L.E.M SIMULATOR 2.0

Contents

I- Introduction

Lunar Excursion Module Simulator 2.0

Welcome to the LEM Simulator, the most advanced lunar lander simulator for Palm/Treo devices!

Lunar Excursion Module or LEM for short was the name of the lander used by Apollo astronauts to land on the Moon nearly 40 years ago!

Unlike past versions of lunar lander game, this is NOT an arcade game. Extensive research has been employed to provide you with the most realistic simulation of a moon landing on a PDA. As with other sophisticated flight simulators the challenge will be in perfecting your skill. Remember, astronauts didn't learn to land on the moon in a day and neither can you.
We hope this user manual will help you make the most of your gaming experience.

A quick note about version 2.0 versus 1.0

For some of you who are already familiar with version 1.0, this new version has many major new features which we hope you will like. Here a quick list of them:

- Cockpit view! You now can see the Moon surface move under your lander.
- In addition to the Moon, you now can land on any solar system planet
- The game auto-save so you can quit the app and finish the mission later
- The lander sub-systems failures are now less frequent and so less predictable. You can even disabled the failures and pilot a perfect lander.
- You can set your own initial conditions like starting altitude or fuel level.

These new features will be described in more details in this user manual.

We appreciate your purchase and thank you very much for the support.

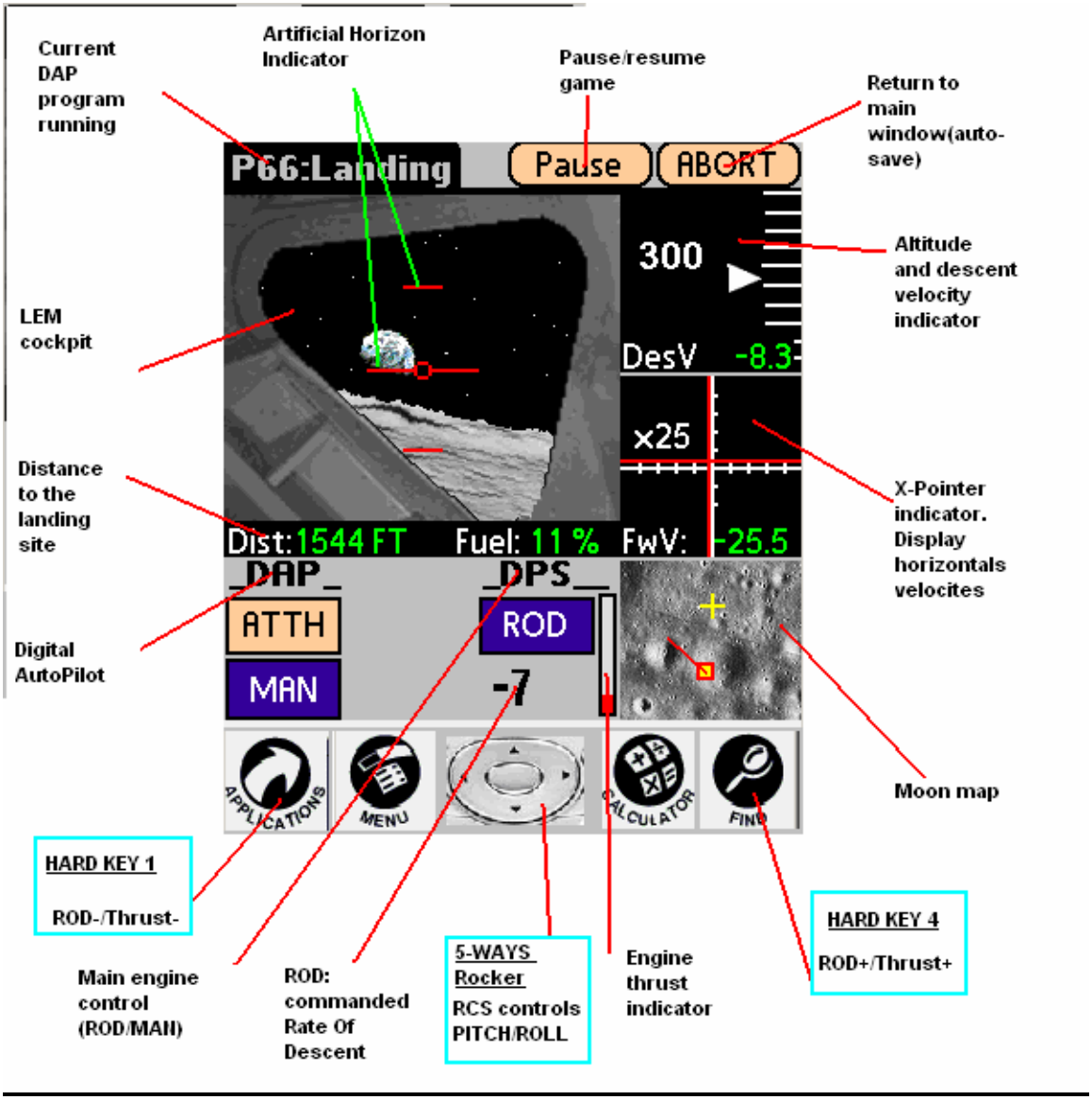
Enjoy!

The developer.

II- LEM controls/instruments description

Before you can attempt your first landing, let's review your LEM Simulator controls and instruments. If you need more detailed descriptions of the lander controls/instruments, please see section VI of this guide.

Here the LEM cockpit display:



LEM Sim instruments and indicators

1) **Current DAP computer program running**

   a. **P64 Approach:** is one of the on-board computer (DAP) program. "P64" will be displayed on top left of the screen during the approach phase to the moon. P64 starts at about 8000 feet. During P64, the on-board computer controls the rate of descent (ROD). During this phase, you can only control the lander attitude (pitch/roll) using the 5-Ways rocker at the center of your Palm device (see below for more details)

   b. **P66 Landing:** is the DAP program used during the final landing phase (below 500 feet). The computer basically gives up control of the rate of descent but keeps the direct control of the engine thrust. During this phase, you will need to control your lander rate of descent so you don't crash! Hard key 1-4 are used to control the rate of descent. Lander attitude is controlled by the 5-Ways rocker at the center of your Palm device (see below for more details)

2) **Altitude Tape:** Display your current altitude from your landing radar.

3) **Descent Velocity:** or DesV, shows how fast the LEM is dropping toward the moon surface. Negative number means you are going down; positive number you are going up. This data is also coming from your landing radar.

4) **X-Pointer**: Displays your horizontal velocities. The red horizontal line shows your forward speed. Your forward speed is also displayed at the bottom of the X-Pointer indicator (FwV). Two cases:

- A negative value for FwV means you are traveling forward and the red horizontal line will be shown above the center of the X-Pointer indicator.

- A positive value for FwV i means that you are traveling backward and the red horizontal line will be shown below the X-Pointer center.

The vertical red line shows your lateral (left/right) velocity. If you are going left then the red vertical line will be to the left of the center scale, if you are going right then the red vertical line will be shown to the right of the center scale. The farther the red lines are from the center, the faster your are going (Vertical line: left/right and Horizontal line = forward/backward). The X-

pointer has also an automatic scale (X25 and X1). If any of your horizontals speed is higher than +/- 25 feet/second then the X25 scale will be shown. To land safely, you will need the X-Pointer to show the X1 scale. Once you are slow enough (scale=X1) then a small white will be displayed at the center of the X-pointer. That small box shows the max touchdown speed both for forward and lateral speed(+/- 10 feet/sec). To land safely, the intersection of the two red lines needs to be inside that white small box at touchdown.

5) **Artificial Horizon**: Use the moon (or planet) horizon and the center red scale bars on the cockpit window to judge your lander current attitude angles (pitch/roll). If the horizon is lower than the center line then you are pitching up (or back) and if the horizon is higher than the red center bar then you are pitching down (or forward). The two other shorter bars indicate maximum pitching angles for the lander (+/- 45 degrees)

6) **Engine Thrust Gauge**: Displays current engine thrust (0-100%).

7) **DPS:** Stands for Descent Propulsion System. Essentially the main descent rocket engine. The DPS mode is normally set to ROD during the all flight. ROD stands for Rate Of Descent. Basically it is represent the commanded descent velocity. If the DAP (see next) is in semi-automatic mode (ATTH) the ROD is controlled by the computer. If the DAP is in manual mode (MAN) then ROD is controlled by you (Hard key1-4) and the ROD number will be displayed under the ROD button.

8) **Digital Auto Pilot :** Or DAP is the LEM on-board computer. You can toggle between two DAP modes:

   i. ATTH – (or Attitude Hold) In this mode the computer controls the Rate Of Descent (ROD). This is the normal mode during the approach phase or P64. You will only need to worry about your lander attitude (pitch/roll) the computer will deal with the rest.

   ii. MAN – In this mode, you control both the lander attitude and rate of descent. This is the normal mode during the final landing phase or P66.

9) Digital Map: Shows the LEM position on the moon surface. There is two maps. One when your lander distance to the landing site is farther than 10000 feet. In this first map, the yellow box is the general area where the landing site is and you will need to steer your lander toward the center of that box. Once you are less than 10000 feet from the landing site then another map will be displayed and it will show you a closer view of the

planned landing site (blinking yellow cross). The red box represents the lander and the line coming out of it represents your velocity vector (basically where the LEM is heading). The end of the line coming out from the lander represents where you will be in the next 30 seconds if you keep the same horizontal velocities.

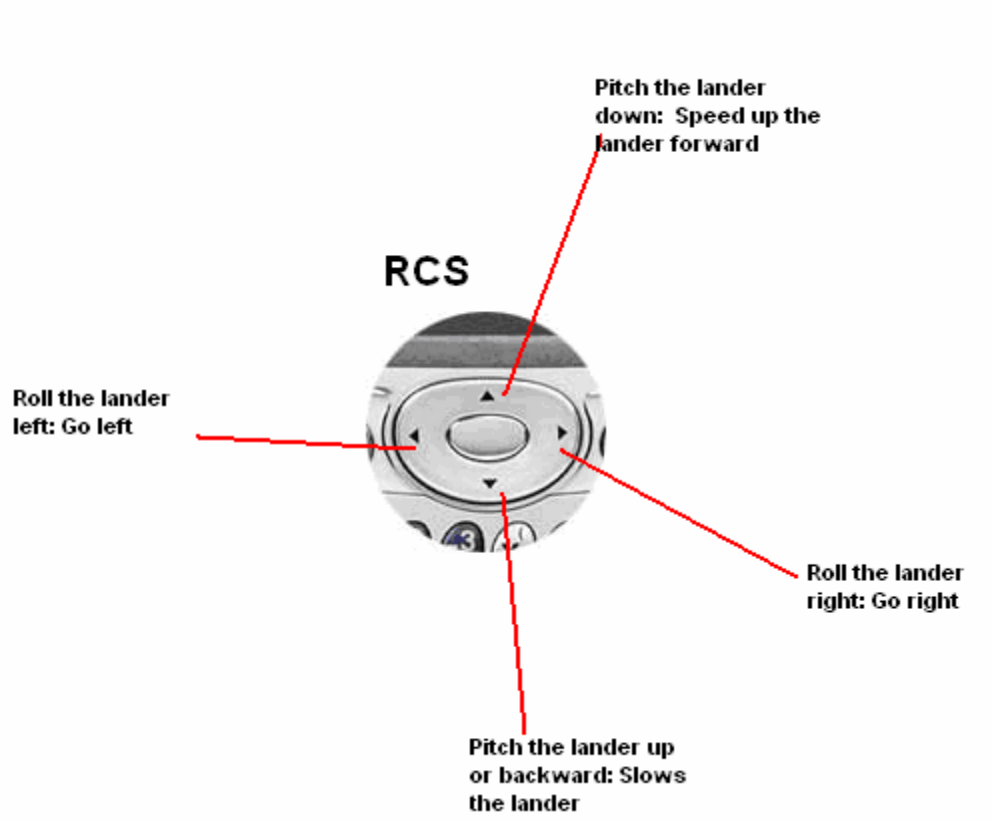
10) **Master Alarm:** This normally invisible button/indicator appears to alert you to a LEM malfunction. The alarm sound can be turned off by pressing this button once (the malfunction will continue of course)

Main engine (DPS) and thrusters control (RCS)

Thrusters control (RCS):

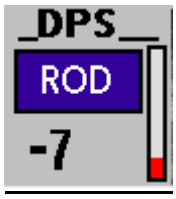
RCS stands for Reaction Control System and it is basically your attitude thrusters. You control your lander attitude (pitch and roll) using Palm/Treo 5-ways navigator pad as a joystick. On the moon, you control the movement and direction of your lander by basically tilting the LEM forward,backward,left or right. By doing so, you are vectoring (directing) the main rocket engine force to help you either slow or speed up your movement in any direction you choose. So for instance, during the initial descent, the lander is pitch backward (up) about 30 degrees so the lander rocket nozzle is facing a little bit forward. The force of the engine is fighting your initial forward movement (- 80 feet/second). The end results is that your lander will slow down progressively until hopefully you reach the landing site with more or less zero forward speed.

If on the other end you pitch the lander forward (pitch down) then the engine nozzle will face backward and the engine thrust will push your lander forward. This is additional acceleration of course will add to your initial velocity and so you will speed up. So if you pitch your lander up and/or down correctly, you can precisely control where in the moon you will land. Hopefully as close as possible to the planned landing site!



Note: If your device does not have a 5-ways navigator pad then use the UP/DOWN buttons to pitch up or down your lander. Then use Hard Key 2-3 to roll left or right. Hard Key 2-3 are usually located on both side of the center UP/DOWN buttons.

Main Engine controls (DPS)



The lander engine thrust (or rate of descent) is controlled by the Hard Key 1 and 4. Hard Key 1/4 actions will depend on the DPS engine mode.

<u>If DPS mode is set to ROD (normal mode):</u>

Then you are requesting a rate of descent (ROD) In return the computer will throttle the main engine (DPS) to try to match your request. In this mode you do not control the engine throttle directly.

Hard key 1: Increases your descent velocity by 1 feet/sec (you drop faster)
Hard key 4: Slows your descent velocity by 1 feet/sec (you slow down)

** The negative number shown under the ROD button (here – 7) is your requested (or commanded) rate of of descent (ROD) in feet/sec.

If DPS mode is set to MAN:

In this manual mode, you are controlling the engine thrust directly.

Hard keys 1 and 4 will then have the following actions:

- Pressing Hard Key 1 will reduce your engine thrust by 1%
- Pressing Hard Key 4 will Increase your engine thrust by 1%

** This mode was never actually used by the Apollo astronauts during the moon landings (other than during training in the simulator!). It is a difficult mode because you have to monitor your current descent speed (FwV) very carefully in addition to all the other things you need to worry about ,like lander attitude, direction and fuel level to name a few. In short you risk to experience information overload! Another problem is that since you have a limited amount of fuel, controlling the main engine manually is not very efficient to fly the lander fuel wise and you so risk to run out of fuel. Of course because this mode is very challenging, you will get a lot of bonus points if your use this mode (you get extra points only below 500 ft altitude). We suggest to switch to this mode only after you mastered the game fully. Again it is challenging but a lot fun too!

IMPORTANT: Unfortunately hard keys 1-2-3-4 locations are devices depended. Hard keys are functions keys that are used to launch Palm/Treo applications such as Calendar, Memo and so on. Hard key 1 is the first button located on the left side of the device and hard key 4 on the right of the device. Here a list of Palm devices and their hard keys location/function. If your device is not listed then you will need to experiment a little to find out which function keys increase/decrease the ROD number displayed during the descent.

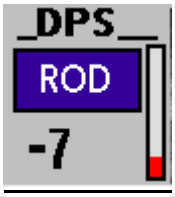
Here a short list of devices and their hard keys default functions:

Palm TREO 650:
Hard key 1= Red ON/OFF button
Hard Key 4= Phone dial green button

Palm Tungsten C:
Hard Key1= Calendar button
Hard key 4= Web button

Palm LifeDrive:
Hard key 1= Home button
Hard Key 4= Files button

Commanded ROD: Commanded Rate of Descent. If you are below 500 feet altitude (P66 phase) or if you switch the DAP to manual mode, a number indicating the current requested descent rate will appear under the DPS mode button. For instance the "-7" in the figure below means you are requesting a rate of descent of -7 feet/sec. You can adjust that number by pressing on the hard key 1 or hard key 4. If the DAP mode is set to ATTH then the number will not appear (because it then controlled by the computer internally).



Note that the requested rate of descent (ROD) is different from the displayed DesV value which is the actual lander descent rate. The computer will try to match those two numbers by automatically adjusting the engine thrust for you.

Of course because of the lander always changing weight (as fuel is spent during the descent) the computer is constantly changing the engine thrust (as seen on the DPS thrust gauge moving up and down) to try to match your requested rate of descent.

← Actual descent rate

If there is a malfunction of the DAP then the DPS will be switch to MAN(manual). In that case you will have no other solution but to control the main engine DIRECTLY (also with hard keys 1-4). Be aware that in this mode, the lander is very difficult to fly and so you will get extra bonus points for that.

III- Quick Start Guide

Now that you familiarized yourself with your lander controls and instruments, it is time to take the LEM for a ride!

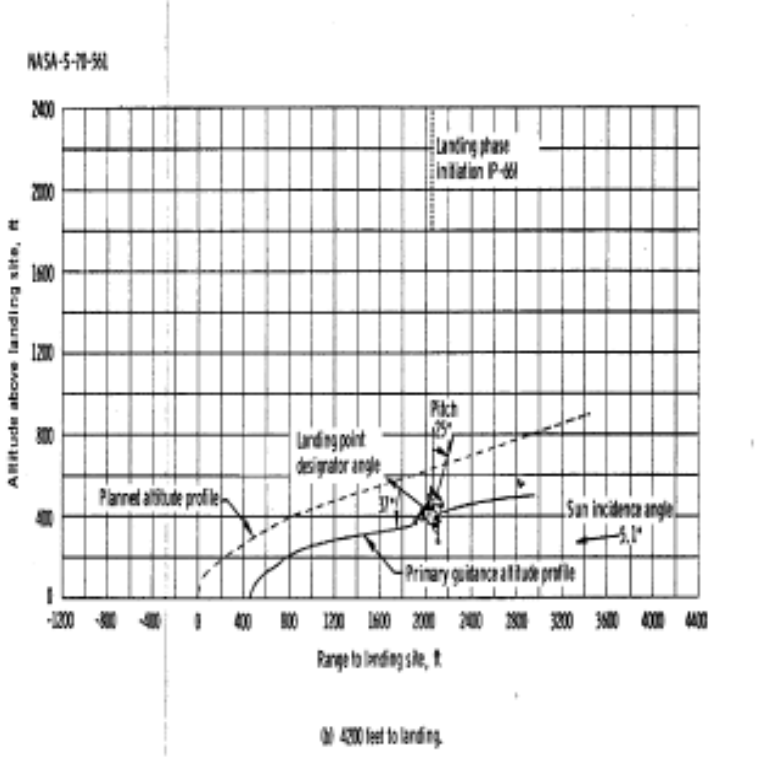
The goal of the game is to:

- land on the surface of the moon (or planet) as softly as possible,
- as close to the NASA planned landing site as possible
- with the LEM upright, and
- with as much fuel as possible in the tank.

All these variables will be taken into account for your final score. In addition, using manual mode for the engine (DPS mode set to MAN) during the descent will add bonus points to your total. We strongly suggest that you do not attempt to set the DPS mode to manual for your first flight!

A) Landing Phase Mission

The default mission in LEM Simulator is the final landing phase also called P66 (see flight plan trajectory below). You lander is about 500 feet from the moon surface and about 3000 feet from the landing site. You are pitching up (back) about 25-30 degrees. This means that your main engine is slowing your descent down (about -17 ft/sec initially) but also slowing your forward velocity (initially about -80 ft/sec).



1- Launch the application by clicking on the LEM Sim icon:

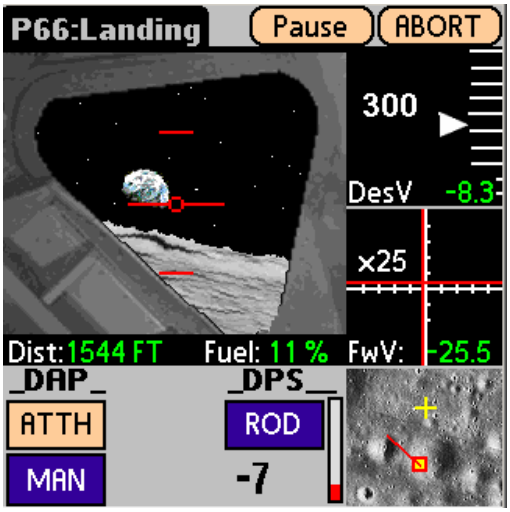
Note: You can access a much shorter version of this user manual directly on your Palm by tapping on the **i** icon on the top right of the main screen.

Here are your starting conditions

The default mission is the “Landing Phase”. You can change LEM Sim game options like mission type, game and sound levels by using the drop down menu on the main screen. The game starts with the following initial conditions:

- game level: Rookie Pilot
- Sound Level: 50%
- Altitude: 500 ft
- Rate of descent: -8 ft/s
- Forward velocity: - 80 ft/s
- Lateral velocity: 0 ft/s
- DAP mode = MAN (manual mode)
- Program running : P66 (landing phase)
- DPS engine mode= ROD
- Fuel level: 12%

2- Press the “New” button to start a new mission



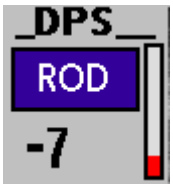
3- The LEM cockpit above will be displayed and you will hear CapCom (the **Cap**sule **Com**munication officer in Houston) say "**You are go for landing,over"**

4- At any time during the descent, you can abort the mission and come back to the main screen by pressing the **ABORT** button on the top right of the screen. The mission will auto-save. You can go back to where you left off later (Resume button) or start a new mission (New button). To exit the game you either need to abort or pause the game and then exit the app by pressing the HOME button on your Palm/Treo. You can also pause the game at anytime.

5- The DAP mode will be in "MAN" mode which means that you are in control of the descent rate(manual mode)

Digital AutoPilot (DAP)

6- During the mission, your first job is to reduce your descent velocity (DesV) to less than 10 feet/sec when you reach the ground.



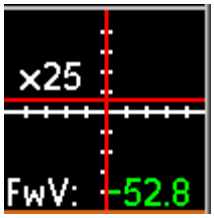
← **Requested Rate of Descent**

7- To reduce (slow) your descent speed, click on Hard key 4. To increase it press hard key 1. You can monitor the requested rate by watching the negative number which is displayed under the button ROD. Note that you lander cannot go up (at least when the DPS is in ROD mode). The ROD number can only be negative (going down) or zero which means that you are hovering (zero descent rate). Please note that hovering (ROD=0) is very costly in fuel (twice as much as when ROD is<0.

IMPORTANT: The actual descent speed of the lander is displayed in the altitude indicator box as DesV. ROD is the commanded rate (what you want the rate to be).

← Actual descent rate

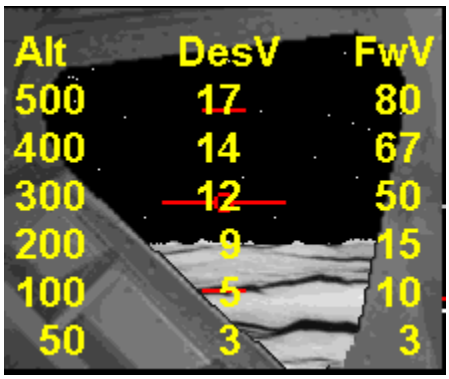
8- During this landing, your second job is to reduce your horizontal speed (forward speed: FwV around zero feet/sec) at touchdown. To change your forward velocity, you will need to pitch your lander up or down. You do this by using the 5-ways rocker on your device. Pitching up will reduce your forward speed, pitching down will increase it. Each click on the pad will change the lander attitude about +/- 5 degrees. During this P66 phase, the LEM computer will limit your pitch and roll angles to +/- 30 degrees (+/- 45 degrees during P64). Use the X-pointer instrument to judge your forward (moving red horizontal line) velocity. Since your initial lateral velocity is zero, there is no need to worry about lander roll angle at this time (a different story when in Pilot or Commander game level modes!). The X-Pointer has two scales. X25 is for horizontal velocities (forward and lateral) higher than +/- 25 feet/seconds. X1 is for velocities lower than +/- 25 feet/sec. The switch between scales are done automatically for you. To land safely, you will need to be in scale X1.



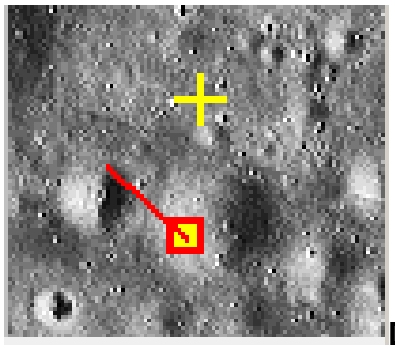
X-pointer

9- DO NOT reduce your forward velocity to around zero too fast or you will take too long to make it to the landing site risking a crash for lack of fuel. Use your initial forward velocity (-80 ft/s) to your advantage and adjust your pitch to arrive at the landing site (yellow cross) with a velocity of about zero.

10- At any time during the flight, you can access your flight plan by tapping your finger on the moon picture (tap again to turn off). The flight plan shows you a realistic descent and forward velocities for specific altitudes. Apollo astronauts used a similar table to judge whether or not they were following the nominal descent trajectory. You can leave the table displayed during the all flight if you wish.



Flight plan


Digital Map

11- Again you can adjust your rate of descent during P66 anyway you want but your chance of landing softly will greatly depend on how much fuel you have left (critical while in Pilot or Commander game level). If you have plenty, you can afford to go down slowly most of the way. If on the other end your are short on fuel then you better increase your rate of descent to conserve fuel and only at the last minute slow your lander rate of descent. Again hovering (setting the ROD=0) is extremely costly in terms of fuel. If you can limit your ROD setting to negative numbers (i.e: - 1 ft/sec)

12-You can land anywhere but of course the closer your are to the planned landing site indicated by the green box the better. If you land more than 3,000 feet from the landing site (see your radar distance indicator on the bottom left of the cockpit view Dist:2813 FT) then you will not receive points for accuracy. If you do not crash, you will still get points for touchdown velocities, fuel left and so on. Just not for accuracy. Of course it is better to land far away from the landing site than to crash. So if you do not have enough fuel to reach the landing site then by all means just

land where you can. Also watch your attitude (pitch/roll angles) at touchdown.

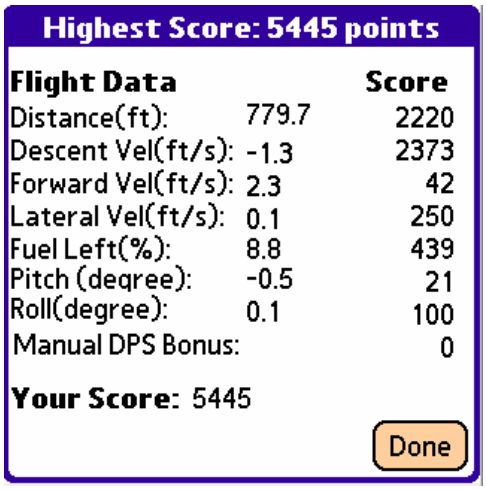
13- When your altitude is below 6 feet, the contact light will turn on indicating that you are very close to the surface and you will hear CapCom say "**contact light!**" The engine will automatically shut off once your are below 1 feet from the moon surface. That's will be the end of your mission.

14- At touchdown, You will make a successful landing if:

- all your velocities are below **+/- 10 feet/sec**
- AND your attitude (pitch/roll angles) are below **+/- 15 degrees**

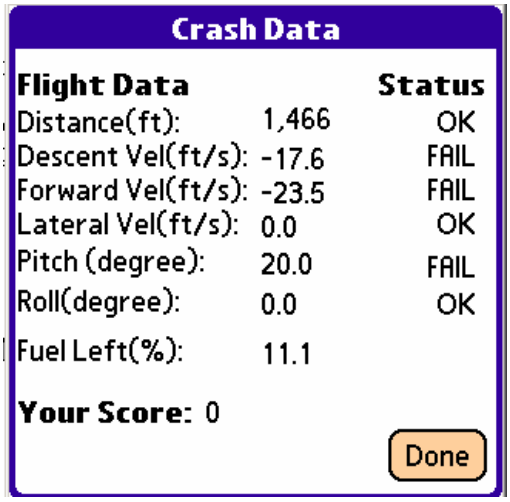
Anything else will be considered a fatal crash. Of course the softer you land the higher your score will be.

15- If you successfully landed, you will be presented with your score. Which also displays the highest score achieved to date:



If you unfortunately crash, then a "crash data" window will be displayed providing you information on what went wrong! In the example below,

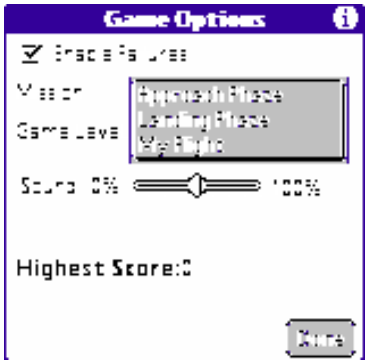
1- You descended too fast (DesV= -17.6 ft/sec, max is -10 ft/sec)
2- You also were moving too fast forward (FwV=-23.5 ft/sec, max is -10 ft/sec)
3- And finally your lander was not upright enough (pitch angle= 20 degree, max is +/- 15 degrees)



So use this “crash data” information to do better next time!

B) Approach Phase Mission

This mission, also called P64, is the phase just prior to the final landing phase. You can access this mission by selecting “approach phase” from the options window (mission).



In this phase, the goal is to reach the moon surface from a much higher starting altitude of about 8000 ft. Your forward speed is also much higher (-400 ft/sec). Once you reach about 500 ft altitude, the computer will switch to the landing phase (P66) and then the rest of the descent will follow the “landing phase” steps described earlier.

<u>Here are your starting conditions for the approach phase mission</u>

- game level: Rookie Pilot
- Sound Level: 50%
- Altitude: 8000 ft
- Rate of descent: -150 ft/s
- Forward velocity: - 400 ft/s
- Lateral velocity: 0 ft/s
- DAP mode = ATTH (semi-manual mode)
- Program running : P64 (approach phase)
- DPS engine mode= ROD
- Fuel level: 18%

1- Press the “New” button to start a new mission

2- The LEM cockpit will again be displayed and you will hear CapCom (the **Cap**sule **Com**munication officer in Houston) say “**You are go for landing, over”**

3- The DAP mode will be in “ATTH” mode this time which means that the computer is in charge of your descent rate. You only have to

worry about your forward velocity and lander direction (pitch control) using the 5-ways as a joystick.

4- Using the flight plan (tap on the cockpit screen to see it) and your pitch controls (5-ways UP/DOWN) try to arrive at about 500 feet altitude with a forward velocity of about -80 ft/sec. Pitching up (back) will slow you down, pitching down will speed you up.

5- Since your initial lateral speed is zero (left/right) you will not need to worry about the roll control. The lander is heading directly to the landing site.

6- The landing site is somewhere in the center area of the yellow rectangle. Once your distance to the landing is lower than 10000 ft then the digital moon map (bottom right of the screen) will zoom in to your landing site. There you will see a blinking yellow cross. That's your planned landing site. Aim toward that blinking cross.

7- Continue to monitor your forward velocity (FwV) and distance to the landing site.

8- Once you cross the 500 feet level, you will hear NASA CapCom say "P66". That's your indication that you have started the final landing phase.

9- The DAP computer mode will switch to MAN (manual) and the ROD number will be displayed. This means that the computer have just given you the manual control of the lander rate of descent.

10- The rest of the mission is similar to the "landing phase mission" steps described earlier.

IV- Game Levels and missions

Currently in LEM Sim, you have a choice of three game levels:

Rookie Pilot Level

In this first level:

1. The LEM sub-systems failures are disabled
2. The landing site location is always the same
3. Initial conditions are always the same for each mission, altitude, velocities, etc.
4. the fuel depletes more slowly than at other levels

This level was specifically designed to allow you the time to concentrate on developing your skills with the lunar lander controls and indicators rather than focusing on fuel level or LEM malfunctions.

LM Pilot Level

This intermediate (Lunar Module Pilot of LMP) level feels more like the real thing. All initial conditions are different on each mission. This includes:

1. fuel level
2. landing site location
3. initial velocities and altitude

In addition, there is a likelihood that some of your lander subsystems would fail during the descent to the moon. Some of those failures are recoverable. One example is a leak in the fuel tank developed during the descent. This will of course reduce the amount of fuel available for landing requiring you to land quickly.

Other failures may be fatal. For instance, if the main descent engine shuts down for too long then NASA may as well name a new crater after you! Please note that most sub-system failures last only for a few seconds but some can last up to a minute or more (especially in game level three). LEM sub-system failures will happen randomly during your descent while in game level 2 or 3 realistically providing you with a new mission each time.

LM Commander Level

This level is not for the faint of heart. Initial conditions can vary much more and failures will happen much more frequently and last longer. To add to an already difficult level, the fuel will deplete faster than in the two first levels which will force you to watch that fuel gauge more closely. While you may want to start with this level we strongly suggest you master the lower levels of this game first.

There are also two missions you can choose from and a third special mission called MyFlight. Here a quick description of the first two missions. The special MyFlight mission is also described below:

Landing Phase Mission

This is the game default mission. This mission simulate the last few minutes of the moon landing. In this mission, your LEM initial conditions are:

- game level: Rookie Pilot
- Sound Level: 50%
- Altitude: 500 ft
- Rate of descent: -8 ft/s
- Forward velocity: - 80 ft/s
- Lateral velocity: 0 ft/s
- DAP mode = MAN
- Program running : P66 (landing phase)
- DPS engine mode= ROD
- Fuel level: 12%

Approach Phase Mission

This mission simulate the approach phase of a moon landing which starts around 8000 feet. Once you reach 500 feet altitude, the system will automatically switch to the "landing phase" program (P66). Your LEM initial conditions for the approach phase are:

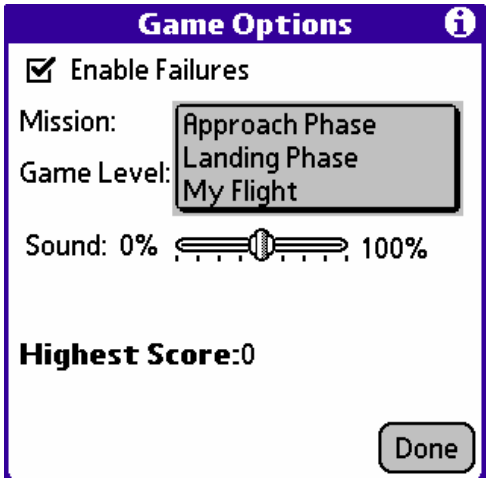
- game level: Rookie Pilot
- Sound Level: 50%
- Altitude: 8,000 ft
- Rate of descent: -160 ft/s
- Forward velocity: - 470 ft/s
- Lateral velocity: 0 ft/s
- DAP mode = ATTH
- Program running : P64 (approach phase)
- DPS engine mode= ROD
- Fuel level: 18%

MyFlight mission

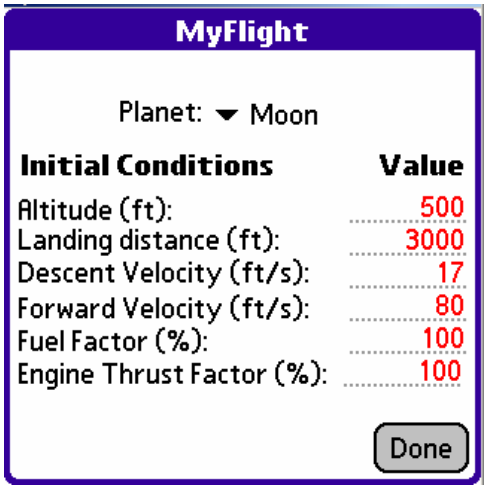
This is not really a mission but a way for you to keep the game interesting even after you master the two above missions. **MyFlight** basically allow you to set

your own initial conditions like starting altitude, fuel level and so on. You can even set the planet you want to land on! Here the step to take in order to set your own initial conditions.

1- Change the mission to "**MyFlight**" in the Game Options window



2- Open the "**MyFlight**" window (in the menu under Options)



3- Select the planet and set any initial conditions you wish to use.

Please note the following:

1- The forward and descent velocities are assumed to be negative values. This means that you do not need to enter any sign (+ or -) before those numbers (actually you can't because the game only accept number input)

2- For the "fuel level factor", you will need to enter a percentage of the default value. So for instance if you want to start a mission with twice as much fuel than the default (whatever it is) then you need to enter the number 200. This means 200% of default value (X2). If you want to challenge yourself, you can try landing on half of the default fuel. In this case you will enter 50 (as in 50%) in this fuel factor box.

3- Same as apply to "engine thrust factor". For instance if you need too boost the lander engine five times the default max thrust then enter the number 500. Which means 500% or X5.

IMPORTANT NOTE

Why would you need to boost the lander engine thrust? A good example is Jupiter. The gravity force is so high that if you simply set the planet to "Jupiter" and attempt to land with your regular lunar lander engine thrust (default value) you will crash in less than 10 seconds even if you increase the engine thrust to max value! This is of course because the lunar lander engine was only designed to land on the moon with its weak gravity force.

An opposite example is trying to land on the planet Pluto. Again if you simply choose MyFlight mission and set the planet to "Pluto" you will not be able to land! You will have the opposite problem. The default lunar lander engine thrust even set at minimum will be too strong to let you land and you will never be able to reach the ground (at least until your fuel is completely depleted). Of course it is because Pluto gravity is even weaker than the Moon. For weaker gravity level than the moon then you will need to reduce the engine max thrust by typing a number lower than 100. For instance if you to cut your engine max thrust by half then just type 50 (as in 50%).

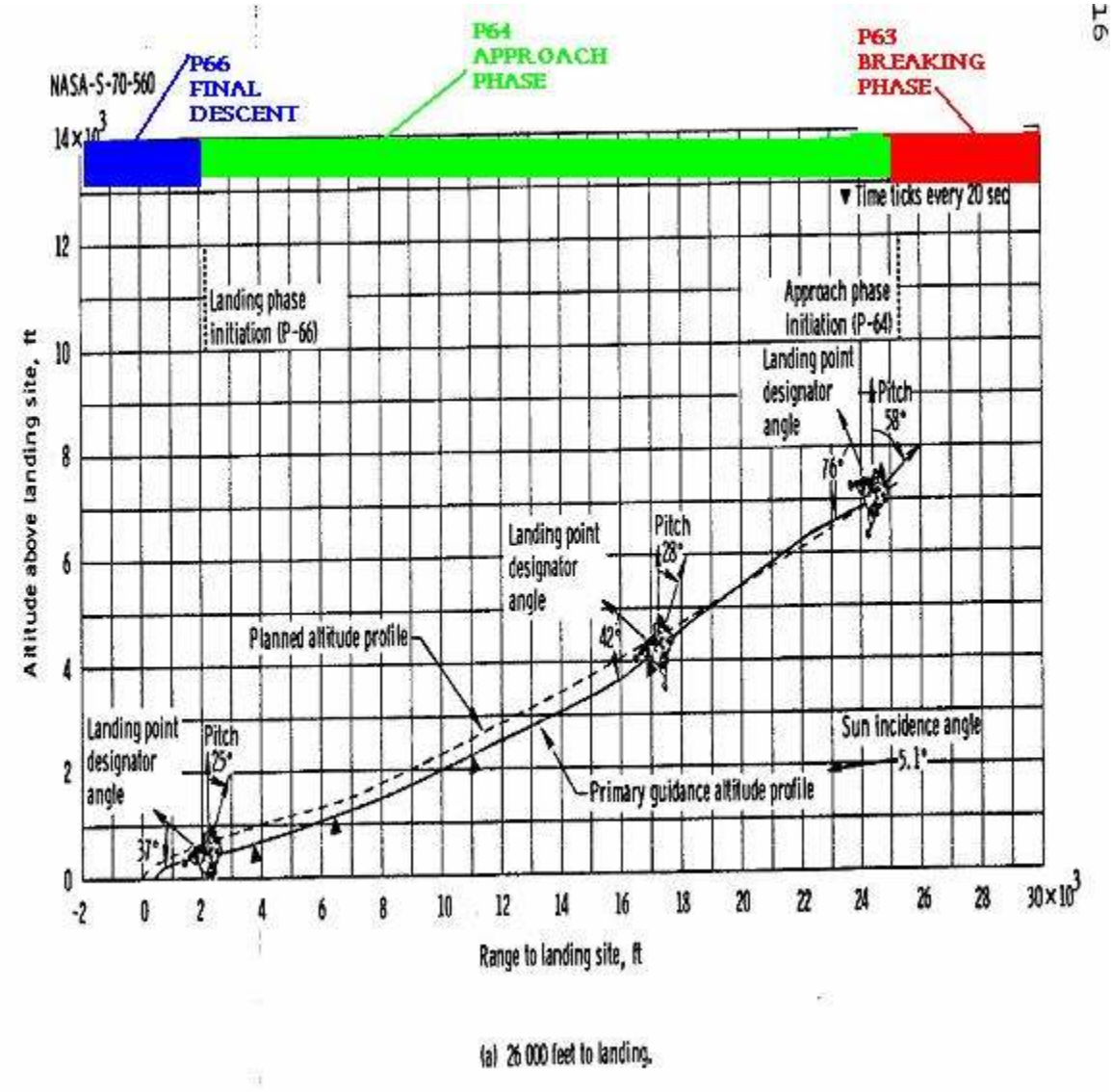
So for MyFlight type missions, you will need to experiment with fuel level and engine thrust factor to adapt your lander to the planet you wish to land on. By the way, if you select any other body than the Moon then the surface seen thru the cockpit will be change from gray (Moon) to color. This is to indicate that you

are not landing on the Moon. The “P99: MyFlight” displayed on the top of the screen will also indicate that you are flying a custom mission (MyFlight)

V- The Apollo lunar landing

To better understand what a moon landing really entails you will find here a description of a typical Apollo mission and how it relates to the LEM Sim game.

The moon landing was indeed the most demanding step of a moon mission. The landing was accomplished in three distinct phases as shown on the figure below taken directly from NASA documents. P63, P64 and P66 refer to internal computer programs which the on-board computer (DAP) followed in order to assist the astronauts land on the moon surface. Some programs like P63 were entirely automatic but others (P64 and P66) allowed the astronaut to have some or complete control of the LEM. Here is a description of the different phases:



(a) 26 000 feet to landing.

The breaking phase (P63): This first phase (not modeled here) starts with the LEM orbiting around the moon at an altitude of 50,000 feet and a forward velocity of about 5,500 feet/sec. The LEM is first pitched up 90 degrees so the main engine nozzle is facing forward in preparation for the breaking burn. During this phase which lasts approximately 9 minutes, the main descent engine is fired up at maximum thrust to slow down the LEM to about 400 feet/sec after the 9 minute engine firing. This breaking phase also lowers the LEM altitude to around 8000 feet. These become the initial conditions for the next phase of the landing. It is important to note that this phase is entirely automatic and under the control of the on-board computer (DAP). For this reason, the LEM Sim will not simulate this phase. This is suppose to be a fun game and so there is no much fun to stare at the PDA screen for 9 minutes while the on-board computer is doing its thing!

The approach phase (P64). This is where LEM Sim game begins. At about 8000 feet altitude, the LEM will pitch over to about 30 degree angle from vertical which allows the crew to see the moon surface and especially the landing site. The goal of this phase is to slow down the LEM even more (80 feet/sec forward velocity) and bring down the LEM to about 500 feet above the moon surface. Unlike the breaking phase (P63), P64 is semi-automatic phase. To assist you the on-board computer (DAP) will control the descent rate following its internal program. During this phase, which normally lasts around 2 minutes, the only manual control you will have is pitch and roll. The computer will automatically throttle up or down the main engine so that you reach 500 feet with a descent velocity of about -17 feet/sec. At least that's what the DAP will attempt to do. If you feel that the DAP is bringing you down too fast (or too slow), you can switch the DAP to manual mode. In that mode you can adjust the descent rate with the hard key 1-4 buttons. As soon as the LEM altitude is lower than 500 feet, the on-board computer will automatically switch to the final phase P66 (DAP mode=MAN).

The Landing phase (P66): This final phase should last about 2 minutes and is entirely done in manual mode. Below an altitude of about 500 feet, DAP will switch to manual mode and keep the last rate of descent you had at the end of P64 (which was about -17 feet/sec). It is your job now to slow your descent rate and horizontal velocities (forward and lateral). The mechanical limit at touchdown of the LEM dictates that you need to slow all velocities (ROD, forward and lateral) below +/-10 feet/sec at touch down. A landing with any velocity higher than +/-10 feet/sec would be considered a fatal crash. Any landing with a pitch or roll angle at touchdown higher than +/-15 degrees will also be considered a crash since you will not be able to take off with the lander at high degree of tilt.

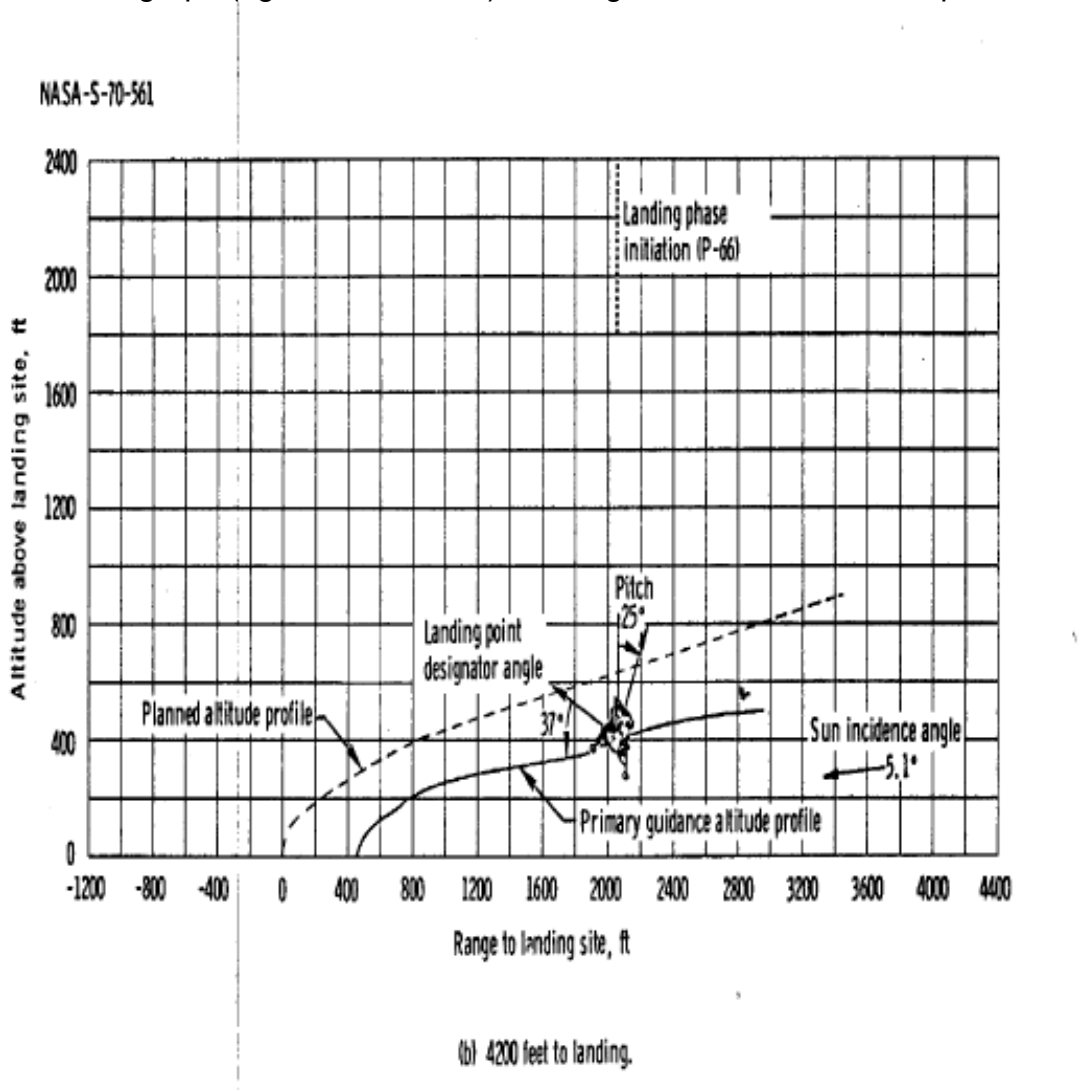
Of course the softer the landing the bigger the score will be. Once you reach about 6 feet of altitude, the contact light will illuminate indicating that you are very close to the surface (the Apollo LEM used probes wires that dangled under the lunar module feet). The engine will be cut off shortly after the contact light turns on.

Obviously, the goal of the game is to:

1. land on the surface of the moon as softly as possible,
2. as close to the landing site as possible
3. with the LEM upright, and
4. with as much fuel as possible in the tank.

All these variables will be taken into account in the calculation of your final score. The game also keeps track of your main engine (DPS) throttle mode (AUTO versus MAN mode) and awards you bonus points for your time in manual mode.

Here is a graph (again from NASA) showing the final descent P66 phase:



(b) 4200 feet to landing.

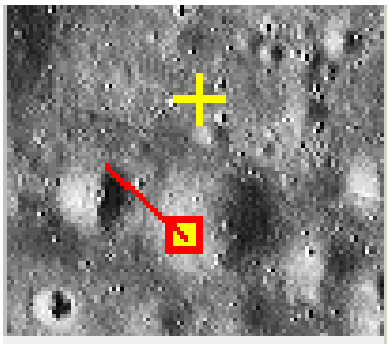
VI- LEM Sim Sub-Systems Description

To help you land safely on the moon, you will need instruments to monitor your flight, a propulsion system to slow your descent and control your attitude, and as in the real thing, an on-board computer to help during the most demanding phase of a moon mission.

Here is a more complete description of instruments, controls and systems that you have at your disposal in LEM Sim.

Instruments and indicators

Digital Lunar Map



The digital lunar map shows your location and direction above the moon surface. The yellow cross is where your landing site is located. It will be revealed to you only when your distance to the site goes below 10,000 feet. The red line coming out from your red lander is a velocity vector. This line basically shows your lander direction and speed. The end of the line tells you approximately where you are going to be in the next 30 seconds if you keep the same velocities.

Altimeter Tape

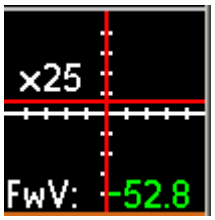
Located on the top right side of the screen, this instrument relays your altitude from the descent radar. It is called a tape because originally it was basically a

long piece of tape with markings scrolling up or down. The white arrow indicates your current altitude as measured by landing radar.

The number in green on the bottom right shows your rate of descent velocity or DesV (vertical speed). It is negative when you are going down and positive when are going up.

Contact Light indicator
This indicator, also located on the altitude tape screen, illuminates when you reach 6 feet from the lunar surface. The real LEM had contact sensors hanging down from its feet in order to detect contact with the lunar surface. The sensors signaled the commander to shutdown the main engine before touching the ground. This prevented the descent engine nozzle from being damaged by the engine's flames.

X-Pointer

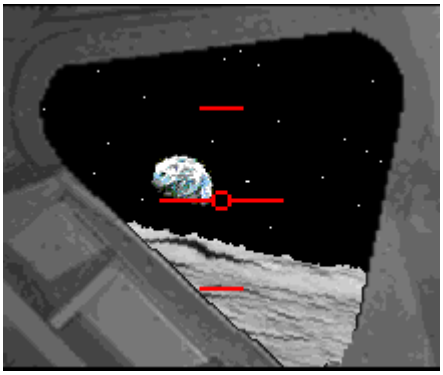


Located just below the altitude tape is the X-pointer. This instrument graphically displays your forward and lateral velocities. This data is also coming from your landing radar. The red horizontal line is your forward velocity. The line is above zero when you are going forward and below zero when going backward. You can also read your forward velocity at the bottom of the screen. FwV (forward velocity) is negative when going forward.

The vertical red line is your lateral velocity (left or right speed). So for instance, if you are drifting right then the vertical red line will be shown to the right of the white center line.

To help you better judge your velocity close to the surface (when your speed is low), the X-pointer has two scales (X1 and X25). The scale will automatically switch from X1 to X25 if any of your velocity becomes higher than +/- 25 feet/sec.

Artificial Horizon



The red line with circle at the center of the cockpit window is your artificial horizon indicator. It helps you judge your lander attitude. If the moon (or planet) horizon is below this line then your lander is pitching up (or backward). If the horizon is above the center line, then your lander is pitching down (or forward). The two shorter red lines at the mid-bottom/mid-top of the indicator indicate +/-45 degree pitch angle.

Of course the artificial horizon indicator can also be used to judge your roll angle. If you are rolling right (try to go to the right) then the moon/planet horizon will seem to rotate to the left. Same when you roll left (horizon seems to rotate right). This of course is because you are inside the lander and rotating with it. The moon/planet is not rotating but it feels like it does!

Also, remember to watch this indicator when you about to land because a touchdown any pitch/roll angles higher than +/- 15 degree will be considered a crash.

Fuel Level indicator

This number of course shows you the amount fuel left in your tank (in percentage of maximum fuel). Please note that you never start a mission with 100% fuel level but more likely around 15-20% (depends on the game level). The reason is simple. LEM Sim game starts few seconds after the end of the breaking P63 program. This means that the engine has been firing for almost 9 minutes and went through about 80% of the fuel in order to slow you down. That's before you even take over the LEM controls for P64 phase of the landing.

When the fuel tank level goes below 5%, the color of the fuel-level number will change from green to red and you will hear CapCom saying "**low level**". This means that you have only few minutes of fuel left and you should start thinking about landing or risk crashing because of a lack of fuel.

Master Alarm indicator

Yet another invisible indicator, this audio warning will indicate that the DAP (digital auto pilot) has detected an anomaly with one of the LEM sub-systems (fuel tank, main engine, RCS thrusters and so on). The Dap will also display a short description of the failure such as "**FAIL:Thrusters**" or "**FAIL:fuel tank leak**". To stop the loud siren sound just press the "Master Alarm" button once. The button will turn blue. Of course this action will not stop the failure which you will still need to cope with. Here are some of the failures you may encounter and what you can do about them:

- **Fuel leak**: Every second that this alarm is on, the fuel will deplete a little faster than normal. Hope it won't happen while you are low on fuel and very close to the surface!

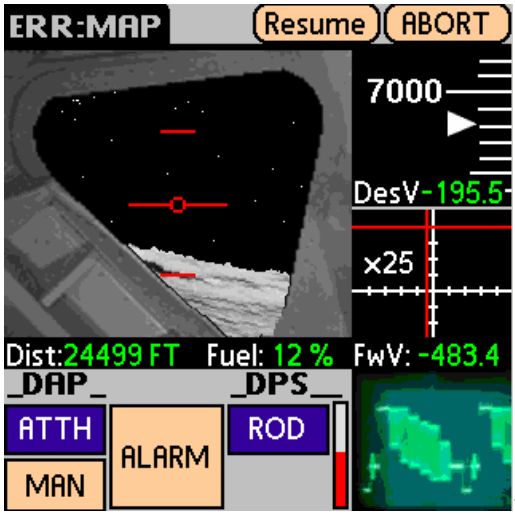
- **Engine**: This alarm indicates that there is something wrong with the descent engine (DPS). This failure will bring the engine down to 0% for a short period of time (engine shutdown). You can compensate by going in manual mode (DPS=MAN) and increasing the engine thrust yourself after the malfunction stops.

- **Thrusters**: Pitch or/and roll RCS thrusters may get stuck and will change the attitude of the LEM. You can compensate for this effect by using the opposite thruster. So for instance, if the LEM seems to pitch up, you can try to pitch down. Same for the roll angle

- **DAP**: The DAP main engine throttling routine (ROD) is no longer working. The DPS mode is switched to MAN. This means that you need to take DIRECT control of the main engine until the alarm goes off. The ROD number will become engine thrust percentage number (% of max thrust)

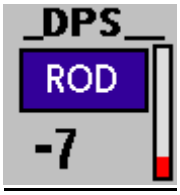
- **False alarm**: No need for explanation! Sometimes the alarm sound even so everything seems nominal. That 's a false alarm!

Here is a screen shot of a failure: In this example you just have lost the digital map so it impossible to know where the lander is heading during the malfunction.



←Map display failure

Propulsion/Attitude Control



To slow down your descent to the moon, your LEM is equipped with a rocket descent engine also called DPS (descent propulsion system). The DPS can be throttled between 10% and 90% of maximum thrust. The DPS cannot be shutdown during flight (unless there is an engine failure)

The red gauge at the bottom right of the screen is your engine thrust indicator (0-100%). The hard key 1 and hard key 4 are your engine controls. The large number under DPS mode button is your requested rate of descent or ROD. If the DPS mode is set to MAN then that the ROD will switch to a engine thrust number (THR: 10%-90% max thrust).

The DPS has two modes of control:

Normal mode (DPS = ROD): In normal situations, the autopilot (DAP) actually controls the engine thrust through a computer routine called ROD which stands for Rate Of Descent. So when you press hard-key 1 or hard-key 4, you are actually requesting a LEM rate of descent change. The DAP in return will control the engine thrust trying to match your request. Please note that to save fuel, you cannot in this mode request a positive rate of descent (make the LEM go upward) but you can request the LEM to hover (zero rate of descent). Hovering can help you "bleed" some large horizontal velocities before going down again. Of course hovering is very costly in term of fuel usage and should be used sparingly.

Manual mode (DPS = MAN): As described above, the DPS in ROD mode is the normal mode used by all Apollo astronauts. If you wish to make a landing more difficult, and get bonus points in the process, or if there is an autopilot malfunction, you will have to switch the DPS to manual mode (press the DPS mode button). In this mode a click on Hard Key 1- 4 will directly affect the engine thrust. This mode is difficult to use, especially close to the moon surface. This is why you will get extra points on using the manual DPS mode.

The LEM on-board computer (DAP)

The LEM is also equipped with a Digital AutoPilot also known as DAP. DAP is an on-board computer designed to assist you during the landing. The DAP has many functions:

- Monitor the status of the LEM sub-systems
- Gather altitude and velocities from radar, attitude from gyro platform and fuel level from the fuel tank sensor
- Display all this info in the cockpit
- Control the LEM descent engine during the automatic (P63) and semi-automatic (P64) phases of the descent
- Throttling the main engine to try to match the pilot rate of descent request (ROD function)

DAP has essentially three operational modes:

Automatic mode
This mode is not simulated in LEM Simulator 2.0. In this mode, the computer controls everything and it is used during the breaking phase (P63). The breaking phase of the landing goes from 50000 feet to around 7500 feet when the approach phase starts (and where this game simulation starts also)

Semi-automatic mode (Attitude Hold or simply ATTH)
In this mode, the computer controls the descent rate following its internal program P64. You control the LEM attitude. Below 500 feet the DAP mode will automatically switch to manual mode.

Manual Mode: In this mode, in addition to the RCS controls, you will need to control the main descent engine (DPS). The type of control you will have over the DPS will depend on the status of the DPS mode button. In the manual mode the DAP will still monitor the health of your lunar and display important information like your altitude or rate of descent.

VII- Frequently Asked Questions

Here some answers to questions you may have about the game.

Q: Can I pause the game?
A: Yes. During the descent, just click on the top of the screen. The game will be paused and the button will change to “Resume”. At this time, you will be able to start a new mission, change game settings or simply exit the application from the menu bar at the top of the screen. Or you can simply click on “Resume” to continue the mission.

Q: Why are my Palm keys disabled during game play?
A: This is needed to keep the device from exiting the game while you are playing. If you need to exit the application, first press the ABORT button.

Q: Why does the descent rate indicator become positive, i.e going up, when I request a rate change?
A: If you are at a low descent velocity and you request a change, the on-board routine is so realistic that it may overshoot while its adjusting the engine thrust to match your requested rate of descent change.

Q: How often do the malfunctions happen during a game?
A: In the Pilot mode they are not frequent but occur from time to time. In the Commander level, you may experience multiple failures during a single mission. In version 2.0 you are now able to disabled the failures completely not matter the game level. To do that, open the options window and uncheck the box labeled “Enable Failures”. You have now a “perfect lander”!

Q: Can I switch to manual DAP mode during the Approach phase?
A: Yes you can. You will need to adjust your descent rate manually.

Q: Why can’t I change the DPS mode to manual while the DAP is in ATTH mode?
A: When the DAP is in the ATTH mode, the computer controls the engine using its internal ROD routine. If at any time you wish to switch the DPS engine mode, first set the DAP mode to MAN.

Q: Why do I crash sometimes without any apparent reason even when my descent and horizontals velocities are below the crash limits?
A: The most likely problem is that you touched down with the LEM tilted. NASA forbids astronauts from landing with a pitch or roll angle higher than +/- 15 degrees. The bottom part of the lander is used as a launch platform and you want the LEM to land as upright as possible. Use the “Crash Data” screen to find out why you crashed.

Q: Why when I try to land on a planet with large gravity, the pitch/roll controls are so sensitive (a small change in lander angle make a huge difference in forward/lateral speed)?
A: If you try to land on let say Jupiter, you need to boost your descent engine incredibly (engine factor> 500%). This means that the engine force vector is enormous! All that thrust is needed to stop your fall but it is an overkill when it comes to direct your lander. So change your angle very slowly and stay upright as much as possible.

Q: I have landed on the moon successfully many times now (even in commander mode). What else can I do with LEM Simulator which will be even more challenging and fun?
A: The most challenging (and fun!) thing you can do is to set the main engine DPS mode to manual from ROD. In this mode you basically have full control of the lander. It is challenging because of the information overload involve. You not only need to worry about your lander attitude but also worry that your engine thrust is correctly set for whatever rate of descent you whish to have. Because the lander weight is always changing as you spent fuel, you constantly need to adjust your engine thrust so not crash. Please note that this mode was never used in real Apollo landing but you can be sure that those guys prepared themselves in the NASA LEM Simulator for any eventuality.

VIII- Registration and Support Information

You can register LEM Simulator 2.0 at the site where you downloaded this copy. There you will also find the developer (SimToGo) contact information which you can use If you need assistance with the game registration or have any comments/suggestions about this application.

With the LEM Simulator loaded on your Palm/Treo device, you are now ready to have fun landing on the moon (or any planet) anywhere and anytime.

Thank you for your support and please enjoy L.E.M Simulator 2.0