision Distance	(X1) =	3042.478	(ft)
Balanced Field Length	(BFL) =	5399.453	(ft)
Critical Time	(Tcrit) =	22.841	(s)
Decision Time	(T1) =	25.841	(s)
OEI Takeoff Time	(TBFL) =	48.333	(s)