LunarLander2 Program for the HP Prime

By ENS

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This program was based on Jim Storer's 1969 Lunar Lander simulator program that was written in FOCAL 1969. Storer's program is a one dimensional, text-based program that printed a table of the lander's position on a TTL terminal and asked for the fuel burn rate. This LunarLander2 program is also one dimensional, but plots an altitude versus time chart instead of a table, similar to the chart used in Eric Peters' 1973 basic version of Storer's program. At the end of the program, a table is printed on the print terminal with landing comments.

Instructions

To play, run the LunarLander2 program from the toolbox key. After the instructions appear on the screen, press the continue tab. The starting point of the lander is plotted on an altitude versus time chart. The instrument panel is also displayed on the chart. Enter a fuel burn, and press the Enter key. The program plots the new position and asks for the next fuel burn input. Fuel burns must be either 0 for a no burn or a value between 8 and 200 lbs/sec. The program advances the time by 10 seconds. When the lander falls below 8,000 feet, the altitude scale changes from miles to feet.

Comments.

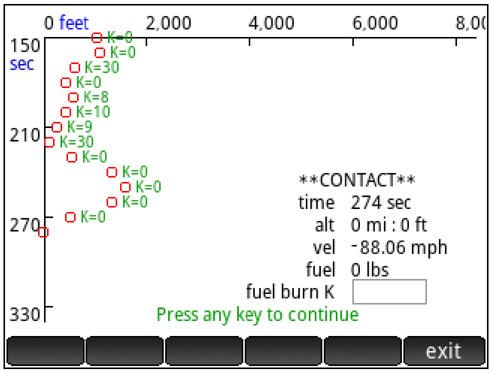
This program uses WAIT(-1) command, and will not run on the G1 physical calculator running software 2.1.14588 (2021 05 05).

This program uses the modern sign convention where downward velocity is negative, and the moon's acceleration constant is negative.

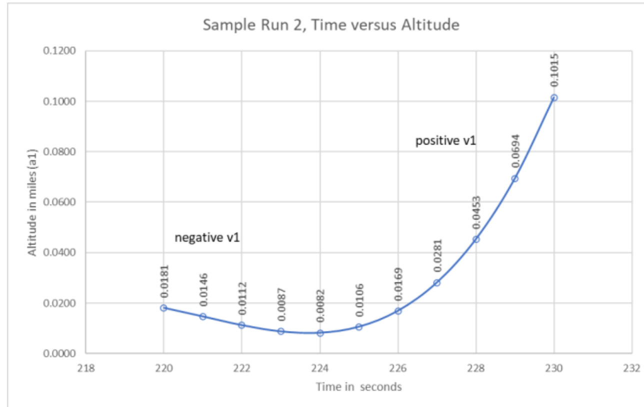
When the lander runs out of fuel, the program will advance the time by 10 seconds and calculate the new velocity and altitude.

Storer used three different equations to calculate $\Delta t1$ that can, at times, return a complex root. This program uses one equation to calculate $\Delta t1$, where thrust is calculated using Storer's advance thrust equation. The advantage of using the latter equation is that it does not appear to return a complex root. When $\Delta t1 < 10$ sec, the equation is solved by successive approximation to compensate for the shortened fuel burn.

This program plays a little differently from Storer's program. When running example 1, the program gives a slightly different landing time due to the use of successive approximation to calculate $\Delta t1$. When running example 2, after the last fuel burn, the lander will rise then fall before landing on the surface.



Display for Sample Run 2



Detail of altitude (a1) from 220 sec to 230 sec for Sample Run 2. Calculated separately on Excel.

This program was revised to use David Hayden's Lunar Lander bug fix by testing for Δt1. Storer's program tested a1, v, and v1 to check to see if the craft has landed. This program checks a1 and Δt1.

References

Jim Storer's 1969 Lunar Lander Game Related Documents web page at www.cs.brandeis.edu/~storer/lunarLander.lunarLander.html. This website contains Jim Storer's FOCAL source code and output from two sample runs. Storer sent this program to the Digital Equipment Computer Users Society, whom acknowledged receipt on Feb. 20, 1970.

Focal Demonstration Programs, Digital Equipment Corporation, 1st printing July 1970, 2nd printing June 1971, pp 19-20. This book included Jim Storer's Lunar Module FOCAL source code (uncredited) and output from a sample run, where key fuel burn rates were blackened out.

Digital Equipment Corporation's promotional handout for FOCAL 1969. This booklet described how to write programs in FOCAL 1969.

101 BASIC Computer Games, Digital Equipment Corporation, 1st Printing July 1973, 2nd Printing April 1974, 3rd Printing, Mar 1975, pp 182-185. This has a BASIC version of Storer's program along with a sample run. The basic version uses 16,500 lbs of fuel instead of 16,000 lbs, so it gives different altitudes and velocities when compared to Storer's FOCAL program. The book also includes a variation of Storer's program, where the lander starts its decent from an altitude of 500 feet, Δt equal to 1 second, and prints an altitude versus time chart. Another variation of Storer's program is 2D and allows one to control the time interval, thrust, and attitude angle.

Lunar Lander Bugs by David Hayden, Datafile, Apr-Sep 2014. This article discusses two bugs in the HP-29C Lunar Lander program and notes how to fix the bugs.

Uncompacted FOCAL Source Code of Jim Storer's 1969 program

```
01.04 T "CONTROL CALLING LUNAR MODULE. MANUAL CONTROL IS NECESSARY"!
01.06 T "YOU MAY RESET FUEL RATE K EACH 10 SECS TO 0 OR ANY VALUE"!
01.08 T "BETWEEN 8 & 200 LBS/SEC. YOU'VE 16000 LBS FUEL. ESTIMATED"!
01.11 T "FREE FALL IMPACT TIME-120 SECS. CAPSULE WEIGHT-32500 LBS"!
01.20 T "FIRST RADAR CHECK COMING UP"!!!;
      E
01.30 T "COMMENCE LANDING PROCEDURE"!"TIME,SECS   ALTITUDE,"
01.40 T "MILES+FEET   VELOCITY,MPH   FUEL,LBS   FUEL RATE"!
01.50 S A=120;
      S V=1;
      S M=32500;
      S N=16500;
      S G=.001;
      S Z=1.8

02.10 T "    ",%3,L,"       ",FITR(A),"  ",%4,5280*(A-FITR(A))
02.20 T %6.02,"       ",3600*V,"    ",%6.01,M-N,"      K=";
      A K;
      S T=10
02.70 T %7.02;
      I (200-K)2.72;
      I (8-K)3.1,3.1;
      I (K)2.72,3.1
02.72 T "NOT POSSIBLE";
      F X=1,51;
      T "."
02.73 T "K=";
      A K;
      G 2.7

03.10 I (M-N-.001)4.1;
      I (T-.001)2.1;
      S S=T
03.40 I ((N+S*K)-M)3.5,3.5;
      S S=(M-N)/K
03.50 D 9;
      I (I)7.1,7.1;
      I (V)3.8,3.8;
      I (J)8.1
03.80 D 6;
      G 3.1

04.10 T "FUEL OUT AT",L," SECS"!
04.40 S S=(FSQT(V*V+2*A*G)-V)/G;
      S V=V+G*S;
      S L=L+S

05.10 T "ON THE MOON AT",L," SECS"!;
      S W=3600*V
05.20 T "IMPACT VELOCITY OF",W,"M.P.H."!,"FUEL LEFT:"M-N," LBS"!
05.40 I (1-W)5.5,5.5;
      T "PERFECT LANDING !-(LUCKY)"!;
      G 5.9
05.50 I (10-W)5.6,5.6;
      T "GOOD LANDING-(COULD BE BETTER)"!;
      G 5.9
05.60 I (22-W)5.7,5.7;
      T "CONGRATULATIONS ON A POOR LANDING"!;
      G 5.9
05.70 I (40-W)5.81,5.81;
      T "CRAFT DAMAGE. GOOD LUCK"!;
      G 5.9
05.81 I (60-W)5.82,5.82;
      T "CRASH LANDING-YOU'VE 5 HRS OXYGEN"!;
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      G 5.9
05.82 T "SORRY,BUT THERE WERE NO SURVIVORS-YOU BLEW IT!"!"IN "
05.83 T "FACT YOU BLASTED A NEW LUNAR CRATER",W*.277777," FT.DEEP.
05.90 T !!!!"TRY AGAIN?"!
05.92 A "(ANS. YES OR NO)"P;
      I (P-0NO)5.94,5.98
05.94 I (P-0YES)5.92,1.2,5.92
05.98 T "CONTROL OUT"!!!;
      Q

06.10 S L=L+S;
      S T=T-S;
      S M=M-S*K;
      S A=I;
      S V=J

07.10 I (S-.005)5.1;
      S S=2*A/(V+FSQT(V*V+2*A*(G-Z*K/M)))
07.30 D 9;
      D 6;
      G 7.1

08.10 S W=(1-M*G/(Z*K))/2;
      S S=M*V/(Z*K*(W+FSQT(W*W+V/Z)))+.05;
      D 9
08.30 I (I)7.1,7.1;
      D 6;I (-J)3.1,3.1;
      I (V)3.1,3.1,8.1

09.10 S Q=S*K/M;
      S J=V+G*S+Z*(-Q-Q^2/2-Q^3/3-Q^4/4-Q^5/5)
09.40 S I=A-G*S*S/2-V*S+Z*S*(Q/2+Q^2/6+Q^3/12+Q^4/20+Q^5/30)
```

Example 1, sample of a play session of Jim Storer’s FOCAL program

```
 G
CONTROL CALLING LUNAR MODULE. MANUAL CONTROL IS NECESSARY
YOU MAY RESET FUEL RATE K EACH 10 SECS TO 0 OR ANY VALUE
BETWEEN 8 & 200 LBS/SEC. YOU'VE 16000 LBS FUEL. ESTIMATED
FREE FALL IMPACT TIME-120 SECS. CAPSULE WEIGHT-32500 LBS
FIRST RADAR CHECK COMING UP


COMMENCE LANDING PROCEDURE
TIME,SECS   ALTITUDE,MILES+FEET   VELOCITY,MPH   FUEL,LBS   FUEL RATE
    0              120      0       3600.00      16000.0       K=:0
   10              109   5016       3636.00      16000.0       K=:0
   20               99   4224       3672.00      16000.0       K=:0
   30               89   2904       3708.00      16000.0       K=:0
   40               79   1056       3744.00      16000.0       K=:0
   50               68   3960       3780.00      16000.0       K=:0
   60               58   1056       3816.00      16000.0       K=:0
   70               47   2904       3852.00      16000.0       K=:170
   80               37   1474       3539.86      14300.0       K=:200
   90               27   5247       3140.80      12300.0       K=:200
  100               19   4537       2710.41      10300.0       K=:200
  110               12   5118       2243.83       8300.0       K=:200
  120                7   2284       1734.97       6300.0       K=:200
  130                3   1990       1176.06       4300.0       K=:200
  140                0   5040        556.96       2300.0       K=:190
  150                0   1581     -   97.44        400.0       K=:0
  160                0   2746     -   61.44        400.0       K=:0
  170                0   3383     -   25.44        400.0       K=:0
  180                0   3492         10.56        400.0       K=:0
  190                0   3073         46.56        400.0       K=:0
  200                0   2126         82.56        400.0       K=:0
  210                0    652        118.56        400.0       K=:20
ON THE MOON AT   214.03 SECS
IMPACT VELOCITY OF   102.10 M.P.H.
FUEL LEFT:   319.47 LBS
SORRY,BUT THERE WERE NO SURVIVORS-YOU BLEW IT!
IN FACT YOU BLASTED A NEW LUNAR CRATER    28.36 FT. DEEP
```

__Example 2, sample of a play session of Jim Storer's FOCAL program__

TRY AGAIN?
(ANS. YES OR NO):YES
FIRST RADAR CHECK COMING UP

COMMENCE LANDING PROCEDURE

TIME,SECS	ALTITUDE,MILES+FEET		VELOCITY,MPH	FUEL,LBS	FUEL RATE
0	120	0	3600.00	16000.0	K=:0
10	109	5016	3636.00	16000.0	K=:0
20	99	4224	3672.00	16000.0	K=:0
30	89	2904	3708.00	16000.0	K=:0
40	79	1056	3744.00	16000.0	K=:0
50	68	3960	3780.00	16000.0	K=:0
60	58	1056	3816.00	16000.0	K=:0
70	47	2904	3852.00	16000.0	K=:170
80	37	1474	3539.86	14300.0	K=:200
90	27	5247	3140.80	12300.0	K=:200
100	19	4537	2710.41	10300.0	K=:200
110	12	5118	2243.83	8300.0	K=:200
120	7	2284	1734.97	6300.0	K=:200
130	3	1990	1176.06	4300.0	K=:200
140	0	5040	556.96	2300.0	K=:170
150	0	1040	- 21.21	600.0	K=:0
160	0	1087	14.79	600.0	K=:0
170	0	606	50.79	600.0	K=:30
180	0	436	- 27.90	300.0	K=:0
190	0	581	8.10	300.0	K=:8
200	0	425	13.17	220.0	K=:10
210	0	253	10.30	120.0	K=:9
220	0	96	11.11	30.0	K=:100

FUEL OUT AT 220.30 SECS
ON THE MOON AT 226.12 SECS
IMPACT VELOCITY OF 21.36 M.P.H.
FUEL LEFT: 0.00 LBS
CONGRATULATIONS ON A POOR LANDING

Partial flow chart of Jim Storer's 1969 program with annotations

In Storer's program, downward velocity is positive and the moon's gravity constant is also positive.

```
03.10 I (M-N-.001)4.1;                              if f<0
      I (T-.001)2.1;                                if t<0
      S S=T                                         ?
03.40 I ((N+S*K)-M)3.5,3.5;                         if fuel burn > f
      S S=(M-N)/K                                   calc Δt1
03.50 D 9;                                          do group 9 (calc v1, a1)
      I (I)7.1,7.1;                                 if a1<=0
      I (V)3.8,3.8;                                 if v<=0

      I (J)8.1;                                     if v1<0

03.80 D 6;                                          do group 6 (update values)
      G 3.1                                         go to 3.1


group 6 update values
06.10 S L=L+S;                                      time counting upwards by Δt
      S T=T-S;                                      time counting downwards by Δt

      S M=M-S*K;                                    set total mass = total mass - fuel burn
      S A=I;                                        set a = a1
      S V=J                                         set v = v1


group 7 calc Δt1
07.10 I (S-.005)5.1;                                if Δt <0
      S S=2*A/(V+FSQT(V*V+2*A*(G-Z*K/M)))           calc Δt1

07.30 D 9;                                          do group 9 (calc v1, a1)
      D 6;                                          do group 6 (update values)
      G 7.1                                         go to 7.1 (successive approx.)


group 8 calc Δt1
08.10 S W=(1-M*G/(Z*K))/2;
      S S=M*V/(Z*K*(W+FSQT(W*W+V/Z)))+.05;          calc Δt1
      D 9                                           do group 9 (calc v1, a1)
08.30 I (I)7.1,7.1;                                 a1<=0?
      D 6;                                          do group 6 (update values)
      I (-J)3.1,3.1;                                if -v1<=0
      I (V)3.1,3.1,8.1                              v<=0?, v>0?


group 9 calc v1,a1                                  uses advanced thrust equation
09.10 S Q=S*K/M;
      S J=V+G*S+Z*(-Q-Q^2/2-Q^3/3-Q^4/4-Q^5/5)
09.40 S I=A-G*S*S/2-V*S+Z*S*(Q/2+Q^2/6+Q^3/12+Q^4/20+Q^5/30)
```

text out (print landing report)

quit (end program)