

HP-67/97 Program Form

Title MODEL ROCKET PERFORMANCE IV pub Page 1 of 7

Programmer John Garza (3665) Date 03 Nov 2025

Program Description

Program estimates rocket velocity and altitude via numerical simulation. Engine thrust curve data is stored on separate data cards. Up to 9 points (tc1..tc9) are available to define the curve. Thrust values between points are estimated via linear interpolation. Single stage, 2 stage, and clustered configurations may be used. Air density is variable and properly decreases with altitude. In addition, routines were added to calculate parachute descent velocity and air density.

Ascent equations:

$$d_{n+1} = [((T_n - \rho v_n^2 C_D A / 2) / (m_R + m_F) - g) / 2] \Delta t^2 + v_n \Delta t + d_n$$

$$v_{n+1} = [((T_n - \rho v_n^2 C_D A / 2) / (m_R + m_F) - g)] \Delta t + v_n$$

Parachute diameter:

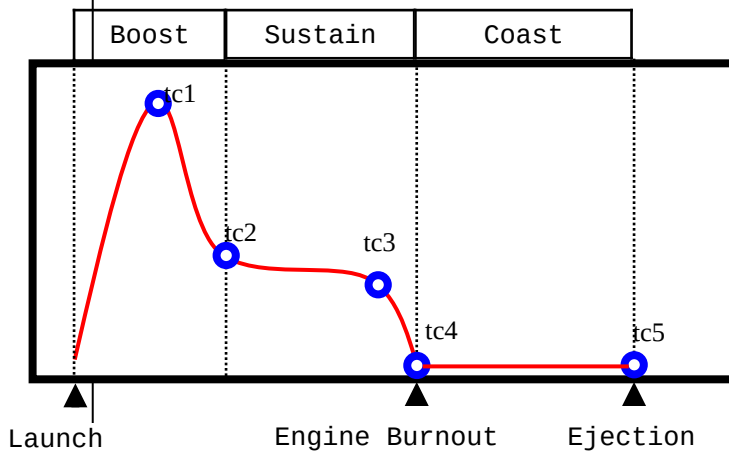
$$D = \sqrt{[(8m_R g) / (\pi \rho C_D v^2)]} \quad \text{Assuming } v=3\text{m/s, } D_{\min} = \sqrt{(30.37m_R)} \quad \{\text{cgs units}\}$$

Terminal descent velocity:

$$V_{\text{term}} = \sqrt{[(8m_R g) / (\pi \rho C_D D^2)]}$$

Air density:

$$\rho_{\text{launch}} = 0.348P / (T_m + 273) \quad \rho_d = \rho_{\text{launch}} / (1 + 0.0001d)$$



where:

T: thrust
 ρ: air density
 v: velocity
 C_D: drag coeff.
 A: frontal area
 m_R: rocket mass
 m_F: fuel mass
 g: 9.807 m/s²
 Δt: time increment
 d: distance
 D: 'chute diameter
 P: pressure (mb)
 T_m: temperature (C)

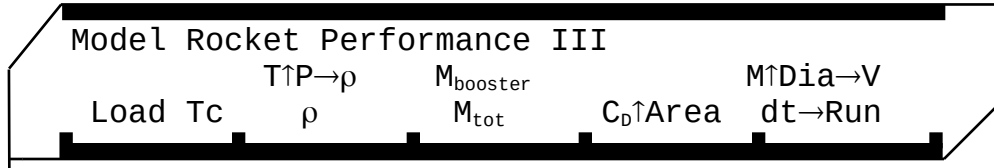
Operating Limits and Warnings

- 1) Run times are long! (several minutes)
- 2) According to Estes TR-11 p.41, it is common to have 5% variation in altitude using A8-5 engines in identical Alpha rockets.
- 3) C_D assumed constant throughout flight (even for 2 stagers).
- 4) C_D=0.75 and ρ=1.22 for parachute calculations as actual results are highly variable due to wind generated lift. (excess accuracy)

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User Instructions				
STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load Program Card, 2 sides			
2	Load Engine Data Card			
3	OPTIONAL: Set pause mode for HP-67 use.		SF 0	
4	Load & Prep Thrust Curve		A	
5	Enter Air Density (typically 1.2 kg/m ³)	density	B	
6	Enter Total Rocket Mass Enter Booster Mass (if any) (all excluding engines)	mass _{tot} (g) mass _b (g)	C f c	
7	Enter Coefficient of Drag and Frontal Surface Area	C _D A (cm ²)	ENT↑ D	
8	Enter time delta, begin run (dt typically 0.01 s)	dt (s)	E	output*
	* output for each segment mission time (s) velocity (m/s) altitude (m)			
	NOTE: In pause mode, use R/S to continue. Do not alter stack contents.			
	Useful routines:			
A)	Determine terminal descent velocity (parachute)	mass (g) dia (cm)	ENT↑ f e	V (m/s)
B)	Calculate air density	T (deg C) P (mb)	ENT↑ f b	ρ (kg/m ³)

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Program Listing							
LINE	KEY CODE	KEY ENTRY	COMMENTS	LINE	KEY CODE	KEY ENTRY	COMMENTS
01		* LBL e		57		9	
02		X ²		58		.	
03		1/X		59		8	
04		X↔Y		60		0	
05		2		61		7	
06		7		62		STO 8	
07		3		63		CLX	
08		x		64		STO 0	
09		x		65		STO 7	
10		√X		66		STO 9	
11		RTN		67		STO 2	
12		* LBL b		68		STO 4	
13		.		69		GTO 6	
14		3		70		* LBL 4	
15		4		71		ISZI	
16		8		72		GSB 1	
17		x		73		STO 2	
18		X↔Y		74		GSB 3	
19		2		75		STO 4	
20		7		76		DSZI	
21		3		77		*LBL 6	
22		+		78		GSB 7	
23		÷		79		GSB 2	
24		RTN		80		RCL 0	
25		* LBL A		81		+	
26		P↔S		82		STO 5	
27		RTN		83		GSB 1	
28		* LBL B		84		STO 1	
29		STO B		85		GSB 3	
30		RTN		86		STO 3	
31		* LBL c		87		RCL 0	
32		EEX		88		* LBL 5	
33		3		89		STO 6	
34		÷		90		RCL 0	
35		STO A		91		-	
36		RTN		92		RCL 5	
37		* LBL C		93		RCL 0	
38		P↔S		94		-	
39		RCL 0		95		÷	
40		P↔S		96		ENT↑	
41		+		97		RCL 4	
42		EEX		98		RCL 3	
43		3		99		-	
44		÷		100		x	
45		STO C		101		RCL 3	
46		RTN		102		+	
47		* LBL D		103		X↔Y	
48		2		104		RCL 2	
49		EEX		105		RCL 1	
50		4		106		-	
51		÷		107		x	
52		x		108		RCL 1	
53		STO D		109		+	
54		RTN		110		RCL 7	
55		* LBL E		111		EEX	
56		STO E		112		CHS	

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Program Listing							
LINE	KEY CODE	KEY ENTRY	COMMENTS	LINE	KEY CODE	KEY ENTRY	COMMENTS
113		4		169		P↔S	
114		x		170		RCL i	
115		1		171		P↔S	
116		+		172		EEX	
117		RCL B		173		3	
118		X↔Y		174		x	
119		÷		175		INT	
120		RCL 9		176		EEX	
121		X ²		177		1	
122		x		178		÷	
123		RCL D		179		RTN	
124		x		180		* LBL 2	
125		-		181		P↔S	
126		X↔Y		182		RCL i	
127		RCL C		183		P↔S	
128		X↔Y		184		EEX	
129		-		185		3	
130		÷		186		x	
131		RCL 8		187		FRC	
132		-		188		EEX	
133		ENT↑		189		2	'3' for S.SS
134		ENT↑		190		x	
135		2		191		INT	
136		÷		192		EEX	
137		RCL E		193		1	'2' for S.SS
138		X ²		194		÷	
139		x		195		RTN	
140		RCL E		196		* LBL 3	
141		RCL 9		197		P↔S	
142		x		198		RCL i	
143		+		199		P↔S	
144		ST + 7		200		EEX	
145		X↔Y		201		5	'6' for S.SS
146		RCL E		202		x	
147		x		203		FRC	
148		ST + 9		204		EEX	
149		RCL 5		205		1	'2' for S.SS
150		RCL 6		206		÷	
151		RCL E		207		RTN	
152		+		208		* LBL 7	
153		X≤Y?		209		EEX	
154		GTO 5		210		P↔S	
155		RCL 5		211		RCL i	
156		STO 0		212		P↔S	
157		PRTX		213		X≤Y?	
158		RCL 9		214		RTN	
159		PRTX		215		RCL C	
160		RCL 7		216		RCL A	
161		PRTX		217		-	
162		SPC		218		STO C	
163		F0?		219		X↔Y	
164		R/S		220		FRC	
165		DSZI		221		P↔S	
166		GTO 4		222		STO i	
167		RTN		223		P↔S	
168		* LBL 1		224		RTN	

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Registers				
0 time	1 NN.N _t	2 NN.N _{t+1}	3 GG.G _t	4 GG.G _{t+1}
5 segment end time	6 segment current time	7 current altitude	8 gravity constant	9 current velocity
S0 engine mass	S1 tc ₉	S2 tc ₈	S3 tc ₇	S4 tc ₆
S5 tc ₅	S6 tc ₄	S7 tc ₃	S8 tc ₂	S9 tc ₁
A booster mass	B air density	C liftoff mass	D C _D *A/2	E dt
I tc index				

Labels				
A load tc	B density	C mass	D C _D ↑Area	E dt→run
a	b calc density	c booster mass	d	e term velocity
0	1 read thrust	2 read time	3 read mass	4 new segment
5 segment loop	6 initial segment	7 staging check	8	9

Flags			
0 pause mode	1	2	3

Set Status	
TRIG MODE	DISPLAY
DEGREE	FIX 2
FLAGS 0 ON 1 OFF 2 OFF 3 OFF	

Historical Notes and References
<p>An eventual culmination of early work predicting model rocket altitudes, starting with the TI-59 and BASIC language simulations. This program employs a rigorous routine good for most model rocket work. NOTE: 13 Dec 2014 Corrected bug in code and adjusted C6 engine data. 02 Nov 2025 Corrected transposed steps in listing documentation.</p> <p>References:</p> <ol style="list-style-type: none"> 1) <u>Handbook of Model Rocketry</u>, G. Harry Stine. 2) <u>Estes Technical Report #10</u>, Estes Industries. 3) <u>Estes Technical Report #11</u>, Estes Industries. 4) <u>Estes Technical Note #1</u>, Estes Industries. 5) <u>NAR Technical Review Vol 4 1979</u>, "A New Approach To Coast Phase Altitude Calculation and the Inclusion of Variable Air Density", Kuechler & Kelley.

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Programmer John Garza (3665) Date 03 Nov 2025

Additional Notes

Data Card Contents

R0: engine mass (including fuel) in grams
RI: number of thrust curve data points
R1-R9: thrust curve data in packed format (last point in R1)

Thrust Curve Data Format

B.NNNSGGG0

B = Staging flag
NN.N = Newtons thrust
S.S = Seconds this segment
GG.G = Cumulative grams
burned

Drag Coefficient Estimates

Estes Alpha rocket:
unpainted, unsanded = 0.98
sanded, painted, sq fins = 0.78
sanded, painted, airfoil = 0.65
Estes Sprint rocket:
expert finish, boat-tail,
airfoil elliptic fins = 0.42

Sample Engine Data Cards:

A8-3

R0: 16.2
R1: 0.000300310
R2: 0.000010310
R3: 0.130020160
R4:
R5:
R6:
R7:
R8:
R9:
RI: 3

B6-4

R0: 20.1
R1: 0.000400620
R2: 0.050040620
R3: 0.050020300
R4: 0.130020120
R5:
R6:
R7:
R8:
R9:
RI: 4

C6-7

R0: 26.9
R1: 0.000701670
R2: 0.000011290
R3: 0.044121250
R4: 0.044020320
R5: 0.130020160
R6:
R7:
R8:
R9:
RI: 5

D12-5

R0: 43.1
R1: 0.000502800
R2: 0.000012490
R3: 0.090102450
R4: 0.090031000
R5: 0.275030500
R6:
R7:
R8:
R9:
RI: 5

3 X C6-5
(cluster)

R0: 76.5
R1: 0.000503750
R2: 0.000013750
R3: 0.132123600
R4: 0.132020960
R5: 0.390020480
R6:
R7:
R8:
R9:
RI: 5

C6-0, C6-7
(2 stage)

R0: 49.6
R1: 0.000702920
R2: 0.000012500
R3: 0.044132450
R4: 0.044021570
R5: 1.130021410
R6: 0.044121250
R7: 0.044020320
R8: 0.130020160
R9:
RI: 8

A3-2T

R0: 7.2
R1: 0.000200350
R2: 0.030050350
R3: 0.030020180
R4: 0.080010070
R5:
R6:
R7:
R8:
R9:
RI: 4

C6-5

R0: 25.5
R1: 0.000501250
R2: 0.000011250
R3: 0.044121200
R4: 0.044020320
R5: 0.130020160
R6:
R7:
R8:
R9:
RI: 5

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Programmer John Garza (3665) Date 07 Nov 2025

Additional Notes

Data Card Contents (3 second times S.SS with old Estes data)

R0: engine mass (including fuel) in grams

RI: number of thrust curve data points

R1-R9: thrust curve data in packed format (last point in R1)

Thrust Curve Data Format

B.NNNSSSGGG

B = Staging flag
NN.N = Newtons thrust
S.SS = Seconds this segment
GG.G = Cumulative grams
burned

Drag Coefficient Estimates

Estes Alpha rocket:

unpainted, unsanded = 0.98

sanded, painted, sq fins = 0.78

sanded, painted, airfoil = 0.65

Estes Sprint rocket:

expert finish, boat-tail,

airfoil elliptic fins = 0.42

Sample Engine Data Cards:

A8-3

R0: 15.5
R1: 0.000300061
R2: 0.000010041
R3: 0.021010039
R4: 0.022010036
R5: 0.025010032
R6: 0.030010027
R7: 0.100010017
R8: 0.050010004
R9:
RI: 8

B6-4

R0: 17.8
R1: 0.000400178
R2: 0.000005065
R3: 0.045040063
R4: 0.045010038
R5: 0.060008030
R6: 0.090004021
R7: 0.120018016
R8:
R9:
RI: 7

C6-7

R0: 24.3
R1: 0.000700151
R2: 0.000002122
R3: 0.045140121
R4: 0.045016037
R5: 0.055006026
R6: 0.148018018
R7:
R8:
R9:
RI: 6

D12-5

R0: 45.7
R1: 0.000500295
R2: 0.000005242
R3: 0.100110239
R4: 0.100010098
R5: 0.120010084
R6: 0.300030058
R7:
R8:
R9:
RI: 6

3 X C6-5
(cluster)

R0: 72.0
R1: 0.000500444
R2: 0.000002366
R3: 0.135140364
R4: 0.135016110
R5: 0.165006078
R6: 0.444018054
R7:
R8:
R9:
RI: 6

C6-0, C6-7
(2 stage)

R0: 45.7
R1: 0.000700273
R2: 0.000005244
R3: 0.045150243
R4: 0.045012156
R5: 1.148018141
R6: 0.045150119
R7: 0.045012032
R8: 0.148018017
R9:
RI: 8

A10-3T

R0: 8.1
R1: 0.000300048
R2: 0.000005035
R3: 0.016055034
R4: 0.016010022
R5: 0.125015013
R6:
R7:
R8:
R9:
RI: 5

C6-5

R0: 24.0
R1: 0.000500148
R2: 0.000002122
R3: 0.045140121
R4: 0.045016037
R5: 0.055006126
R6: 0.148018018
R7:
R8:
R9:
RI: 6

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Additional Notes

Example using 2 digit times data:

Alpha rocket:

C6-5 engine

$\rho = 1.2\text{kg/m}^3$, mass = 34g, $C_D = 0.65$, $A = 4.83\text{cm}^2$, $dt = 0.01$

Results:

0.20 seconds (segment 1, launch to tc1)
35.33 m/s
3.79 m

0.40 seconds (segment 2, tc1 to tc2)
59.94 m/s
13.77 m

1.60 seconds (segment 3, tc2 to tc3, sustaining thrust)
114.08 m/s
124.40 m

1.70 seconds (segment 4, tc3 to tc4, engine burnout)
122.86 m/s (velocity @ burnout)
137.36 m (altitude @ burnout)

6.70 seconds (segment 5, tc4 to tc5, coast to ejection)
10.21 m/s (velocity @ ejection)
380.42 m (altitude @ ejection)

Note:

Velocity at ejection is a bit high. This could possibly damage the recovery system. A better choice would be a C6-7 engine with longer delay to bleed off excess velocity by gaining additional altitude.

