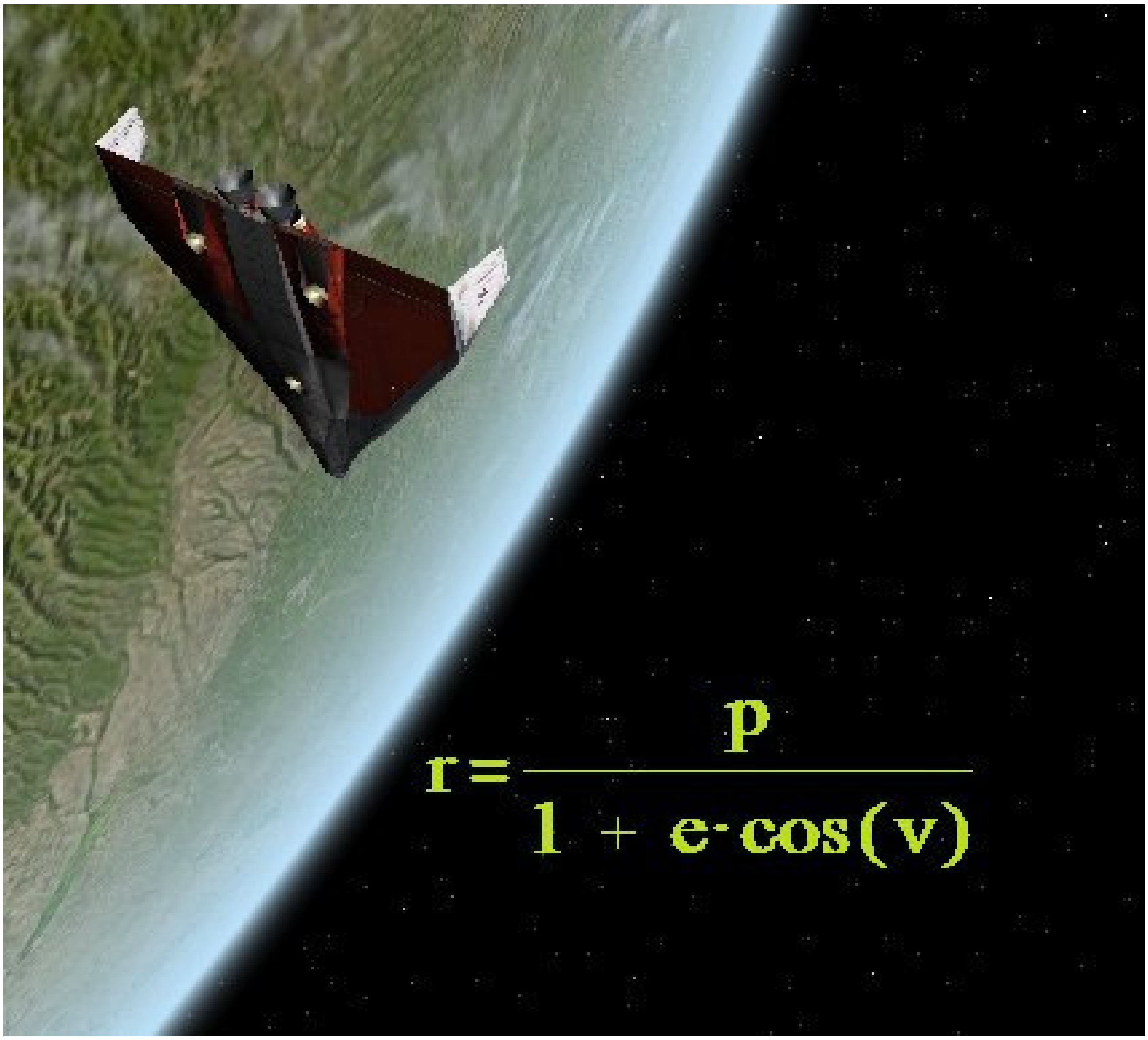
Equation MFD User Manual



Introduction

Welcome to the EquationMFD tool. It's a handy device that will help you to plan your basic maneuvres in advance.

Operation

WARNING:
This MFD fully relies on the knowledge of the user. At no time the numbers are garanteed to state a true result of the equation shown. It`s up to you, the user, to keep track of what you are doing and which numbers are valid. This is NOT an Excel worksheet

Equation MFD is activated with **SHFT E**.

At the top of the MFD there`s a line showing the directories available.

They are:

B**OP** Basic Operations: Addition,Subtraction,Multiplication and Division and several other functions

ORB Orbit: Several Equations to help you to planning your orbit changes and adjustment.

ESC Escape: How to escape an orbit in the proper way to achieve an interplanetary trajectory.

FUE Fuel: Fuel use and burn time prediction .

INC Inclination: Change plan Delta V calculation formulas.

MOV Movement: Basic Movement Equations.

LNC Launch: Some formulas that are useful in very simple launch procedures.

RNT Rotation: Planet rotation tool for launch and deorbit planing.

RNT Rotation: Planet rotation tool for launch and deorbit planing.
GLD Glide: A glide angle calculator to plan your final descent landing path.

You can move through the directories using the **SHFT +** and **SHFT -** keys. The selected directory is highlighted with a blue background.

The second line shows a serie of numbers from 0 to 9. This represents the equations available inside that directory. The actual amount of equations vary from one directory to another.

You can move through the available equations using the **SHFT]** and **SHFT [** keys. The selected equation number is highlighted with a blue background and the equation enunciate appears in the lines below.

The equations available inside each directory are:

ORB
`r=p/(1+e*COS(v))` An old general orbital movement equation.
`Vt=SQRT(p*G*M)/r` Useful to find circular orbit and transference injection speeds when V=Vt .
`Vr=e*SQRT(G*M/p)*SIN(v)` The radial Velocity related to the angular distance from perigee.
`e=SQRT(Vr^2*p/(G*M)+p^2/r^2-2*p/r+1)` How to find eccentricity having Vr,r and p.
`V=SQRT(Vt^2+Vr^2)` Components and module of the Velocity vector
`E=G*M/p*((1+e^2)/2-1)` The energy per mass for an orbit.
`e=(ra-rp)/(rp+ra)` Eccentricity given apogee and perigee.
`p=rp(1+e)` Semi latus from perigee and eccentricity.
`e=(ra/r-1)/(cos(v)-ra/r)` For determining basic ballistic paths.
`t= -(2*atanh(sqrt((e-1)/(1+e))*(cos(v)-1)/sin(v))*(1+e*cos(v))+e*sin(v)*sqrt(e^2-1))/((e*cos(v)+1)*sqrt(pow((e^2-1),3)))*p^2*sqrt(p*G*M`); How long it takes to reach a v angle distance from perigee?
`t= 2*PI()*sqrt(((ra+rp)/2)^3/(G*M)` ; Closed orbit revolution time.

ESC
`Vhx^2=Vbo^2-Vesc^2` Hiperbolic Excess Speed Formula. V at infinitum distance from departure body.
`lbo=ls+k-vbo` Longitude you should fire your engines.

FUEL
`DV=LN((ms+ml+mi)/(ms+ml+mf)))*Isp` Fuel consumption for a given speed change.
`tbn=(mi-mf)*Isp/THRUST` Burn time calculation.

INC
`DV=Vc*SQR(2*(1-COS(Deltai)))` Speed increase vector for inclination changes in circular orbits.
`DV=Vc*Delta i` ; Speed Variation for Continous normal att.maneuver(Delta i is in rads in formula but is inputed in degrees as usual).

MOV
`r=DV^2/(2*ap)` How far it takes for a speed change with a constant acceleration?
`DV = Vf - Vi` Useful to calculate and have a record of final and initial speeds.
`DV=sqrt(DVt^2+DVr^2)` Total Speed variation from radial and tangential components.

LNC
`rme=(-GM*ap+rs*ap^2*rma+SQRT(G^2*M^2*ap^2-2*G*M*ap^3*rs*rma +rs^2*ap^4*rma^2+4ap^3*rma^2*G*M))/2*ap^2*rma` Where to cut off to achieve a certain altitude.
`tme=rme/ap` When cut off.
`Vme=SQRT(2*(G*M/rma-G*M/rme))` Speed at cut off.
`cos(Azm)=cos(Inc)/cos(Lat)` Heading to set the ship at launch to achieve a given inclination.

RNT

(lb-la)=(wb-wa)(t-to)+(lob-loa)* Single and relative circular uniform movement. Hint: make la,wa,loa values equal to zero to deal with a single movement.

T=360/|wb-wa| Single and Synodic Period. Hint: Set wa to zero to deal with a single movement.

GLD

a=atan(Vh/Vd) Glide Angle regarding speeds. 2 degrees is a nice number to set

a=atan(d/h) Glide Angle regarding numbers. 2 degrees is a nice number to set

The remaining lines are used by a variable list. Each directory has its own variable list. The variables that appear in the currently selected equation are highlighted bright white and can be selected. These can be selected using the **SHFT .** and **SHFT ,** keys. The selected variable is highlighted with a blue background. You have two sets of variables that work independently. Switch between them with **SHFT R**. Keep track of the current variable set you are working with checking the VARSET indicator.

Some variables are preceded with a "➔". The current flight, ship or astronomical value for these marked variables is available in the ship's system and can be retrieved using **SHFT G** you can get all current system information available at that directory by pressing **SHFT A**.

When selected the variable value can be entered through an input box activated with **SHFT L** key, can be retrieved, if available, using the **SHFT G** key or can be calculated from the value of the other variables present in the same equation with the **SHFT S** key.

You can also send a selected variable value to the clipboard with the **SHFT C** key and set it to the value stored in the clipboard with the **SHFT V** key. Equation MFD clipboard works in a slightly different manner than the one you're used to in Windows. It accepts up to ten values in a first-in-last-out mode, that is , you can stack a group of values pressing **SHFT C** and retrieve the values you stored in the reverse order that they were stored using **SHFT V**. Check the CSP (Clipboard Stack Pointer) indicator at the upper left corner of the display to keep control on how many values you have stored there.

You can make the presently selected variable value equal to zero by pressing **SHFT Z**.

Tutorial One

First of all make sure that, in Launchpad's parameters, the Nonspherical Gravity Sources is OFF.

Load the "Tutorial 1" scenario.

After the scenario loads, load Equation MFD with a **SHFT E** and have a Orbit MFD at the other MFD.

As you can see our orbit is not quite circular so let's circularize it at our perigee radius.

1.Get your current state vectors. Go to the **ORB** directory pressing **SHFT +** or **SHFT -**. Go to the equation 1 pressing **SHFT]** or **SHFT [** . Select r pressing **SHFT .** or **SHFT ,** and press **SHFT G** to retrieve current distance value from the system. Select Vt pressing **SHFT .** or **SHFT ,** and press **SHFT G.** Select M pressing **SHFT .** or **SHFT ,** and press **SHFT G.** Go to equation 2 pressing **SHFT]** or **SHFT [** and press **SHFT G** to get Vr value from the system. The faster you do it the better since the data is changing all the time. One faster way to do it is to press **SHFT A** and get all values at once.

2.Get p value from the acquired values of Vt,M and r going to equation 1 with **SHFT]** and selecting p variable with **SHFT .** . Press **SHFT S** to calculate p value. (The value is around 6.73e6m)

3.Go to equation 3. Select e variable and get e value from Vr,r and p. (aprox. 2.97e-2). Check with OrbiterMFD that your data is coherent.

4.With p and e we have determined our orbit characteristics within its plane. Let's figure out how fast we will be at perigee: Go to equation 7. Select rp. Solve the equation for it (aprox. 6.532e6 m) Place this value at the clipboard with **SHFT C**. Go back to equation 1 pressing **SHFT [** and paste the clipboard contents in the r variable pressing **SHFT V**. Select Vt and solve Equation 1 for it with **SHFT S** (aprox. 7.927e3 m/s) This will be our initial speed so transfer it using the clipboard to the MOV directory\Equation 1\Variable Vi (You can open another EquationMFD at the other MFD to make the transference. The two MFD's can be set at diferent directories, equations and variables but they share all the same variable set values and the clipboard. You can use **SHFT R** to choose between two sets of variables.)

5.Let's calculate the speed for a circular orbit at perigee. Get back to the ORB directory. In a circular orbit p is equal to r that is constant and e is equal to zero. so let's change our variables accordingly. Make p equal to r using the clipboard, set e to zero selecting it, pressing SHFT L and input 0 as the new value or press **SHFT Z** that set the currently selected variable to zero instantly.
Then Select Vt at equation 1 and press **SHFT S** to calculate it for the new values of r and p. (aprox. 7.811e3 m/s). This is our final speed so use the clipboard to take it to the directory MOV\Equation 1\ Variable Vf. Then use this equation 1 to calculate the value for the DV variable selecting it and pressing **SHFT S**. (aprox. 1.154e2 m/s). Store this new value of DV in the clipboard.

6.Go to the FUE directory. Paste the Delta V value into the DV variable. Then get all information available from the system for ship's mass ms, load mass ml, present fuel load mi, and the ship's fuel specific impulse Isp. Now select mf and calculate the fuel final mass after the burn with **SHFT S** (aprox. 7.91e3 kg - the maneuver will take about 45 kg of fuel).

7.Move to Equation 1. Select THR and get the value for the ship's main thrust with SHFT G. Now solve the equation for Burn Time tbn with **SHFT S** (aprox 7 s). You can set this time as burn time in Timer MFD. You can divide this value by two at BOP and subtract the result from 1000 (996.5s) to get the coast time to set in Timer MFD and start countdown at 1000s to perigee.

8.Now you have all the needed information to circularize your orbit. Wait for the perigee point with a retrograde attitude and ......make it so.

Tutorial Two

Load the scenario Tutorial 2

In this tutorial we are going to launch the Shuttle-A from the Moon and put her in a stable circular orbit 120km above the lunar surface. Equation MFD is loaded with **SHFT E**.

1.Go to the LNC Directory,Equation 0 using **SHFT +** and press **SHFT A** to get all local data such as Moon's mass and Moon's surface distance from the center. Use **SHFT .** to highlight the rs value and send it to the clipboard with **SHFT C**.

2. Let's calculate how distant from the center of the Moon an altitude of 120km is. Return to the BOP Directory Equation 0 with **SHFT -** and paste the value in the clipboard at b using **SHFT .** to select it and **SHFT V** to paste the value there. Select b and press **SHFT L** to activate the input value box.
Input '120000' (or '120e3').Return the cursor to the a variable and calculate the sum using **SHFT S** (the result is 1858km).Copy this value to the clipboard.

3.Return to the LNC directory. Paste the number in the clipboard to the rma variable. Select ap using SHFT . Make ap equal to 1m/s2 using **SHFT L** and entering the number. This is the acceleration value we are going to keep manually while we ascent.

4. Press **SHFT,** to return the cursor to rme value and calculate for it using **SHFT S** (Should be aprox. 1809km). - Use BOP/ Equation 0 to calculate the altitude over the surface this value represents (aprox. 71.2km) This is the MECO distance where we are going to cut off ascent engines (Shuttle A hover engines in this case).

5.Go to LNC Equation 1 with **SHFT]**. Select tme and calculate for it with **SHFT S** (aprox. 377s). Go to Equation 2 and calculate Vme (377m/s).
Now you know that keeping an acceleration of 1m/s2 throughout the ascent you should cut off at 71km of altitude. This should occur after 377s of launch and at that point you should have 377m/s of vertical speed. If our calculations are correct, inertia should take us up to 120km where our vertical speed will be zero and then we are going to start falling.
At this point we are going to fire main engines until we have orbital speed. Let's calculate this orbital speed:

6. Copy the rma value to the clipboard using **SHFT C**.Notice that the CSP indicator increases its value.

7. Go to the ORB directory Equation 1. Select M and press **SHFT G** to get the Moon's mass. Because this is going to be a circular orbit the values for r and p are the same and e is equal to zero. Paste the value in the clipboard at r and p and make sure that e is equal to zero selecting it and pressing **SHFT Z**. Then use equation 1 to calculate Vt (aprox. 1624m/s).
Now you have all the data you need. Ascent keeping 1m/s2 (monitor the Surface MFD VACC display) up to 71 km alt with a speed of 377m/s. Cut off hover engines. Wait untill you get at 120km and your vertical speed drops to zero. Fire main engines adjusting pitch to keep zero vertical speed (or up to +/- 5m/s to achieve small corrections) keep correcting pitch and cut off when your speed is 1624m/s (make sure surface MFD is indicating orbital speed). One eye at the eccentricity value of the Orbit MFD reaching zero is helpful. Most probably there will be minor adjustments to be made.

Tutorial Three

Load the scenario Tutorial 3

In this tutorial we are going to align planes with Earth to prepare our insertion to Moon-Earth trajectory.

1.Load Align MFD and set the target to Earth. Check that the misalignment between our orbit plane and Earth's is 9.38dg.
Let's calculate DeltaV needed for the 9.38dg plane change. Press **SHFT E** to load Equation MFD.

2.Go to the INC Directory pressing **SHFT +**. Use **SHFT .** to select the Di variable. Press **SHFT L** to display the input box for this variable and enter the misalignment value of 9.38dg.

3.Go to the ORB Directory pressing **SHFT -** and press **SHFT A** to get the vector states for our current orbit (V and r). Select Equation 1 with **SHFT]** . Highlight the Vt variable using **SHFT .** and press **SHFT C** to place its value in the clipboard. Return to the INC Directory and select the Vc variable. Paste the value in the clipboard to Vc using **SHFT V**. Now go to Equation 1 by pressing **SHFT]**. This is the equation we are going to use. Select DV and press **SHFT S** to solve the equation for its value (aprox 265.6m/s).
Now we are going to know how much this is going to co$t.

4.Store the calculated DV value in the clipboard. Go to the FUE directory pressing **SHFT -** . Press **SHFT A** to get all relevant ship data such as mass Thrust and Isp. Paste the clipboard content in the DV variable. Press **SHFT .** to select mf and press **SHFT S** to solve for it (aprox. 48137kg). Change to Equation 1 by pressing **SHFT]**. Select tbn and calculate for it (aprox 23s). You can now input this value in Timer MFD's burn time. You can divide this tbn value by two (at BOP directory Eq 1) and subtract the result from a 'desired coast-timer-engage-interval-from-AN/DN-node' to calculate a coast time to set at Timer MFD. In this case we can set Timer MFD coast time to 988.5s and start countdown at 1000s to reach the descent node as shown in Alignment MFD.

5. Using the clipboard take this value to BOP and use the equations there to divide Di value by two and add 90 (should be 94.69dg). This is the pitch value we have to estabilish at burn time.
Engage auto prograde. When burn time approaches disengage auto prograde, load Attitude MFD. At 2 minutes to the burn set Attitude MFD reference to zero and pitch up (we are approaching an descent node if it were a ascent node we would have to pitch down) to the above calculated pitch. Wait for the countdown. Do not readjust pitch during the burn! Good luck. You should at least finish the burn with a misalignment of less than half degree.
Check the status of your orbit after the burn .Due to gravity action during the burn you should correct for the negative Vr, set for a return to the original altitude and recircularize your path.

Tutorial Four

Load the scenario Tutorial 4

In this tutorial we are going to insert the Shuttle A , from an orbit around the Moon to Moon-Earth trajectory.

First thing let's estabilish what we want: the characteristics our trajectory to Earth should have.
Suppose we want a perigee at 200km above Earth from an apogee at our current Moon distance, or 398000km from Earth.
1. Get Earth radius and mass pressing **CTRL i** and selecting Earth. The values are 5.9737e24kg and 6371.010km.
How above this rs value is an altitude of 200km? We're going to use Equation MFD to find the answer.

2.Load Equation MFD At BOP directory Equation 1 (the sum) select b variable using **SHFT .** . Press **SHFT L** to display the input box. Input '6.371010e6'. Select c variable using **SHFT .** . Use **SHFT L** again and input '200e3'. Get back to the a variable pressing **SHFT ,** and calculate the resulting sum pressing **SHFT S** (it's 6571.010km). Place this value in the clipboard two times pressing **SHFT C** twice.

3.Goto the ORB directory with **SHFT +**.Proceed to the equation 6 pressing SHFT] six times. Select the rp variable pressing **SHFT .** . Paste the last copied value in the clipboard to the rp variable pressing **SHFT V**. Select the ra variable using **SHFT ,** . Press **SHFT L** and input Moon's current distance from Earth i.e. '398e6' (this value can be taken from Orbit MFD). This enables us to calculate the e value from ra and rp in equation 6. Select e using **SHFT ,** and press **SHFT S** to calculate (The result should be 0.9675). Now get back to equation 1 using **SHFT [** . We are going to use the equation 0 and the fact that we know perigee distance , excentricity and real anomaly, which is zero at perigee, to calculate semi-latus. Set r value to 6.571010e6, from the clipboard with **SHFT V** and make sure that v is zero. Select p and calculate its value pressing **SHFT S** (it's aprox. 1.293e7m).
Now we have the parameters for the trajectory we want to inject our ship. We need to calculate the all tangential speed at apogee that we should have at our current distance from Earth that will set us into this trajectory.

4. Go to Equation 1 Pressing **SHFT]**.Press **SHFT L** to show an input box for the r variable. Input 398e6 and press enter. Select Vt using **SHFT .** . Solve the equation for it pressing **SHFT S** (should be aprox. 180.37m/s).
However this is not the speed we should accelerate. This is the speed that must remain after we have escaped the gravitational influence of the Moon. So, actually, we need to use this value to find out the speed we need to accelerate to escape Moon's gravity and still have a residual speed after leaving the Moon that makes the escape point our intended Moon-to-Earth path apogee.
Ok but remember that our apogee speed of 180.37m/s is relative to Earth and we are going along with the moon which is travelling at 987m/s (check Orbiter MFD). Therefore we need to subtract this value from Moon's speed to know how much our residual speed in relation to the moon should be.

5.Do it at BOP Equation 1 setting the a variable to 987, b variable to 180.37 and calculate for the c variable. It gives 987-180.37=806,63. Copy this result to the clipboard.
This is the so-called 'hyperbolic excess speed'. It's the residual speed,relative to the Moon, we should have after leaving the Moon in a hyperbolic path. We need to know now the escape path that provides us this hyperbolic excess speed. It will define both the speed we need to acelerate and the orbit angle at which we should do it.

6.Go to the ESC directory, equation 0. Place the value in the clipboard at the vhx variable.
As you can see in Esc\equation 0 ,to calculate Vbo , we need the parabolic escape speed that applies to our current distance from the Moon, so let's get it.

7. Go to the ORB directory and press **SHFT A** to get Moon's mass and current speed and distance. With r equal to our current distance, set e value to 1 to estabilish a parabolic escape. Knowing e and r, check that v variable is equal to zero and calculate p using equation 0 . Then go to equation 1 ,and calculate Vt at perigee (should be 2297.27m/s).Copy this value to the clipboard. Go to the ESC directory and place the value in the clipboard at the Vsc variable.
We are going to calculate now Vbo: the speed we should accelerate to in order to escape Moon's influence and still have Vhx after leaving Moon's influence.

8. Then from Vhx and Vsc calculate the value for Vbo (it is about 2434.77m/s). Load it in the clipboard.
This value will lead our navigating actions from now on.
First we are going to calculate our burn time. Let's find our DeltaV.

9.Go to the MOV directory and store the value in the clipboard in the Vf variable since this is going to be our final speed.
Our initial speed the current speed that keeps our circular orbit around the Moon, that is 1624m/s, so get this value from the system at ORB with **SHFT G** or **SHFT A**. Use the clipboard to transfer this value to the Vi variable of the MOV directory. The use the Equation 1 in MOV to calulate DV(it is 810.34m/s) Copy this value to the clipboard.

10. Go to the FUE directory. Get all current values from the system with **SHFT A.** Paste clipboard value into DV variable and calculate the value for the mf variable (about 43668kg). Go to Equation 1 and calculate tbn (should give aprox. 69s). This is the value you should input as burn time in Timer MFD.
Our final trajectory also determines the angle we should fire our engines.

11. Using the clipboard move our hyperbolic escape speed of 2434.77 m/s to the Vt variable in ORB. with our current r , Moon's mass and equation 1 calculate p (4174.18km). Go to equation 1 and calculate e (it is 1.24658). With the eccentricity value we can know the max angle (anomaly) from perigee we are going to get at great distanes from the Moon. One easy method to find this value is to give r an extremely large value (such as 1e300) and calculate for the anomaly v. Do it and confirm that this anomaly at infinitum is 143.34 degrees. Transport this value to the vnf variable at directory ESC. the ls variable is the true longitude angle related to from the central celestial body (Earth in this case) to the orbiting celestial body (Moon in this case). This value can be taken from the Orbit MFD setting Earth as a reference and Moon as a target. Check that the value is about 266 degrees and, with SHFT L, input it manually to the ls variable in ESC directory. Input 270 to the k variable and solve for the lbo variable (the result is 392.66 , however this 360 , a complete turn, should be subtracted from this value to give us 32.66 degrees).
We can use this information to set a coast time before fire.

12. Go to the ORB directory and press SHFT A to get the state vectors (r, V) for the current orbit. Use equation 1 to calculate p and equation 3 to calculate e. We are going to use these values to find our current orbit revolution time. Go to equation 9 and input 360 into variable v . Then calculate for the t variable (7187s-check with Orbit MFD) . Copy this value to the clipboard.

13. Go to the RNT directory Equation 1 and paste the value in the T variable. Calculate for wb (.00501 degress per second). Now use Orbit MFD to get a simulation time for a particular True Longitude angle relative to the Moon. Wait for a particular angle and take note of the time. In my case I got that the ship was at 350 degrees at 2019s simulation time. Store this data at lob and to respectively.

Get our firing angle of 392.66 dg at the ESC's lbo variable and place it at the RNT's lb variable. Then using RNT\equation 0 calculate for t variable (should give 2870.64 s).

14. Use BOP Equation 1 to divide the 69s burn time value at FUE's tbn by 2 (This gives 34.5s). We are going to subtract this value from the time we're going to spend to arrive at the engine fire point. Subtract the result from the t value at RNT (it is 2836.14s)
Now that we know our ignition must occur at 2836.14s sim time we can program Timer MFD coast time to wait for 536.14s if we want to start countdown at 2300s. Or set coast time to 136.14 and start countdown at 2700. It's up to you. Do not forget to be in a prograde attitude at burn point. Good luck.

Tutorial Five

Load the scenario Tutorial 5. (Maybe it's a good idea slow down the simulation in this one)

Here we are happily going back home. However , a look to the Orbit MFD shows that things are not as good as they seem. We are dangerously off course and our current predicted perigee stands a good distance into the surface of planet Earth (look that rp= 4460km which is less than Earth's rs=6371km). This is not good to your health. We need to do something about it. In this tutorial we are going to use Equation MFD to quickly and precisely (well...almost) correct our course back to the one we intended when we left the Moon which leads us to a confortable perigee at 200km above the surface of the Earth. What we are going to do is to estabilish a distance from Earth before we reach it , find out the speed we would have there in our intended, correct, course and the speed we are going to actually have in our present, wrong, course. Then we are going to calculate the speed difference between these two states in terms of radial and tangential speed. After that it is just a matter of setting our ship to accelerate from one speed to the other in a single burn when our selected distance arrives.

1.Go to the ORB directory by pressing **SHFT +**. Press **SHFT A** to get the state vectors and the mass of the Earth. Go to equation 1 pressing **SHFT]**. Select p variable pressing **SHFT .** and solve the equation for this semi lactus variable pressing **SHFT S** (the result is 8820km). Then select equation 3 pressing **SHFT]**, select e variable pressing **SHFT .** and solve the equation for the eccentricity pressing **SHFT S**.(the value is .9776-check with Orbit MFD). Now we have the parameters for our current orbit.
We are going to set our intended course now in the variable set 2. Our intended course has an apogee of 398km and a perigee of 6571km.

2.Go to the Variable Set 2 pressing **SHFT R**. Go to the ORB directory with **SHFT +** or **SHFT -** .Select equation 6 with **SHFT]** . Highlight ra variable using **SHFT.** . Press **SHFT L** to display an input box that allows you to key in a value for ra. Enter '398e6' and press enter. Select rp variable pressing **SHFT .** once more. Press **SHFT L** and input a value of '6571010' for rp. Then select e variable pressing **SHFT ,** . Press **SHFT S** to solve the equation 6 for the eccentricity (the value is aprox. .9675). Go to the equation 7 with **SHFT]** . Select p variable with **SHFT .** and solve the equation for it with **SHFT S** (the value is 12928km)
Now that we have our current orbit parameters in variable set 1 and our intended orbit parameters in variable set 2 we are going to find out DeltaV radial e tangential components at 160000 km from the Earth.

3. Go back to variable set 1 pressing **SHFT R**. At the ORB directory go back to equation 1 pressing **SHFT ,** . Press **SHFT L** to input '160e6' to the r variable. Select the Vt variable pressing **SHFT .** and solve the equation for it with **SHFT S**.(it's 370.56m/s) Now go to the equation 3 with **SHFT]** and select the vr variable with **SHFT .** . Solve the equation for vr with **SHFT S** (it's aprox 1687.55 m/s). Go to Equation 4 and solve the equation for V to find the module of the speed vector at 160000km (about 1727.76m/s).

4. Let's repeat step 3 for variable set 2 and find the speed we should have there:
Go back to variable set 2 pressing **SHFT R**. At the ORB directory go back to equation 1 pressing **SHFT ,** . Press **SHFT L** to input '160e6' to the r variable. Select the Vt variable pressing **SHFT .** and solve the equation for it with **SHFT S** (aprox. 448.66m/s). Now go to the equation 3 with **SHFT]** and select the vr variable with **SHFT .** . Solve the equation for vr with **SHFT S** (about 1676.52m/s). Go to Equation 4 and solve the equation for V to find the module of the intended speed vector at 160000km (it's 1735.52m/s).
We will at this time calculate radial and tangential deltaV.

5.Go to variable set 1 pressing **SHFT R.** Select Vt and copy it to the clipboard. Check that CSP goes from 0 to 1 . Then Go to variable set 2 and copy Vt to the clipboard too. CSP indicates 2 now. Return to variable set 1. (You can always have two Equation MFD's active, each on one different directory or variable set.

They will share the variables and the clipboard.) Go to the MOV directory. Select Equation 1. Paste the last copied clipboard value (448) to the Vf variable. pressing **SHFT V**. CSP indicator should go back to 1. Select Vi and paste the first value that was copied to the clipboard (370) there. CSP indicates 0 now.Then select DV with **SHFT ,** and solve the equation for it with **SHFT S**.(the result is 78.10m/s). Copy this value to the clipboard. Select equation 2. Select variable DVt and paste the value there.

6.Go back to the ORB directory.Select Equation 3. Go to variable set 1 pressing **SHFT R**. Select Vr and copy it to the clipboard. Check that CSP goes from 0 to 1 . Then go to variable set 2 and copy Vr to the clipboard too. CSP indicates 2 now. Return to variable set 1. Go to the MOV directory. Select equation 1. Paste the last copied clipboard value (1676) to the Vf variable. pressing **SHFT V**. CSP indicator should go back to 1. Select Vi and paste the first value that was copied to the clipboard (1687) there. CSP indicates 0 now. Then select DV with **SHFT ,** and solve the equation for it with **SHFT S**.(the result is -11.05m/s). Copy this value to the clipboard.

7. Select equation 2. Select variable DVr and paste the value there.Use equation 2 in MOV to calculate overall DV(it's 78.88m/s).Copy this result to the clipboard. Go to the FUE directory. Press **SHFT A** to get all ship's parameters. Paste clipboard contents into DV variable and solve equation 0 for the mf variable (aprox. 43259kg). then go to equation 1 and solve for the tbn variable (should be 6.627s). Use this result as the burn time in Timer MFD.

8. Now transfer the MOV's DVt value calculated in step 5 to the a variable in BOP directory and the MOV's DVr calculated in step 6 to the b variable in BOP. Then calculate a/b selecting c variable and calculating the value for it in equation 2.(the value is -7.07). Then calculate the arctangent for this value transfering it to the a variable and calculating for the b variable in BOP's equation 5.(it's 81.95 degrees.).
This is the angle we should have from the ship-to-Earth axis. However, one angle and one axis gives you four possibilities. It's up to you to check with logic which one of the four you should use. In our present case we are going to increase Vt (check DVt value), therefore the position has the <u>same tangential direction</u> of out current Vt direction. We are going to decrease Vr (DVr value is negative or final Vr value is smaller than initial Vr value) . Therefore our position should point <u>away</u> from Earth.

9. Make sure that the deck plane of your ship is coplanar with your Moon-and-Earth trajectory plane. Zoom your cockpit view to 10 degrees, turn on the planetary view presssing F9 and use the rotation RCS to point the bow of yor ship precisely to the center of the Earth. Then Zoom out to 90 degrees and using the ALT key and only the RIGHT ARROW and LEFT ARROW keys (do not touch up or down) bring the Moon as close to a vertical line at the center of the screen as possible. Zoom in to 10 degrees again and using only BANK RCS (do not touch pitch) bring the Moon to the center of the screen. Reset cockpit view to its default front position and redo all the procedure again until you have satisfied both conditions (Earth at the front/ Moon centered with lateral only view shifting and bank movement) properly.

10. Now load Attitude MFD and zero your position in it. Then use rotation RCS <u>yaw left or right only</u> to turn around a full revolution still keeping your deck inside the trajectory plane. Notice in the HUD where your current speed vector is (at Earth right side in this situation). Keep turning and stop when you are pointing away from the Earth. Check that AttitudeMFD shows 180 degrees. Zero Attitude MFD again. Now make a yaw only turn to the direction of your speed vector (remember: away from the Earth in the same direction of the tangential speed- this means 'yaw to the left' in this case) untill you have shifted 81.95 degrees left from the point away position. When Orbit MFD shows you at 160,000 km from the Earth activate Timer MFD to fire engines for the Timer MFD's preset time of 6.627s. Good Luck.
After the burn take a look at Orbit MFD. If your trajectory is not exactly what we intended it is , at least much closer (and safer) to it. You can refine it further repeating the procedure at each half distance i.e repeat for 80,000km, 40,000km, 20,000km. By the time you are close to perigee you are going to be close enough to circularize right on target orbit.

Limitations

The variable values are not saved with the scenario.
Variables values are the same regardless of the ship selected.
Variables are double floating point types. This format gives a range of approximately 1.7E–308 to 1.7E+308 for type double. Precision problems may occur.

Legal Stuff

I will not be held responsible for any damage caused by this software. Use at your own risk.

This software is FREEWARE, exempt of any commercial or currency stated value. As a consequence, it can't honestly be the object of any commercial transaction.

Thanks

To Martin for the great leading in the revolution of the human cultural effort.
To Tuc for trying to help me with pointer to functions . I'll learn it someday.
To Daver for patiently showing me the way to deal with graphic objects handlers.
To people at the Forum who gave suggestions and advice.
To you for the interest from an intelligent being.