Manual for TransX V3.0 MFD

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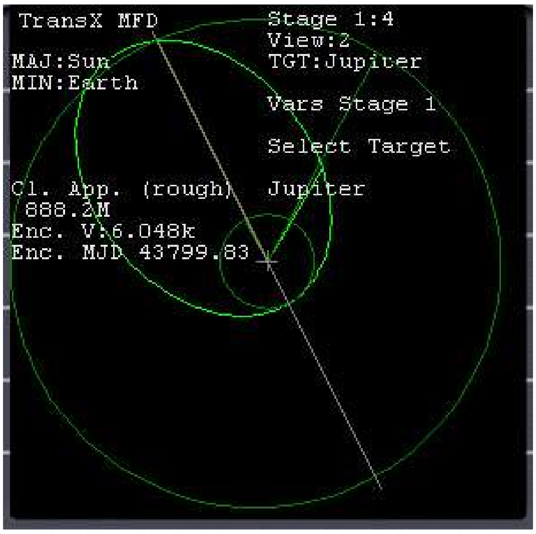

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1 Overview

The TransX MFD is an advanced navigation tool for Martin Schweiger's Orbiter space flight simulator. Its purpose is to enable you to plan and fly complex trips across the solar system.

The MFD is still under active development, and new versions are released every few months. You can find these new versions and the manuals for them at http://www.orbitermars.co.uk/

2 Disclaimer & License

This MFD is free software. Its operation is not guaranteed to be continuous or error free. It is for recreational use only, as an addon to Martin Schweiger's Orbiter. It may crash your computer, cause data loss, or cause other errors to occur. YOU USE THIS SOFTWARE EXCLUSIVELY AT YOUR OWN RISK.

You may not charge for this software. You may redistribute it, but you may not charge any fee other than to cover distribution costs. Source code for the MFD is also available at my web site above, which is covered by the license contained in it.

3 Installation

To install this MFD, copy the transx.dll file into the modules/plugins directory of your Orbiter installation.

To activate the MFD, go to the 'modules' tab on the Orbiter launchpad. Select the TransX module, and activate it.

3.1 Launching the MFD

Either select TransX from the Orbiter MFD menu, or use Shift-J to open it.

4 Basic Concepts

4.1 Stages

The TransX MFD divides your journey plan into a number of stages. Initially, the MFD starts with only one stage, which shows a graph of the body you're currently orbiting, or are landed on. But as you create your flight plan, you will create more stages. A flight from Earth to Mars, for example, would have three stages – one centred on Earth, a second one centred on the Sun, and a third one centred on Mars.

Each stage can be adjusted almost independently of the others. However, some of the planning tools (plans) pass information back and forward between stages – mostly because that is what you'll need.

The number of stages, and the number of the stage you're currently viewing is shown in the top right corner of the MFD. Initially, it will be '1:1' , as at first you're viewing the first and only stage.

You switch between stages, (and create a new stage where that's allowed) by using the FWD and BCK buttons (Shift-F, Shift-R on the keyboard).

Each stage has its own plan – on which more later.

4.2 Views

Each stage has three views. The first view isn't often used – the main views are 2 and 3. View 2 is a generic view of the stage, whilst view 3 may give different information defined by the currently selected plan. (If there is no plan, view 3 is unavailable) Each view of each stage has its own independent set of variables which you can adjust. You can switch between views using the VW button (shift-W).

4.3 Plans

Each stage may have a plan. The MFD will normally automatically select the correct plan for the situation you're in. However, it is possible to select a plan yourself if necessary. Each plan has its own set of variables that allow you to adjust it.These variables are always accessed from view 3 for that stage.

Some plans require information from the stage immediately before or after the current stage, and do not actually come into operation until that information is available.

4.4 Variables

Each view of each stage has its own set of variables. You can move up and down through the list using the VAR and -VR buttons (Shift-> and <). You can change the value of a variable using the ++ and – buttons (shift = and -). Depending on the type of variable, you can also adjust the sensitivity of the ++ and -- keys using the ADJ and AJ- buttons (sh-} and sh-{).

It is by adjusting these variables that you'll set up your flight plan with TransX.

Some variables are hidden at first. TransX will automatically adjust some of these hidden variables in order to make standard flight plans easier to use. It is always possible to turn this automation off if you need to.

4.5 The remaining control keys

There are two more keys that I haven't mentioned. The SW (shift-X) key switches the MFD into a mode where the FWD, BCK and VW keys only operate to select different variable lists, but the graph remains unchanged. This allows you to adjust the variables from one stage whilst viewing the graph from a different stage. You don't need to use this key for most things, and it is probably best to ignore it until you're fairly familiar with the MFD..

The final key is HLP (shift-H) which brings up a small amount of help on the current variable and the current plan.

4.6 TransX's colour coding scheme

TransX uses four different line styles on its graphs.

Solid green is used for two things. In the first stage, TransX uses solid green to denote your craft's path. In subsequent stages, solid green stands for the trajectory passed on from the previous stage. This green orbit is known as the Focus orbit.

Light green is used for the orbits of planets.

Yellow is used for any plan or manoevre that you are setting up in the current stage.

Grey is used for the circle depicting the surface of a planet, or for a line depicting the place in which two orbital planes intersect.

5 Basic setup for a flight

5.1 The Target Variable

The first variable in view 2 is always 'Select Target'. The target variable allows you to select your destination. Very often, this will not be your final destination, but just the next step in your journey. If you have set a target, you'll then be able to use the FWD key to create a new stage, which will show a graph of your onward journey from that object's point of view.

One option is to choose 'Escape'. This tells TransX that you wish to leave the sphere of influence of the current central body altogether. The new stage will therefore look at the big picture surrounding your current planet. If you escape from Earth, the next stage will have the Sun as the central body. If you escape from the Moon, the next stage will have Earth as the central body. The central body in these cases is always the big object that your current planet/moon is orbiting.

The other option is to choose a target object from the list. The list gives every planet / moon that orbits the current central body. So, if your current central body is Earth, the Moon will be the only option of this type. If you're orbiting the Sun, you'll have a list of planets (along with any asteroids you may have added).

The objects are all in order of mass – heaviest first.

TransX works perfectly with addon solar systems – if you install additional planets or moons, TransX will include them in its lists.

5.2 Creating a new stage

Once you have set the Target variable to Escape or a Target, press the FWD (shift-F) key, and TransX will create a new stage with the new body at its centre.

For most trips, you will want to create several stages. To go from Earth to Mars, you'll normally use 3 stages.

Stage 1 – Earth at centre. Target is Escape.

Stage 2 – Sun at centre. Target is Mars.

Stage 3 – Mars at centre. This will show you your orbit as you approach.

6 Taking off to Mars

In this section, we'll be creating a typical flight plan to Mars, to illustrate how to use TransX for flights like this one. You can use the default 'Cape Canaverel' scenario to do this. Once you've read through this section, you should be ready to understand what the MFD is doing, and to use it for simpler interplanetary trips.

The first step is to set up the stages that you need. To set up the first part of the flight, you only need two stages. The first stage you need is one that is centred on Earth. TransX will create this for you automatically when you start up the MFD in a ship near the Earth.

The second stage you need is a Sun-centred one. To create this.

- Set the target variable to 'Escape' to tell TransX that you wish to escape from Earth's gravity.
- Press FWD (sh-F). TransX will create a new stage with the Sun at the centre.
- In this second stage, set the target variable to 'Mars'.

At the same time, if you have Autoplan selected, TransX will also create the plans that you need for this type of manoevre. The plan for the Earth-centred stage is set to 'Escape' whilst that for the Sun-centred stage is set to 'Eject'. These plans are designed to work together with each other.

6.1 Eject plan variables

The second stage plan is the best place to start. Select the second stage, and the third view, to bring up the variables that you need to adjust.

In this view, Earth is known as the Minor body – it is shown by the label 'MIN:' in the TransX window. There are 4 variables in this plan that allow you to adjust how you plan to leave Earth behind.

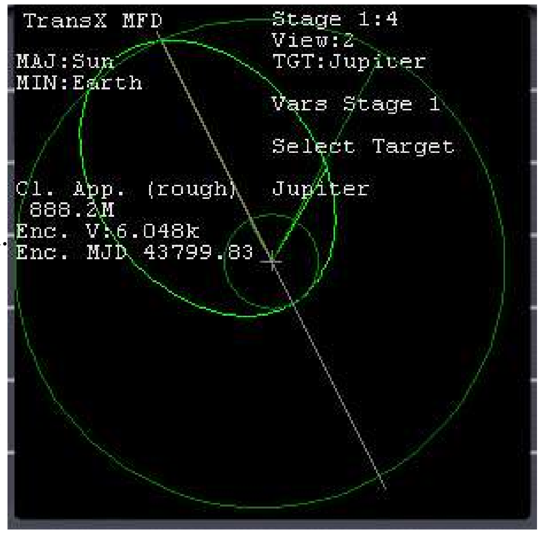
- Prograde vel. This adjusts your planned speed away from Earth in the direction of Earth's current movement. This variable is the most efficient way of increasing (or decreasing) the size of your orbit. Positive values raise your planned orbit towards the outer planets, whilst negative values lower it towards the inner planets.
- Eject Date. This is the day (and the time) when you plan to leave Earth. (To be precise, it's the time when you plan to cross the periapsis of your hyperbolic escape orbit from Earth). Trips to

other planets are much easier to achieve at some times than at others. The easier times are called 'launch windows'. Adjusting this date will allow you to find a launch window, and refine it.

- Outward vel. This adjusts the component of your velocity that's generally outward (away from the central body). The main use of this vector is to adjust your takeoff within a launch window. For Mars, additional outward velocity allows a later takeoff, whilst inward velocity allows and earlier one. (For inner planets, this is reversed) This vector is at 90' to the prograde vector, and is also in the orbital plane of the minor body. If you want the most efficient path, you can normally just use the eject date, and leave this variable alone.
- Ch. plane vel. (Change plane velocity). This allows you to adjust the out of plane portion of your velocity. Different planets orbit in slightly different planes, so you can use this to build an orbital plane adjustment into your flight plan.

6.2 Using the targeting mechanism

This aspect of the MFD hasn't changed from the previous version. The key parameter to watch is “Cl. App” which is closest approach. This is described in metres. K is kilometres, M is Megametres (thousands of kilometres) G is Gigametres (millions of Kilometres) and T is Terametres (billions of kilometres). At this stage, a good approach to Mars will be 1 million kilometres or less (1G or less)



You can see roughly what you need to do from the targeting lines. There are three straight yellow lines and one grey line which are controlled by the targeting system. One line shows the position of the Minor body when you leave it. The other two yellow lines show the closest approach between your projected path and that of the target. The grey line shows where the projected orbital plane of your craft will cross that of the planet. When you are on target, all three lines will coincide.

The best process of achieving this is as follows.

- Increase (or decrease if reqd) prograde velocity until your planned orbit just crosses that of the target.
- Use the eject date to move the takeoff time until the two yellow lines coincide.
- Use the Ch. Plane vel to adjust the grey inclincation line.

Then use all the variables to reduce the closest approach distance until you're happy. When you're finished, TransX should look something like this.

6.3 Escape plan variables

After you have finished this, you can go back to the first stage (BCK, sh-R) and adjust the variables of the escape plan in view 3.

You will see, straight away, a yellow hypothetical orbit which TransX has calculated using the default values, and a grey line showing the intersection of your current orbit with the calculated one. (If you're landed, this doesn't have an immediate use!) This orbit is the track you plan to follow to escape from Earth in the direction you set in stage 2.

It has three variables

- Periapsis distance. If you're taking off, the best place to put this is right above the surface. Lower it slightly, so that it's clear of the atmosphere, but a little lower than before.
- Ej Orientation. This variable allows you to rotate your planned orbit around the eject vector that you planned in stage 2.
- Equatorial view. This variable allows you to choose to view the orbit from the equatorial plane of the current central planet. At present, this view only works if the central planet is also the current surface reference (as decided by Orbiter). It always works in low orbit, or whilst landed. This view can be helpful in aiding you to take off at the right time.

Every hypothetical orbit set up using these variables will send you off in the right direction for Mars.

6.4 Other variables

There are also variables in view 2. These are mostly used for controlling the stage as a whole. This is not an exhaustive list – see remaing variables in section 10.

- Target – You've seen this one already. You use this to set your target, and the way in which you'll leave this stage for the next one.
- Autoplan – This is on by default, and should be left that way until you've made a few flights. When autoplan is on, TransX will automatically select a suitable plan for the stage, based on the target and any previous stages. Plans may have their own variables, and their own graphs and text, and these can be seen in view 3 of any stage.
- Manoevre mode – This is a tool to allow you to define a course correction manoevre (or even a larger manoevre on occasion). For now, leave this switched off.
- Intercept with – This controls which orbit interacts with the targeting system, and also which orbit is 'passed on' to the next stage. Auto works most of the time, but you can manually set it to either the focus orbit (your craft, or the orbit passed from the previous stage), the orbit in manoevre mode, or the plan's orbit.
- Graph projection – This allows you to change the position from which you see the graphs.
- Scale to view – Set to Target if your view of the target orbit is too small.
- Advanced – This gives full access to all TransX variables. Leave off for now to avoid confusion.

6.5 Taking off and leaving Earth behind.

The escape plan's view 3 contains a few things to help you with taking off at the right time and in the right direction. The grey line shows where your planned orbit's plane crosses your current 'orbit'. When this line is close to your actual position, it's a good time to take off.

When you're on the ground, view 3 also shows the heading on which to take off. Make a note of it. Once you take off, TransX instead shows the relative inclination between your craft and your planned orbit. You should use these guidelines to take off directly into almost the correct orbital plane.

When you reach a circular parking orbit in the same plane as your planned orbit, shut down the engines. You may wish to clean up the alignment completely once you reach orbit.

You then need to make a further prograde burn later to take you directly into the hyperbolic orbit that you've planned. TransX provides some angles and timings to make this task easier, but does not compute it directly, as the exact time to burn depends on the type of ship you are using.

There are a number of options.

1. Figure out how long it will take to make the whole burn, and divide this number by 3. This gives a rough estimate of how many seconds before periapsis you should open the throttle.
2. For a more accurate method, save the game at a point safely before the point the burn should be made. Then open the throttle a given number of degrees before periapsis. After the burn is complete, you will be able to see the relative difference between the semi-major axes of your actual trajectory, and that you originally planned. Go back to your saved game, and use this knowledge to open the throttle that either earlier or later by that many degrees. You should hit the required trajectory exactly.
3. You can always use the 'Buck Rogers' technique of just guessing!

Remember you can always save your game before you make this burn.

The DeltaV line will help you gauge when to shut off the engines – it will count down to zero as you move to the required orbit. Alternatively you can watch the graph for stage 2. Either way, shut down the engines when you're happy with the burn.

For planet to planet transfers, the timing of your exit is not too critical – if you're within a day of your planned time, things will be OK. (This may be less true in other, more cramped situations, such as Jupiter's moons).

Coast away from Earth for a while. You will pass beyond the orbit of the moon – further and further from Earth. Eventually, TransX will react to your increasing distance from Earth by declaring stage 1 of your journey completed, and will automatically delete it. There will now be only a single stage again – this time around the Sun.

7 Manoevre mode, and course corrections

If you're anything like me, your flying isn't perfect, and course corrections are sometimes required because of that. TransX also does not take into account the influence of every single body in the solar system, so the subtle influences of distant planets will also change your course (and that of your target planet) over time. So, every now and then, there's a need to correct your trajectory.

For small corrections, it's pretty easy just to use manoevreing thrusters, and by trial and error, find the course correction you want. However, for larger corrections, this becomes wasteful.

This is where the Manoevre mode comes in useful.

Switch manoevre mode on using the manoevre mode variable.

You then have four variables (Prograde vel, Outward vel, Ch plane vel and Man. date) to use to correct your course. These work in a similar way to the variables in the Eject mode, only they are based on your current orbit rather than on the orbit of a planet.

You can then use the manoevre to refine your trajectory towards the target, using the Cl. App. line as a guide.

(It is also possible to create further stages, and view them, whilst adjusting the variables for this manoevre. To do this, select the stage you want to view, then press SW(sh-X). The view will then remain static, whilst you are still able to select variables. This can be useful if you are indirectly adjusting something like a slingshot trajectory.)

Once you're happy with the manoevre, change the view to view 1, which is a special view for the manoevre mode. You will see a target and some crosshairs. Move the crosshairs to the centre of the target, and your ship will be pointing in the right direction for the manoevre. Fire the engines prograde until the remaining velocity is near zero.

It is also possible to use the manoevre mode to create large changes to your orbit. This is also useful in certain situations. In particular, it is the standard way of creating a transfer orbit from low Earth orbit to the moon. Note that for large manoevres in tight orbits, such as low Earth orbit, using view 1 may not work as well as just eyeballing the burn using view 2. You can of course do either, as you wish.

8 Arriving at the planet

To tune your arrival trajectory at the target planet, the best way is to create a new stage at the target. Since the target is already set as Mars, simply move FWD to create the additional stage.

The graph accounts, by default, for the gravity of both the central object and the object it orbits around. It is just as accurate as the Encounter MFD.

Switch to view 3 for further information about your Encounter, which is available on the auto-selected Encounter view. There you can see any surface base that you've selected using the Map MFD, and get information on how close your current trajectory comes to it. (Note that planetary spin is not currently taken into account, as Orbiter lacks any function to return this information.)

You can tune your trajectory whilst viewing this graph to enable you to aim your pass over the planet for a specific altitude and inclination.

9 Slingshots

Please note that slingshot trajectories are more difficult to fly than standard planet to planet transfers. Your first interplanetary trip should probably consist of a simple Earth to Mars or Earth to Venus scenario. However, if you're looking for a new Orbiter challenge, a gravity assist may be just what you're looking for.

To set up a slingshot (gravity assist) trajectory past a planet such as Jupiter, proceed as follows.

- Set Jupiter as a target. Move FWD to create the stage.
- In the new stage, set 'Escape' as the target. Move FWD to create the stage.

This process creates the required stages. If autoplan is on, it also creates two new plans – 'Slingshot' in Jupiter's stage, and 'Sling Direct' in the following stage. Switch to view 3 in the final stage to see the first set of variables.

9.1 Variables for 'Sling Direct' plan.

The process of aiming a slingshot is conceptually similar to that of ejecting from a planet in the first place. The main difference is that, because it's a slingshot, you may not want to change your velocity as you pass the planet. The aiming process is therefore done using polar coordinates. The default is that the slingshot is aimed in a purely prograde direction.

In many cases, a planned slingshot can't be done in practice because the planet you're passing isn't big enough to turn your orbit as required. Because of this, the ratio of your required closest approachof the orbit needed against the planet's radius is shown in view 3 of this graph. If this figure is less than 1, your proposed slingshot isn't actually possible in practice because the planet you're passing isn't man enough to turn your trajectory as much as you're asking it to.

The variables for the sling direct plan are as follows.

- Outward angle. As this is increased, it directs the direction of the slingshot outward, rather than along the prograde vector as it does at 0. Setting this to 180' points the slingshot in a retrograde direction.Negative values of the angle correspond to an inward direction.
- Inc. angle. This is the angle out of the orbital plane that you wish to depart the target planet.

- Inherit vel. Selects whether velocity is to be inherited from the previous stage, or set using a variable. Default is that it should be inherited.
- Velocity. Set the departure velocity from the planet. If you set a departure velocity, TransX will assume that you intend to add extra velocity where it's most efficient to do so – at the periapsis of your pass of the slingshot planet.

The time at which you depart from the planet is not currently adjustable, and is the time at which you reach closest approach.

Adjust these variables until you're happy with the result.

9.2 The slingshot plan

Nearly everything about a slingshot is defined by the stages on either side of it. As a consequence, there is only one variable in this plan, and this adjusts how you view the orbit.

If the exit speed of the slingshot is different from the entry speed, TransX assumes that you make the alteration at Periapsis, where it is most efficient to do it, by either prograde or retrograde thrust.

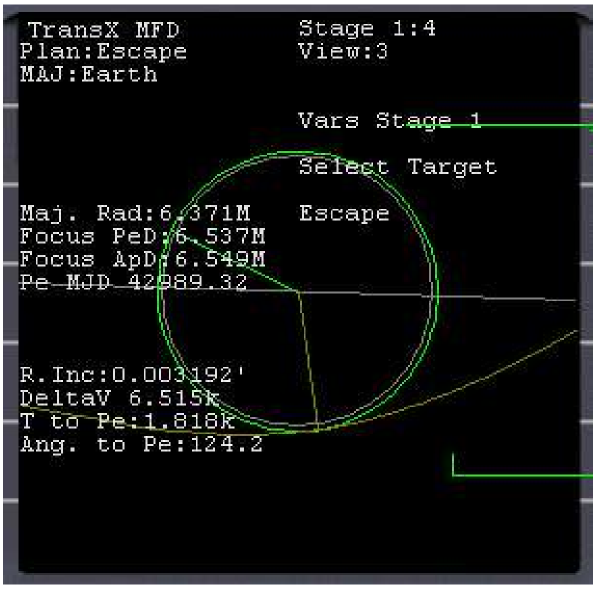
The only variable allows you to select whether you view the calculated graph for the inward or the outward planned path.

View 3 is (unusually) quite different from view 2. It shows two lines – the yellow line is the location of the periapsis of your planned path, whilst the green line is the periapsis of the focus orbit(your craft, or whatever you passed on from the previous stage). Align the two lines to set up the approach to the slingshot accurately.

The best time to set up a slingshot is when you are still a long way from the planet. As you get closer to the planet, the estimated slingshot wanders less and less, but large adjustments take more and more fuel. The ideal method is therefore a succession of adjustment manoevres as you get closer to the planet. For Jupiter in particular, a slingshot can be aligned even when you're several AU from the planet. By the time you enter Jupiter's sphere of influence, it is generally too late to adjust much of anything without enormous wasteage.

10The views

10.1Escape plan view



This view shows information designed to help you get into space, and on your way.

The brown orbit is the hyperbolic orbit you need to follow in order to escape from Earth in the planned direction. Most parameters defining this orbit are set in the following stage.

Maj, Rad, - This is the radius of the major body. The major body is the same thing as the central body. In the graph opposite, this is the Earth.

Focus PeD and Focus ApD. These are the periapsis and apoapsis of the focus orbit. In nearly all cases, this will actually be the orbit of your craft. Whilst taking off, PeD will gradually rise from deep inside the planet. Once PeD is greater than the Major

Radius (and perhaps a bit more to allow for the atmosphere) then you are in orbit.

Pe MJD is the time when you will next reach the periapsis of your current orbit (not of the plan). This isn't useful for most escapes, but it can be useful if you're trying to target a trip to the central body.

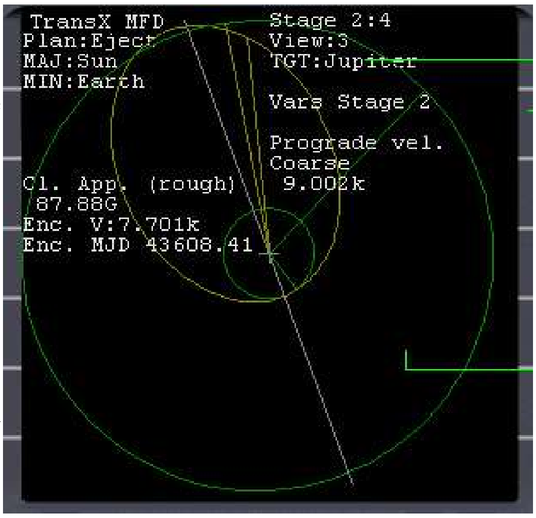
R.Inc. This is the difference in relative inclination between your planned escape orbit and your focus orbit.

Delta V This is the remaining velocity you need to gain in order to escape at the velocity required. (Note that this is purely an energy calculation – it does not check that your energy is in the required direction!)

T to Pe: The number of seconds until your closest approach to the plan's PE. This may help you to judge when to apply power – typically around 1/3rd of the total burn time required should be before Pe.

Ang. To Pe: The angle between your current position and the plan's periapsis.

10.2 Eject plan view



This plan is typically used for setting up a departure from a starting planet. This starting planet is shown on the graph as the Minor planet (MIN). The other figures on the graph are

Cl. App – Closest approach. This is a rough estimate of the closest approach that your planned trajectory will make to the target. This figure does not take account of the target's gravity, which typically will pull the craft in, and make the actual approach closer than this.

In order for the chain of trajectories from one stage to the next to be complete, you should aim to get your trajectory inside the sphere of influence of the target planet or moon. The size of this varies dramatically depending on the situation, but for most planets is at least 800M, and for the outer planets is much more. Adjust your trajectory to lower this distance to get a better quality approach. But for accurate figures of how your trajectory looks at the target, move into the next stage.

Enc V: This is the velocity difference between the target and the craft at closest approach. This figure again doesn't take the target's gravity into account – which can make a big difference. Typically this

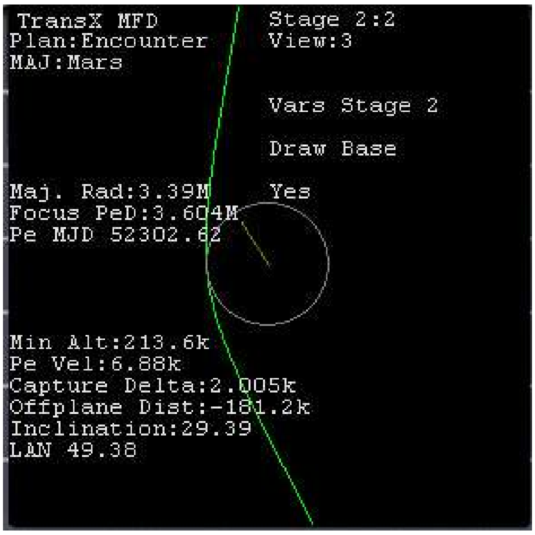
Enc MJD: This is the time of intercept. This also doesn't take the target's gravity into account, but is usually pretty close to the truth

The targeting system creates the two yellow lines and the grey line. The two yellow lines show the closest approach – these should be adjusted so that they are on top of each other. The grey line shows where the orbital planes cross. For a perfect intercept, all the lines should coincide.

10.3 Encounter plan view

This view gives a bit of additional information on your orbit as you approach a planet.

The yellow line shows the location of any surface base you've selected using the Map MFD.



Min Alt: gives the minimum altitude above the planet's surface.

Pe Vel: gives the velocity at periapsis.

Capture Delta gives the amount of velocity decrease needed to turn the orbit into an ellipse.

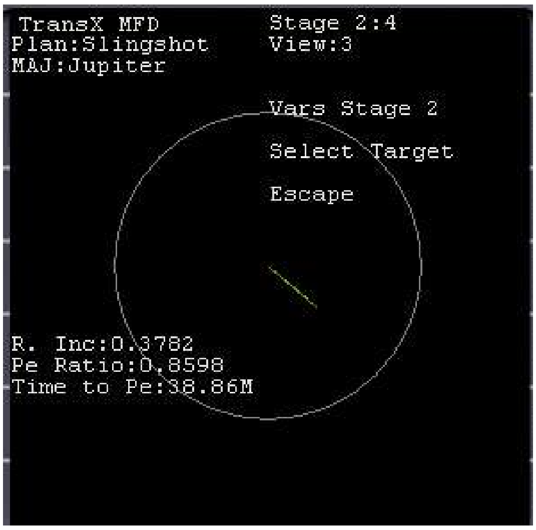
Offplane dist: This is the distance that the surface base is away from the orbital plane.

Inclination and LAN – these are standard orbital parameters, as given as Inc and LAN on the Orbit MFD.

If the orbit actually intercepts the planet, the minimum altitude figure is replaced with "L.site to Base" an estimate of the distance between the landing site and the base. This estimate is based on your current orbit.

10.4 Slingshot plan view

The slingshot view is designed to help you line up a slingshot past a planet. This one shows a slingshot I set up past Jupiter.



You line up a slingshot using a course correction – usually whilst still in the influence of the stage before. As you can see, this one is the second stage out of four, and at this time the craft is still several AU from the planet.

To line up a slingshot, you need to align the green and brown lines (here they are very close). The two lines are the periapsis of your actual (green) and required (brown) orbits. R. Inc shows the relative inclination of the two orbits.

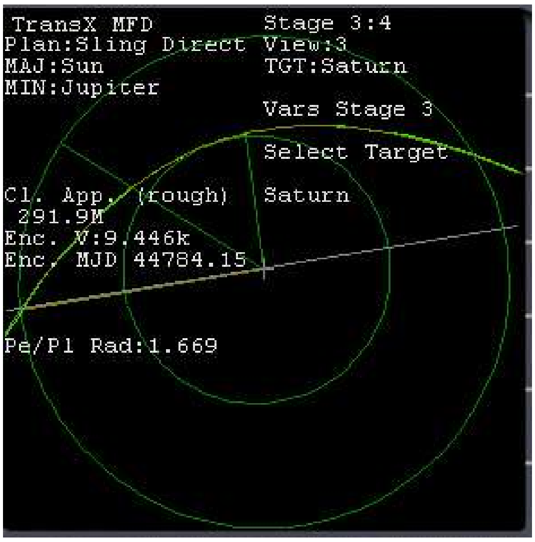
Pe Ratio is the ratio of the lengths of the two periapsis lines. To set up a slingshot, R. Inc should be near to 0, and Pe Ratio should be close to 1.

Time to Pe gives the time in seconds until you are due to arrive at Periapsis.

10.5 Sling Direct plan view

This plan is automatically started following a slingshot manoevre. In this case, there is a slingshot planned at Jupiter in stage 2, and this plan gives the onward leg to Saturn.

There are two significant differences – one is that radial coordinates are used to define the path on from the planet. The other is an extra line – Pe/Pl Rad: This gives the ratio between your Pe at your slingshot planet.and the radius of that planet. If this number is less than 1, then the slingshot is too tight - the planet is too small to be able to turn your trajectory that far.



The trajectory (and velocity) set in this plan will be reflected in the previous slingshot stage.

11 FAQ

Q: How do I use TransX to go to the moon?

A: The best method at the moment is to take off into a coplanar low earth orbit using standard orbiter instruments. Then use the manoevre tool to create a long ellipse out to the moon, by using a prograde burn at the right time.

The time is VERY sensitive with this manoevre. Turn the sensitivity up to at least 'Super' before adjusting the time of the burn.

I'd recommend not using view 1 for the manoevre in this case. Instead, use something like the orbit MFD to help you eyeball the burn.

Q: How do I get to the inner planets?

A: Set a negative prograde velocity in the Eject plan in the second stage.

Q: How do I get back from the moon?

A: That depends on your situation. If you're in a standard craft sitting on the surface, simply set a target of Escape, and use the Eject and Escape planning tools to set up a return orbit to Earth. Set no target in stage 2.

If you're in Apollo, use the manoevre tool to set up a burn from the command module's orbit in stage 1 rather than using the eject plan in stage 2. Turn time sensitivity down, and carefully change the time of the burn and the size of it until you have a suitable Earth return orbit. Target in stage 1 should be 'Escape'.

Q: How do I set up a whole set of complex slingshots like the Voyager mission?

A: Timing is everything. Arrive at a planet at the wrong time, and there could be nowhere you can usefully get to with a slingshot ! Therefore plan these things before you even take off. A Voyager scenario can be planned before you take off – even though it consists of quite a few stages !

Q: I want to set up some complex slingshots in the inner solar system, but it's too hard. Why?

A: It is genuinely very difficult to do this, and this version of TransX doesn't have a full set of tools for this job. Most real trajectories in the inner solar system involve repeated encounters with the same planet, interesting deep space propulsive manoevres, and resonant orbits with planets involving fractional resonances (eg 4 target orbits to 3 spacecraft orbits). You may be able to do a Pioneer-style slingshot past Venus to Mercury, though.

12 Reference

12.1 View 2 variables

Here are the remaining variables for view 2 not covered elsewhere.

- Plan type. This variable is only available in advanced mode. It allows you to choose the type of plan you wish to put in place. Normally this is automatically selected. This variable allows you to select it yourself.
- Plan. The options here depend on the plan type. All the possible plans are Eject, Sling Direct, Escape, Encounter and Slingshot. Further plans will be developed over time. You will see some plan options if autoplan is switched off. To put a new plan into action, simply change the viewmode to 3, and TransX will create the new plan.
- Select minor. This allows you to select the minor body. Normally this is autoselected. Advanced mode only.

12.2 Errata

If you change the target of a stage when there are already stages following it, any attempt to go forward into those stages will delete them. One new stage with the correct target will then be created.

A maximum of 99 stages are permitted at any one time.