Orbital Operations Manual

Aligning, Syncing, and Docking with a Space Station

by Jared "Smitty" Smith

Getting Started

This tutorial will guide you through the process of Aligning, Syncing, and Docking with a Space Station. You will learn not only the procedures for doing this, but the orbital mechanics involved and why you are doing certain things. You will learn a very accurate, efficient, and easy way to complete these procedures.

Requirements:

- Orbiter - Space Flight Simulator 2005
- A ship that is in orbit. This tutorial will use the default Delta Glider, though you can use any ship that has either big fuel tanks or a lot of thrust.
- A space station to dock with. The station should be in a stable orbit. We will be using the ISS as our target.

In the Orbiter Launchpad, select the Parameters tab and enable Orbit Stabilization, deselect Nonsperical gravity sources, and if you are in a ship with limited fuel or thrust, deselect limited fuel before beginning. Once you have mastered these techniques with these parameters set, you can change them for a bigger challenge.

This tutorial uses the default Delta Glider to dock with Orbiter's default International Space Station (ISS), though most any spacecraft and space station with a docking port will work. If you're using the Space Shuttle, then additional adjustments must be made to account for the fact that the main thrusters add an element of rotation. If you're not sure how to get into orbit, figure that out first.

If you'd like a scenario file to get you started, **open the Space Stations\mir.scn** or if you have the Delta Glider III, **open DeltaGliderIII_2005\Earth Scenery\Docked to MIR.scn scenario** from the Orbiter launchpad.

This scenario will place you in orbit docked to the Mir space station, which in real life is about the worst place to be in orbit if you want to go to the ISS because the orbits of these two space stations are very different. This was done intentionally because the Russians did not want to have to track two space stations at the same time, so they insisted that the orbit of the ISS be such that it was never overhead at the same time that Mir was. As such, it makes transfers between the two space stations very difficult.

If you are starting from the surface, you can significantly reduce the amount of work (and fuel) required to reach a space station by using the Map MFD to launch when the space station in question is passing almost directly over your launch location. As you launch, you should use the Map MFD to closely align your orbit with that of the space station.

However, in Orbiter, Mir has been put in a nice ecliptical orbit, though the orbit is still quite different from that of the ISS. This will really help us learn the fundamentals of aligning and syncing our orbits. It also means that we need a theoretical ship such as the Delta Glider because current realistic space ships (such as the Space Shuttle) wouldn't have enough fuel to get from Mir to the ISS.

First, some terminology:

- Aligning Orbits - aligning the plane of your orbit so that it coincides with the orbit of the target space station.
- Syncing Orbits - adjusting the speed and altitude of your orbit so that at some point in time you will pass very close to the target space station.
- Docking - orienting your ship in a manner that you can connect the docking port on your ship with the docking port on the target space station.

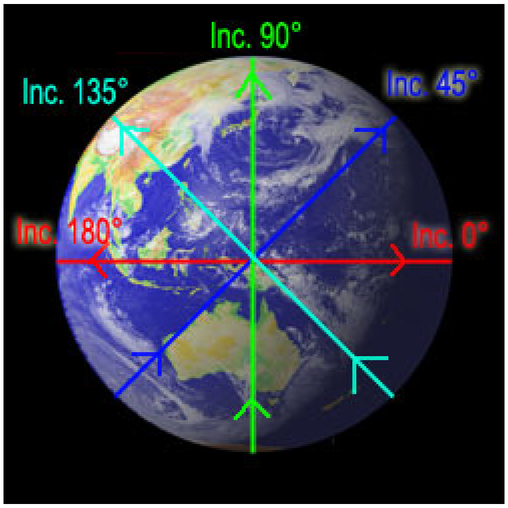
Aligning Orbits

Overview

OK, here's some more terms:

- Orbital Plane - the plane on which your elliptical orbit is placed. The orbital plane always passes thru the center of the earth, but may be tilted to any angle relative to the equator. Imagine taking a BIG piece of flat paper and laying it on top of our orbit. This is the orbital plane.
- Inclination - the amount of tilt of the orbital plane in relation to the equator. An inclination of 0 degrees is an orbit directly above and oriented exactly with the equator at all times. An inclination of 90 degrees is an orbit that crosses over both the north and south poles and passes over the equator at two points.
- Longitude of Ascending Node (LAN) - a measurement of the point at which an orbiting ship crosses the equator heading south to north.

Let's take a closer look at these terms. Inclination and LAN are both measures of the orientation of an orbital plane. They are used to define what the orbit looks like in relation to the Earth. Inclination is the amount of tilt the orbital plane has. This is a number between 0 degrees and 180 degrees. An orbit with an inclination of 0 degrees is exactly over the equator and travels in the same direction as the Earth is rotating (West to East or Prograde). An inclination of 180 degrees is also exactly over the equator, but travels from East to West (retrograde). An orbit with an inclination of 90 degrees passes over the poles.



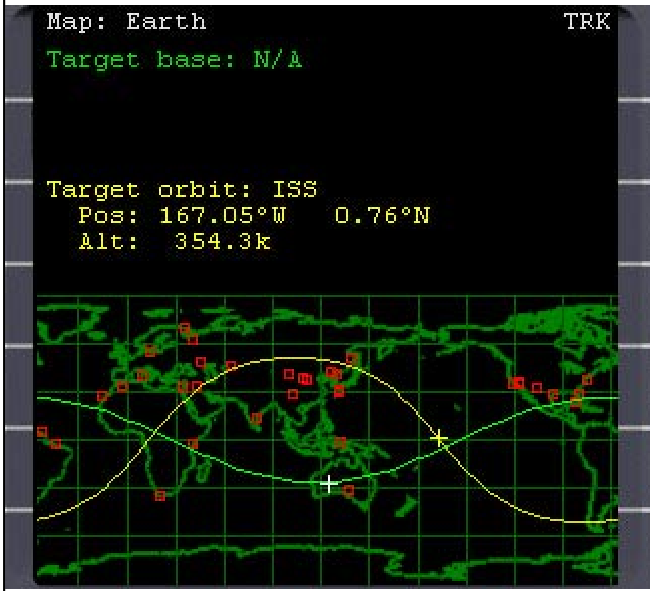
If an orbit's inclination is anything other than 0 or 180 (over the equator), then it will pass over the equator twice in each orbit. Longitude of Ascending Node is a measurement of the point at which the orbit crosses the equator when heading from South to North (ascending). In Orbiter, this is a number from 0 to 360 degrees. Don't confuse the word 'longitude' in this sense with the longitudes used on Earth for navigation. The Earth based longitude (e.g. 40 degrees west longitude) at which an orbit crosses the equator changes all the time because orbits may be short or faster than others and because the Earth also rotates underneath the orbit. Longitude of Ascending Node when talking about orbital planes is a more absolute measurement based on the Earth's position with the sun. It has to do with the Vernal Equinox and a bunch of other complex things, but for our purposes, it's just important to know that LAN is a measurement of the point at which the orbit crosses the equator at a given time.

Technical mumbo jumbo

If you're only interested in getting to the ISS and don't care what is REALLY happening, you can skip this part.

Two orbital planes can have the same inclination, but different LAN's. This is a very important point. In the image above, the 45 degree inclination orbit (blue line) is crossing the equator somewhere north of Australia. At the exact same point in time, another orbit can have the same inclination (45 degrees), yet it might be crossing the equator in South America. The inclinations are the same, but the LAN's are quite different. In fact, in this case, the orbits will basically be perpendicular to each other, even though the inclinations are the same.

So, to get from Mir to the ISS, we not only have to adjust our current orbit so that the **inclination is the same**, but we also need to ROTATE that plane around the center of the Earth so that it crosses the equator at the same place and going the same direction as the target orbit (i.e., the **LAN is the same**). In real life, the inclination of Mir is the same as that of the ISS, but the LAN's are very different. In Orbiter, the inclinations and LANs are both different. You can see this by opening the Map MFD (Shift + M) and targeting the ISS (click the TGT button and enter ISS).



In real life, Mir and the ISS have the same inclination of 51.6 degrees. This inclination was chosen so that the Russian's could launch from their very northerly (51.6 degrees north latitude) launch site and service both space stations. Although the inclinations are the same, the LAN's are very different, making it very difficult to get from one to the other. The inclinations of Mir and the ISS is also quite different from that of the moon or any other planet, making them poor places from which to start interplanetary travels, because a large orbital plane change is required. In Orbiter, however, Mir has been placed on the ecliptic, making it a great starting (or stopping) point for interplanetary missions.

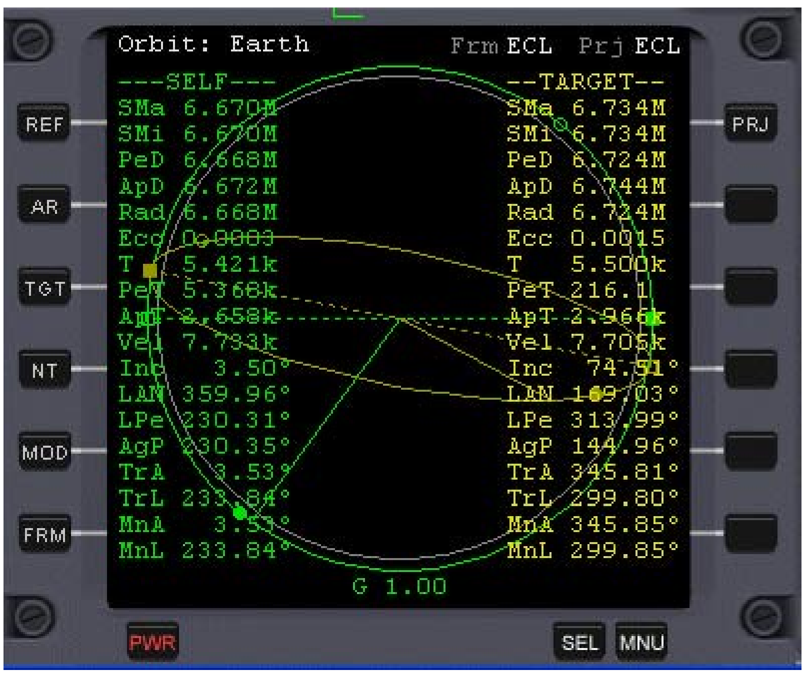
Notice that the orbits cross at nearly right angles. We have to move and rotate our orbit so that it overlaps the orbit of the ISS. Once we're done, we will be either directly ahead of or directly behind the ISS in it's orbit.

The Align Planes MFD

The Align Planes MFD contains all of the tools we need to orient our orbit. As long as you're in a stable orbit around Earth, don't worry about anything else at this point. Orbit eccentricity and altitude really don't matter that much - aligning the plane is the most expensive maneuver (in terms of fuel) that we will be doing - getting the rest of the way to the ISS will require only small maneuvers.

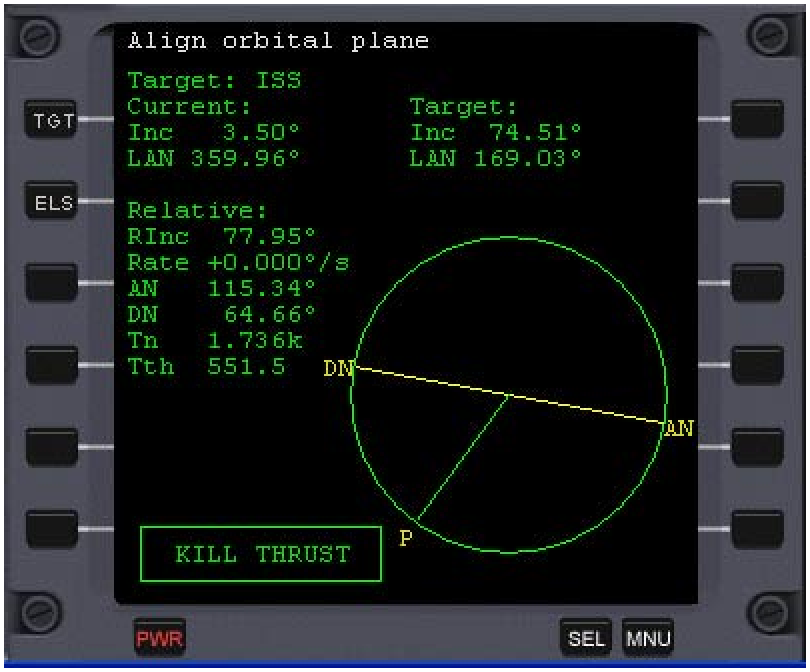
HINT: Many tutorials tell you to set your orbital altitude to that of the target and to reduce eccentricity to 0 before you align orbital planes. While this does work, you will have to change your orbital altitude later to synchronize your orbits (unless you are VERY lucky). I find it easier to align first, then use the existing differences in altitude to help synchronize. This seems to make more sense than to waste time and fuel to set up a perfect orbit and then turn around and HAVE to mess it up to synchronize.

Open the Orbit MFD in the right display (Right Shift + O). **Set the Target to ISS** (Right Shift + T and type in ISS). The Orbit MFD displays your orbit surrounding the Earth from a top-down perspective. The grey line is the surface of the Earth (if all goes well, we will be avoiding that), the green line is our orbit, and the yellowish/tan line is the orbit of the ISS.



You can see the entire orbit of our ship in the top down view. The ISS has an orbital inclination of 74.51 degrees, which you can see is very tilted when compared to our own. At this point, the only thing you really need to be concerned about here is ensuring that your PeD (periapsis, or low point of your orbit) does not go below 6.550. If it does, we'll start hitting the atmosphere and that will corrupt our orbit.

Open the Align Planes MFD in the left display (Left Shift + A). **Set the Target to ISS** (Left Shift + T and type in ISS). This display shows our own current Inclination (Inc) and LAN and the Inc and LAN of the ISS (displayed under Target:). The Align Planes MFD also shows the difference or relative inclination between our orbital plane and the orbital plane of the ISS (RInc). This is the number we are most concerned with. We want RInc to be 0 degrees. The other numbers will help us time our alignment burns.



The Align Planes MFD also shows a graphical representation of our orbit - the green circle. The straight green line and the P indicate our current position in our orbit. The AN (Ascending Node) and DN (Descending Node) markers indicate where our orbital plane intersects the orbital plane of the ISS.

This is NOT to be confused with the Longitude of Ascending and Descending Nodes of our own orbit in relation to the equator. In this case, it is simply where our orbital plane and the ISS's orbital plane meet. If you have two objects that orbit the same object, their orbital planes will either be exactly the same or they will cross each other along a straight line. The points where your ship crosses this line are visible are the AN and DN. You can also see these intersections if you look at the Orbit MFD and at the Map MFD. The Ascending Node is the intersection in which we cross the target orbit heading south to north.

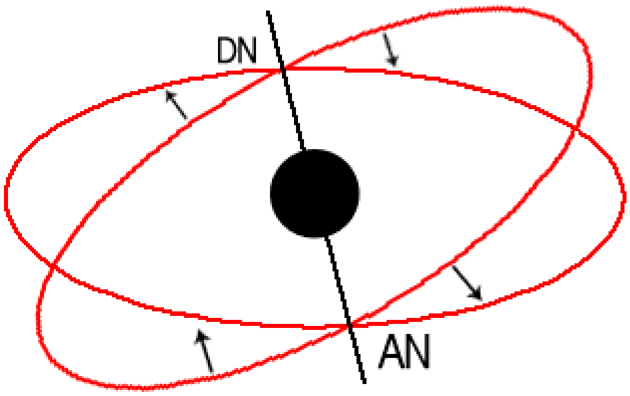
In this case, our ship and the ISS are both heading from West to East (prograde). If one of us were heading the other direction (retrograde), then the Relative Inclination would be even greater (requiring a bigger adjustment to get them aligned).

We want to make our orbital plane adjustments near the Ascending and Descending Nodes. In doing so, we will both change the inclination of our orbit to match that of the ISS AND we will also rotate our orbital plane so that it rests at the same location as the ISS's orbital plane (i.e., the LANs of our orbits will be the same).

Technical mumbo jumbo

Here's more details on what the plane change burn is actually doing. If you're not interested, you can skip this section.

We will time our burn to straddle the points where our orbital plane intersects that of the target's orbital plane (either Ascending Node or Descending Node). We will fire our thrusters so that we are pushed perpendicular to our current orbital plane. If you turn on the prograde autopilot, this would be directly up or down (assuming you're strapped in the pilot's seat and not floating around the cockpit!). Thrusting perpendicular to our orbit will have little effect on the eccentricity or altitude or our orbit. It will merely rotate and move our orbital plane (which always passes through the center of the Earth) around to a different position. The trick here is to rotate it to the correct inclination AND have it cross the equator at the same place as the orbit of the ISS.



Imagine that the orbit of our ship and the ISS are two steel rings that are connected at two points directly opposite of each other. The rings are designed to pivot freely (change their inclinations), but are locked together at the intersection points. If properly rotated, the rings will coincide and appear as one ring. If we time our thrusts to straddle the Ascending Node or Descending Node intersection (as read in the Align Planes MFD), we will pivot our orbit around the point at which the two orbits currently intersect.

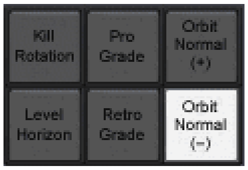
The places of intersection will only change slightly as we do this, but the inclination of our orbit will change a lot. In essence, we will be changing the inclination of our orbit by rotating it around a defined location which happens to be where the two orbits intersect. When we're done, both the inclination and LAN will be the same.

Aligning the Planes

If you haven't done so yet, **undock from the Mir (Shift + D)**. **Ensure that linear translation thrusters are enabled (Numpad /)**. Tap the NumPad 9 key a time or two to thrust away from the space station. **Close your nose cone (K key)**.

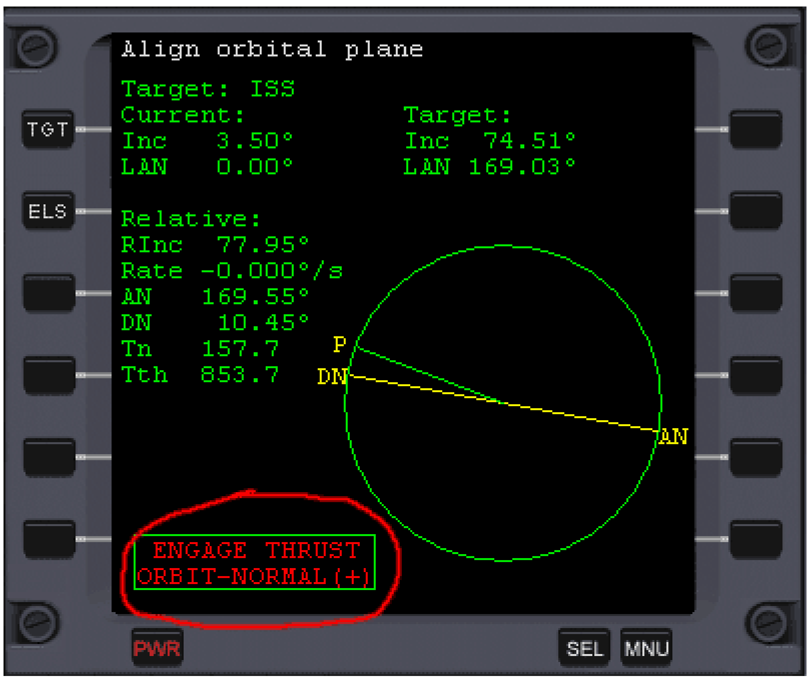
The Align Planes MFD provides all of the information we need. Determine the current location of your ship (P). **If your ship (P) is approaching the Ascending Node (AN) indicator, you want to thrust pointing**

orbit anti-normal, so engage the Orbit Normal (-) autopilot. An easy way to remember this is that **A**scending **N**ode and **A**nti-**N**ormal both start with AN.



If your ship is approaching the Descending Node, you want to thrust pointing orbit normal, so engage the Orbit Normal (+) autopilot.

Watch the Align Planes MFD until the KILL THRUST message changes to ENGAGE THRUST and then **engage main thrusters** at full throttle (NumPad +).

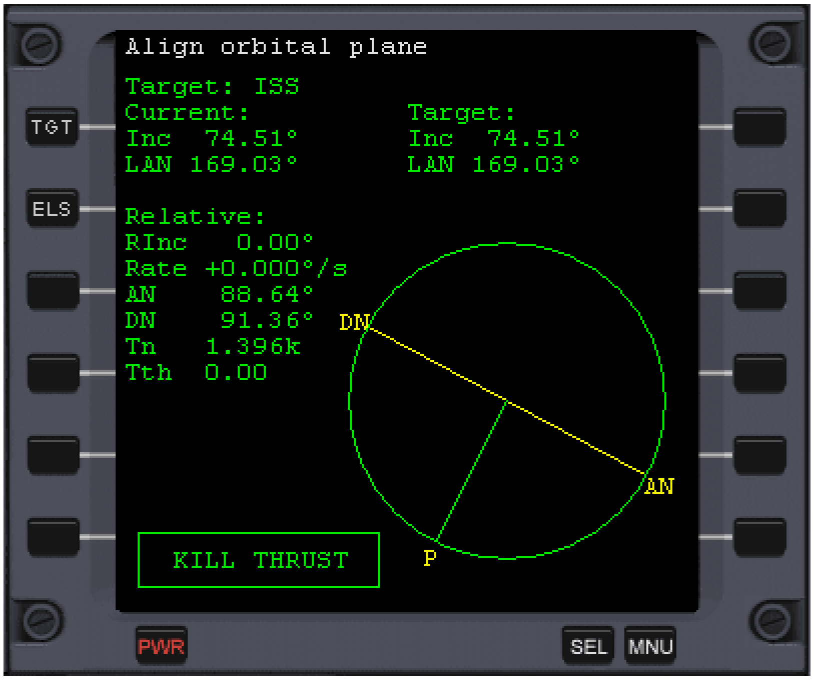


As you thrust, RInc should begin to decrease. If it increases, then you're pointed the wrong direction (and didn't follow the directions above). **Continue to thrust until the either RInc is close to 0° OR the ENGAGE THRUST message changes to KILL THRUST.** If you don't get RInc close to zero on your first time, it's OK, just turn on the opposite orbit normal autopilot and wait for the ENGAGE THRUST message to display again. The Tn number in the MFD is Time to Node in seconds. The Tth is the estimated length of the burn. Because our thrusts will straddle the nodes, the ENGAGE THURST message should display when Tn is one half of Tth. Because of the large difference between our orbit and the orbit of the ISS, the burn will be quite long. You may want to use 10X time compression (T and R keys).

Because of the large RInc, it may take 2 or 3 burns before RInc will get close to 0°. Just engage the thrust when the MFD instructs and make sure your pointed the right direction (orbit anti-normal at AN and orbit normal at DN).

As soon as RInc gets very close to 0°, the AN and DN indicators will quickly move away from you and the

KILL THRUST message will display. With the orbit normal autopilot still engaged (+ or -), you can now ignore the Align Planes messages and tap the main (NumPad +) and retro thrust (NumPad -) buttons to **get RInc as close to 0° as possible**. You can use the linear translation longitudinal thrusters (NumPad 9 and 6 keys) for even finer control. You should be able to get it to less than .1° in this manner. You can further refine this at your next crossing of the AN or DN to get RInc to less than .05°. As you adjust RInc to exactly 0°, you will notice that your ship AN and DN will move so that your ship is located half way between them.



Relative Inclination is 0°. Inclination and LAN of my ship and the target ship are the same.

Congratulations, your orbital plane is now aligned with the orbital plane of the ISS.

Synchronizing Orbits

Overview

The objective of synchronizing orbits is to have us and the ISS be in roughly the same place at the same time while having a manageable difference in our speeds.

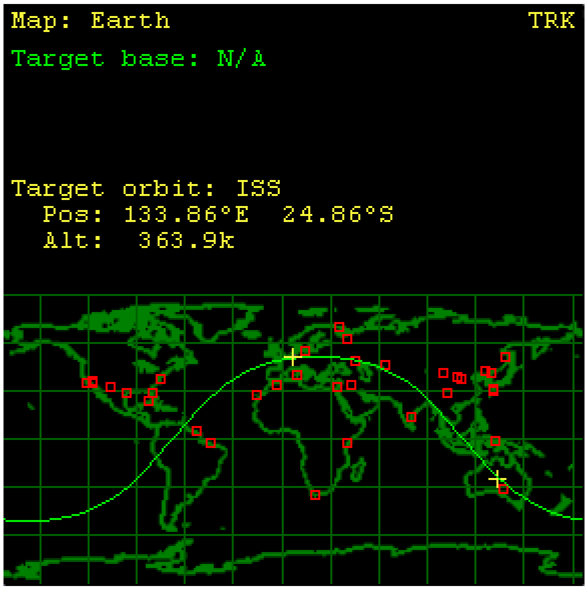
First, turn off the autopilot and just float around for a while and enjoy the scenery while you read this section. The quickest way to NOT dock with a space station is to get in a hurry!

Before we continue, here's a little bit about basic orbital mechanics that is important. The larger the orbit is, the more time it takes to get around the Earth. The smaller the orbit, the faster you are going. OK, so there's little rocket science in those statements. The thing that often confuses newcomers to Orbiter is that if you want to slow down, you must thrust forward, or in the direction you are traveling (prograde). If you want to speed up, you thrust backwards or against your direction of travel (retrograde). This is like using your accelerator in your car to stop at a stop sign and is counter-intuitive at first. When you thrust forward, it increases the size of your orbit and you travel slower in relation to the Earth. By thrusting backwards (retrograde), your orbit becomes smaller and you travel faster in relation to Earth.

I like to sum this up in one statement, "In orbit, you speed up to slow down, and you slow down to speed up!" Crazy, huh!?! If your orbit is oval shaped (has a high eccentricity, then you will be traveling faster when your orbit is closer to the Earth and will slow down when you are farther from Earth. OK, let's move on.

Even though our orbital planes are aligned, we may be higher than (slower than) the ISS, lower than (faster than) the ISS, or maybe both if our orbit is highly eccentric (oval shaped). We want to find a point in time where our location, altitude, and speed are all very close to that of the ISS so that we can dock.

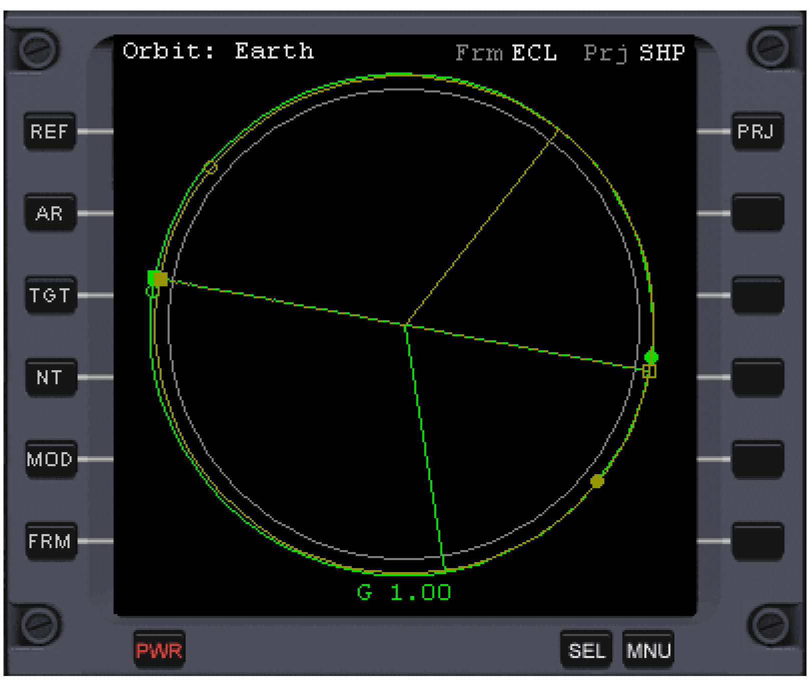
If you now **open the Map MFD (Shift + M) and target the ISS**, you'll notice that the two orbits look exactly the same (in fact, both orbit lines may appear as one line).



The white + indicates the position of your ship within its orbit and the yellow + indicates the position of the ISS on its orbit.

We will now speed up in our orbit so that our ship will catch up to the ISS or slow down in our orbit so that the ISS catches up to us.

Now **open the Orbit MFD (Shift + O)**. Make sure that the **ISS is targeted (Shift + T).** You can select the **MOD button** to toggle the display of all of the numerical data.

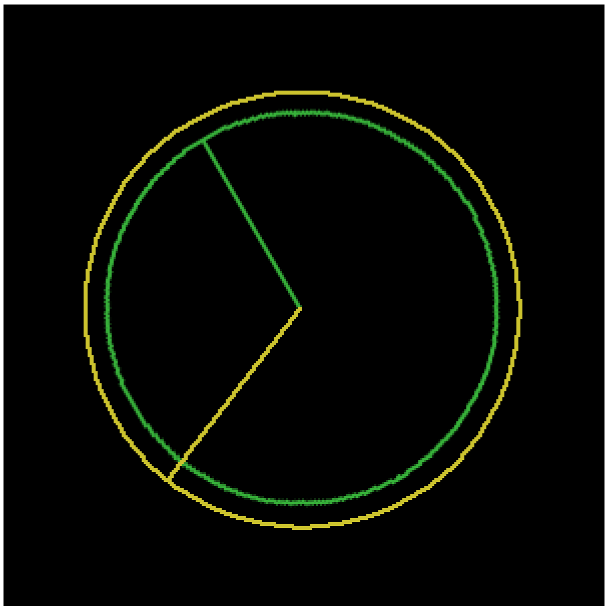


You can see that my current orbit (green circle) and the orbit of the ISS (yellowish circle) are very similar. We started at Mir in a very circular orbit. However, if you were not coming from Mir, your orbit may display much larger or perhaps maybe a little bit smaller than that of the ISS's (if it's too much smaller you'll run into the atmosphere). It might also be highly elliptical and perhaps cross the ISS's orbit. Regardless of what the orbits look like, we must adjust our orbit so we catch up to the ISS or let it catch up to us.

If our orbit looks very similar to that of the ISS (as in the picture above), then our speed will also be very similar to that of the ISS. This means that it might take a long time before we end up in the same place at the same time. It also means that when we do meet, the difference in our speeds will be very small, making it easier (and more efficient) for us to match speeds.

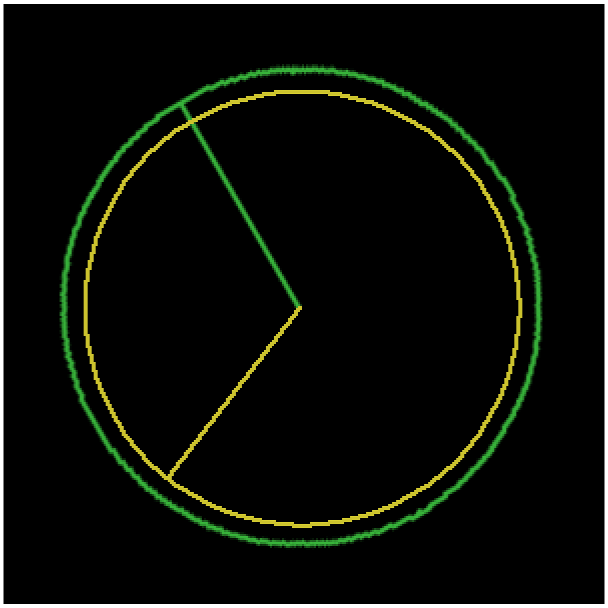
If our orbits are very dissimilar, then the difference in our speeds is much greater and the likelihood of us ending up at the same place any time in the near future is lower. The first thing we want to do is get our orbits SIMILAR to each other, but not exactly the same (so that we will either be faster or slower than the ISS).

FIGURE 1:



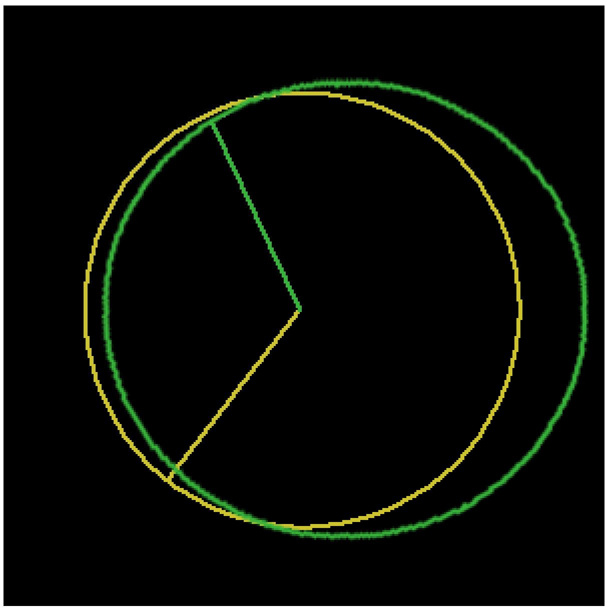
If your Orbit window looks like this (remember, the green line is your orbit and the yellow line is the ISS), then your orbit is smaller than the ISS's. We are going faster than the ISS. The two orbits never intersect (making it pretty hard to dock!).

FIGURE 2:



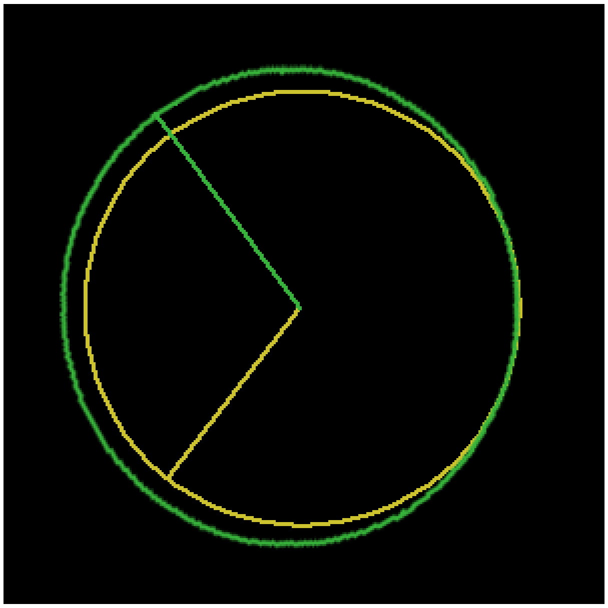
If your Orbit window looks like this, then your orbit is larger than the ISS's. You are going slower than the ISS. The orbits never intersect in this scenario either.

FIGURE 3:

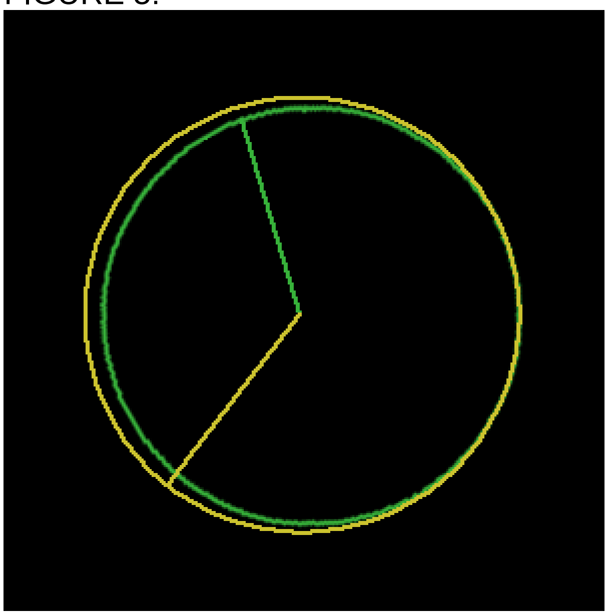


If your Orbit window looks something like this, with your orbit being very eccentric (oval shaped), then your orbits do intersect. The problem is that at the points where they intersect, you and the ISS will be traveling in slightly different directions and at quite different speeds. While synchronizing orbits will work in this scenario, there is a more effective shaped orbit shape for docking.

What we want is an orbit that looks like this:
FIGURE 4:



or this:
FIGURE 5:



In FIGURE 4, our orbit is slightly larger than that of the ISS's, so it will take us just a little bit longer to orbit the Earth than the ISS (the ISS will at some point catch up to us). The point of intersection has both our ship and the ISS traveling at about the same direction and at the same speed. FIGURE 5 provides the same advantages, except that our orbit is slightly smaller than the ISS's, so our orbit is a little bit faster (i.e., we'll catch up to the ISS).

In these two scenarios, it doesn't really matter WHERE the point of intersection is, just that there is one point of intersection with very little overlap, with our orbit being either slightly larger or slightly smaller than that of the ISS. We'll first focus on creating an intersection.

Determining an Intersection

I have found that if your orbit is smaller than the ISS's (FIGURE 1), then it is easier to raise your apoapsis (highest point of your orbit) to match the altitude of the ISS. This means you will be traveling faster than the ISS, but your altitude will be the same as the ISS when you are at apoapsis.

If your current orbit is larger than the ISS's (FIGURE 2), then it is easiest to lower your periapsis (lowest point of your orbit) to match the altitude of the ISS. This means that you will be traveling slower than the ISS, but your altitude will be the same as the ISS's when you are at periapsis.

If your orbit is elliptical and intersects the ISS's (FIGURE 3), then it really doesn't matter. You can either raise your periapsis to match the altitude of the ISS or lower your apoapsis to match the altitude of the ISS. I usually choose the one that is closest already and will thus take the least amount of fuel and time to accomplish.

If your orbit is too close to tell (such as mine above), then I'd recommend adjusting your periapsis.

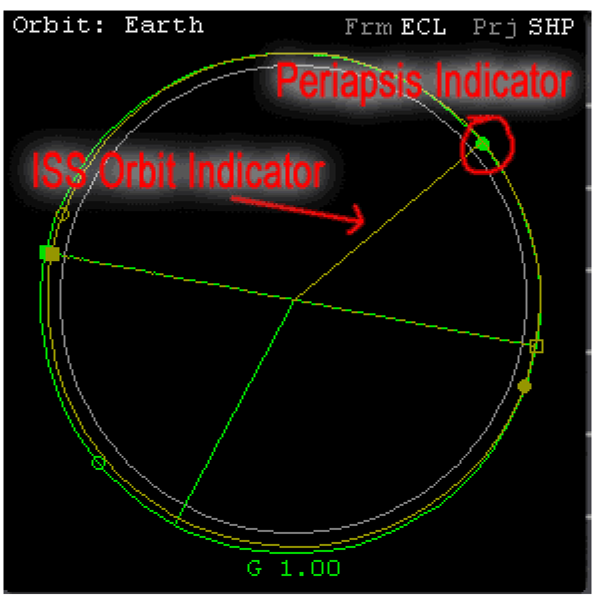
IMPORTANT: From this point on until we begin our docking sequence with the ISS, all of our thrusting will be either pointing prograde or retrograde and will only be done at periapsis or apoapsis!!!

Once you have determined which adjustment you are going to make to periapsis or apoapsis, we have to determine the altitude to which we will adjust it. The problem lies in that the orbit of the ISS is not circular, but slightly eccentric (oval shaped). This means that it's altitude changes at different points in it's orbit.

We have three options:

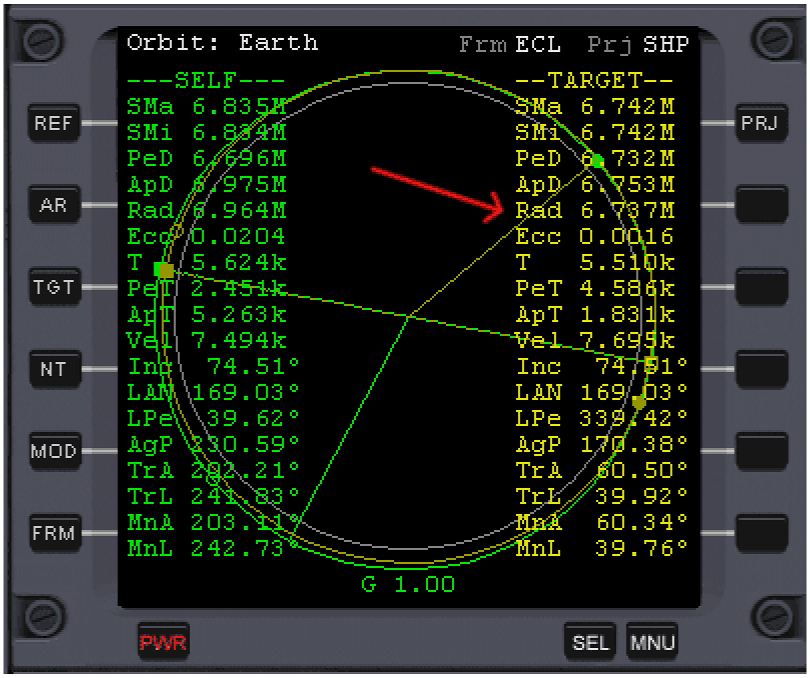
1. Eyeball it and hope it works. This will probably work fine for to get us there, but I don't think that the engineers at NASA take this approach very often.
2. Look up the high point (apoapsis or ApD) and low point (periapsis or PeD) of the ISS's orbit in the Orbit MFD and shoot for somewhere in between. This might get us closer, but isn't as precise as we might want.
3. Use the orbit MFD to determine the exact altitude of the ISS at the point where we want to intersect it. This is the method we'll be using.

With the Orbit MFD open, select the MOD button to the left of the MFD and click it until you can just see the graphical representation of the orbits. Find the marker for the point in your orbit that you want to adjust. Your periapsis is the green solid circle and your apoapsis is the green open circle. Now watch the yellowish/tan line that represents the current orbital location of the ISS until it is crosses or is pointing directly at this marker. You might want to speed up time a little (R and T keys) to pass the time.



The ISS orbit indicator is crossing the periapsis indicator of my orbit.

When the ISS orbit indicator is at the appropriate marker, quickly select the MOD button one more time and write down the Rad (radius) number in the TARGET column on the right. This is the current altitude (from the center of the Earth) of the ISS. If you are adjusting apoapsis, you'll write down this number when the ISS's orbit indicator aligns with the open apoapsis indicator.



My orbit is very similar to the ISS's, so I will be adjusting my periapsis. In the image above, the ISS's altitude is 6.737M (or 6,737,000 meters) at MY ship's periapsis. I want to adjust my periapsis to match this altitude.

Now that we know our target, let's do the burn. Here's how to do it:

- **If you are raising your periapsis, burn prograde at apoapsis.**
- **If you are lowering your periapsis, burn retrograde at apoapsis.**
- **If you are raising your apoapsis, burn prograde at periapsis.**
- **If you are lowering your apoapsis, burn retrograde at periapsis.**

Remember, we will only do burns at either periapsis or apoapsis. We will only burn with either the prograde or retrograde autopilot engaged. Burns at any other times or directions may throw our orbits out of alignment.

Take a look at your ApD or PeD (whichever one you're adjusting) in the left hand column of the Orbit MFD. Compare it to the target altitude. Make sure you are planning on raising or lowering correctly. If your orbits are very similar, you might only have to move it a very small amount (or perhaps not at all).

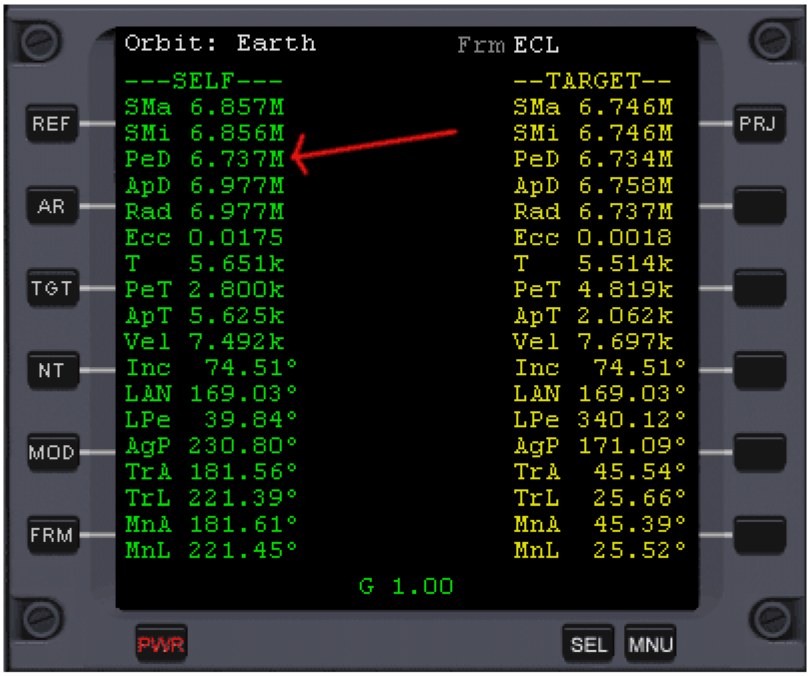
Creating an Intersection

Now, based on the rules above, **turn on either the prograde or retrograde autopilot.**

Use the rules above to determine at which point in your orbit you will burn - at apoapsis if you're adjusting periapsis or at periapsis if you're adjusting apoapsis. You can determine when to burn by watching your orbit indicator (green line) until it hits the correct indicator (solid circle for periapsis and open circle for apoapsis) or more accurately, by watching the the ApT (time to apoapsis in seconds) or PeT (time to periapsis in seconds) numbers on the Orbit MFD.

As you cross the correct point in your orbit or the correct T number hits 0, **fire up your main thrusters (NumPad +).** The key here it to get your PeD or ApD to match the ISS's altitude that you wrote down before. As you thrust, PeD or ApD (whichever one you're adjusting) will begin to change. It will likely change very quickly, so watch closely. **Kill thrust when this number matches the one you wrote down.** Unless your orbits are very different, it will probably only take a few seconds. If you overshoot, quickly use retro thrust (NumPad -) to adjust the number until it is as close as you can get it to the correct altitude. Use linear thrusters (NumPad 9 and 6) for fine control. If this takes longer than around 30 seconds, wait another orbit to polish things off.

In my case, I was raising my periapsis, so I burned prograde at apoapsis until my PeD matched the altitude of the ISS that I had determined earlier - 6.737M.

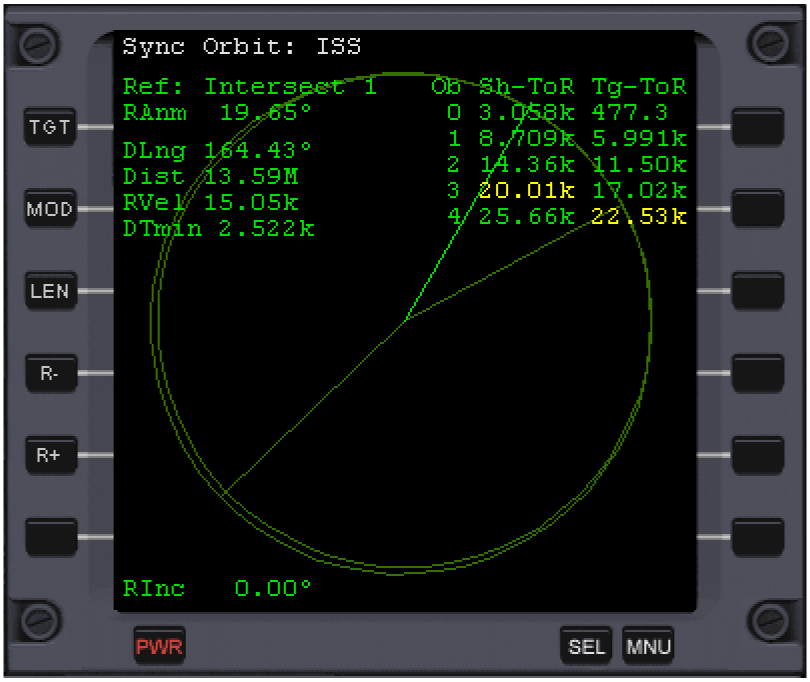


We have now established an intersection (our ship's apoapsis or periapsis) where our ship will be at the same altitude and thus the same speed as the ISS. **You may turn off the autopilot at this time.**

Now, we have to get our ship to that intersection point at the same time that the ISS is at that point. We do this with the Sync Orbit MFD.

Synchronizing our orbits

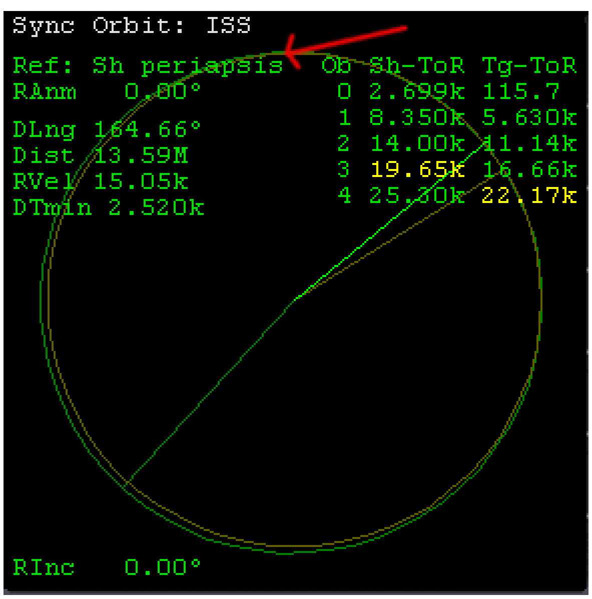
Open the Sync Orbit MFD (Shift + Y). **Target the ISS** (Shift +T and type in ISS). **Open the Orbit MFD in the other panel.**



At the bottom of the Sync Orbit MFD it displays the relative inclination (RInc) between the two orbits. If everything has been done correctly, this should still be very close to 0°. If it is more than around .5° then you will need to back up and realign your planes and then readjust your apoapsis or periapsis to match the ISS's altitude at that point in your orbit. If RInc is more the 1°, the Sync Orbit MFD will not work.

The Sync Orbit MFD will help us determine a point in time when our ship and the ISS will be at our determined intersection at approximately the same time. First, we need to tell the Sync Orbit MFD to analyze our predetermined intersection - which is either our periapsis or our apoapsis (whichever one you just set to match the ISS's altitude).

Hit the MOD button (Shift +M) until the Ref: line appropriately displays Sh periapsis (if the intersection is at your ship's periapsis) or Sh apoapsis (if the intersection is at your ship's apoapsis).



If your Sync MFD says No Intersection, then you were not very precise with setting your apoapsis or periapsis to the height of the ISS at that point in time. You can either raise or lower your intersection point (periapsis or apoapsis) on your next orbit until No Intersection disappears.

The two columns at the right display information about our own and the ISS's current and next four orbits (numbered 0 through 4). The numbers indicate the number of seconds until we will reach our intersection point on that particular orbit. The yellow numbers indicate the point in time within these five orbits when our ship will be at the intersection AND we are closest to the ISS. In the graphic above, this means that on my 3rd orbit in the future, my ship will be closest to the ISS when I cross the intersection (my ship's periapsis). The Sh-ToR column indicates the amount of time in seconds until my ship reaches the reference point (intersection) in that particular orbit.

DTmin indicates how much time difference there is between when your ship reaches the intersection in the yellow highlighted orbit and when the ISS reaches the intersection. In the graphic above, it indicates that my ship will miss the ISS by 2,520 seconds or 42 minutes. We're going to have to get it closer than that if we want to dock! We can do this one of two ways:

1. Wait around until we happen to arrive at the same time. If our orbits are very similar, this might take a VERY long time because we're going very close to the same speed. If our orbits are very different, it might not ever happen, especially if our orbit is, for instance, exactly twice as long as that of the ISS.
2. Adjust our orbital period (time it takes to orbit the earth) until a better match is found.

So, we want to either shorten or lengthen our orbital period, BUT we don't want to move our intersection location. We can do this by either raising or lowering the point in our orbit that is OPPOSITE of our intersection point. In my case, the intersection is defined as my periapsis, so I will raise or lower my apoapsis (ApD) to adjust my orbital period. Doing so will not affect my periapsis (PeD).

So should you lower or raise this point? Really, either one will work, to a point.

- **If your orbit is larger than the target orbit (the intersection is your periapsis), then raise your apoapsis (make your orbit even bigger)**
- **If your orbit is smaller than the target orbit (the intersection is your apoapsis), then lower your periapsis.**

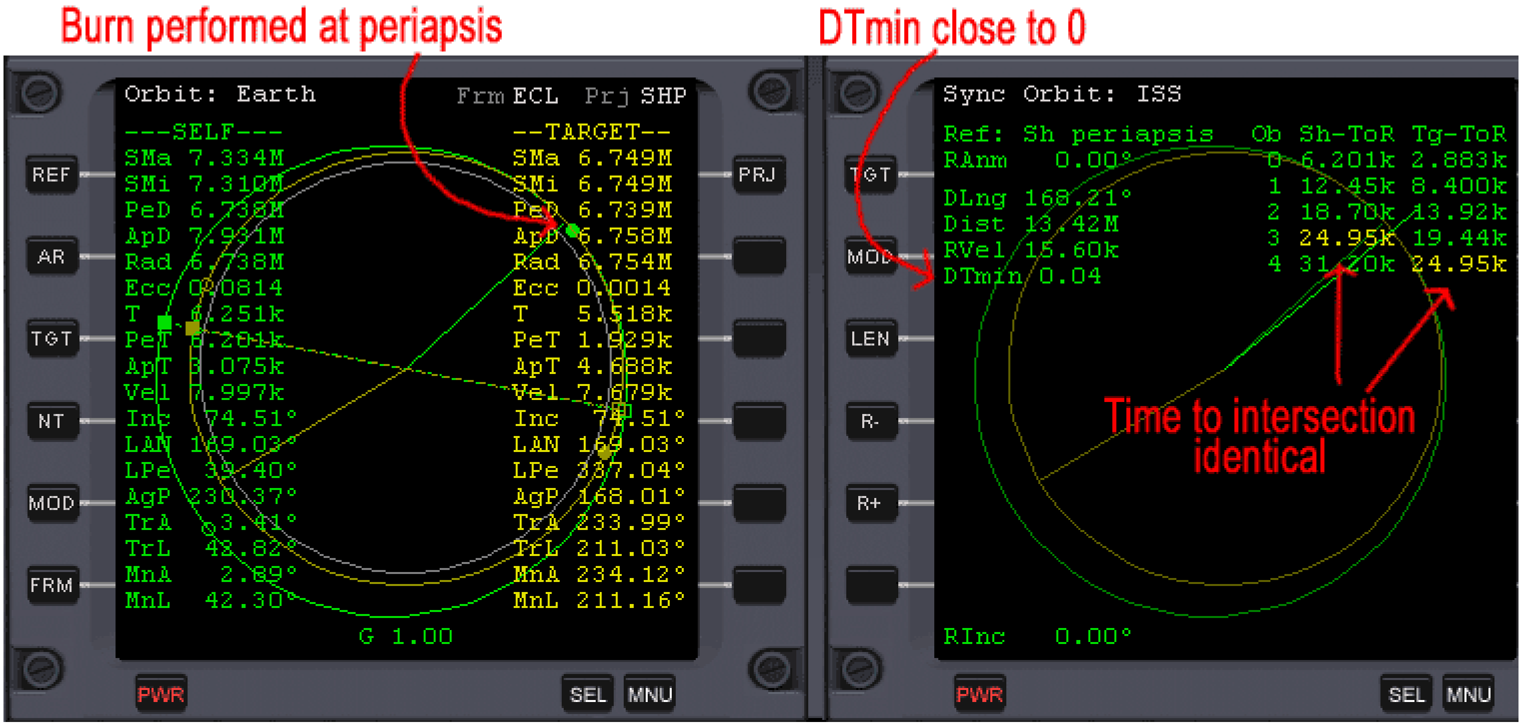
Exceptions to the above:

- If your orbit is A LOT bigger than the targets, then you can lower your apoapsis. This will allow you to shorten your orbital period while still having them be longer than the ISS's orbital period. This way you won't have to float around for a long time before you intercept the ISS.
- If your orbit is smaller than the targets and you're afraid that lowering your periapsis might cause you to hit the atmosphere (PeD ~ 6.550), then you might need to raise your periapsis. However, if you raise your periapsis above the height of your current apoapsis, then your periapsis and apoapsis switch. In this case, you will need to set the Sync Orbit MFD to target Sh. periapsis, as this will have become your new target.

Use the same rules as above to make this adjustment, namely:

- **If you are raising your periapsis, burn prograde at your intersection (apoapsis).**
- **If you are lowering your periapsis, burn retrograde at your intersection (apoapsis).**
- **If you are raising your apoapsis, burn prograde at your intersection (periapsis).**
- **If you are lowering your apoapsis, burn retrograde at your intersection (periapsis).**

On a subsequent orbit, burn appropriately. Use the Orbit panel (PeT or ApT) to time the burn as we did before. **Remember, you will be burning at your intersection point** to adjust the height of the point opposite of your intersection. Make sure you have the correct autopilot mode enabled. As you burn, watch DTmin decrease. **Stop thrusting when DTmin gets close to 0.** It should take less than 10 or 20 seconds. Use retro thrusters if you overshoot and use linear thrusters (NumPad 9 and 6) for finite control. You should be able to get DTmin very close to 0.



The prograde burn was performed as my ship crossed periapsis so that the height of my apoapsis was increased. DTmin is very low and the times to intersection is the same.

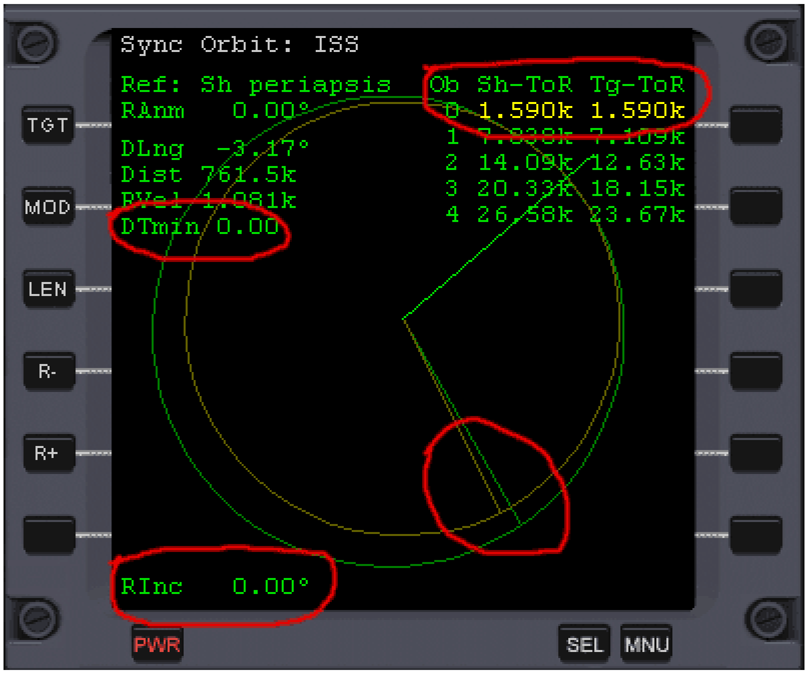
Make sure that you only burn while you're very close to your intersection (apoapsis or periapsis). If your burn takes a long time and you're thrusting at a distance from this point, then your intersection will begin to move throwing everything off. If you cannot get DTmin very close to zero within 20 or 30 seconds, wait until your next orbit and try again. If you are lowering your periapsis, watch the orbit panel to ensure that PeD does not go below 6.550. If **No Intersection** displays, you may need to raise or lower your intersection point SLIGHTLY until it disappears.

The key here is not to make your orbit the same as the ISS's, but to make it different enough that you will either catch up to the ISS (if your orbit is smaller) or let the ISS catch up to you (if your orbit is bigger), while also being able to determine an exact time to intercept the ISS in a subsequent orbit. It's no wonder that NASA hires such smart people!

Find the yellow highlighted numbers under Sh-ToR and determine the subsequent orbit in which you will intercept the ISS at the intersection. It may be a few orbits into the future. In my case (as seen above), it will be on my 3rd orbit (and the 4th orbit for the ISS because it is moving faster than me). If yours is on the current orbit (yellow numbers in the top row), enjoy the scenery for a minute, take a breath, and get ready to dock.

If you have a few orbits to go, you can further refine DTmin at each subsequent orbit by using linear thrusters (simply tapping them momentarily works best) to get it down to exactly 0.00. As your intercept orbit get's closer, you can watch the Orbit or Sync Orbit MFD to see your orbit indicator (green line) and the ISS's orbit indicator (yellow/tan line) get closer together. You can also monitor your orbits in the Map MFD. Be sure you make any adjustments at your intersection point and that you have either the prograde or retrograde autopilot enabled. If your RInc has drifted a little bit, you can use your up/down thrusters (NumPad 8 and 2) to adjust it back to 0, though you'll then need to readjust DTmin at the next intersection. The closer DTMin and RInc are to 0, the closer you'll come to the ISS at your intersection point.

When you begin your final orbit (the yellow numbers under Sh-ToR are in the top row), then stop making adjustments and get ready to dock.



Over the last few orbits I have adjusted DTmin and RInc to 0. I am approaching the intersection on my current orbit and the ISS is close. At this point in time, the ISS is below and slightly behind me in my orbit. When I reach the intersection at my periapsis, we should be within a few kilometers of each other. It's time to dock!

Docking

Getting Ready

You should now be in your final orbit and quickly approaching the intersection point. There is a lot to do during this orbit before we dock, so you may want to pause Orbiter (Shift + P) when you're not working in the cockpit. If you happen to miss the ISS at the intersection, simply resynchronize your orbits by adjusting your orbit again.

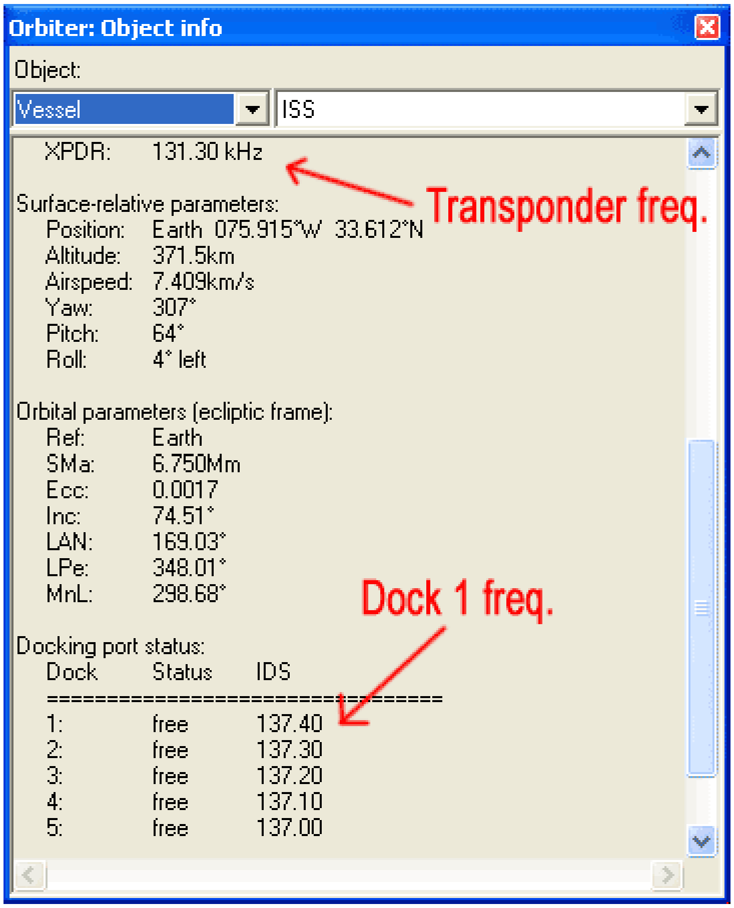
Turn on the Prograde autopilot.

Open the Sync Orbit MFD in the right panel (Right Shift + Y) and look at the orbit indicators (green and yellow/tan lines) to **determine if the ISS is slightly behind and below you OR slightly ahead and above you**. This will help orient us as we get closer to docking.

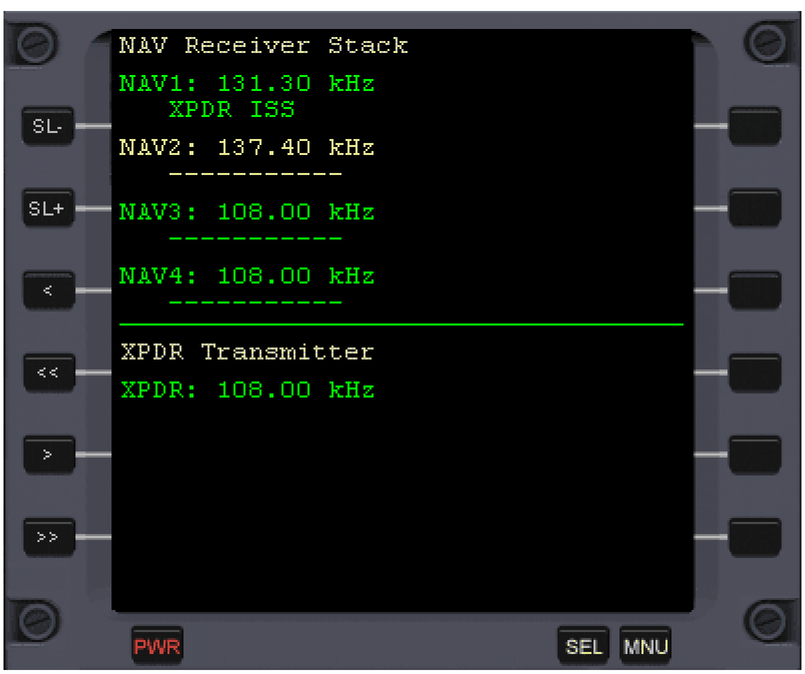
In Orbiter, space stations transmit information on various radio frequencies. The ISS has what is called a transponder. The transponder simply broadcasts the position of the ISS at all times. We'll tune into the transponder to help us get real close. The ISS also broadcasts information about each of it's five docking ports. Once we're very close to the ISS, we'll tune to a docking frequency to help us dock.

To find the frequencies for the ISS, hit F4 on the keyboard, then select Object Info. Select "Vessel" from the left hand drop-down and then select ISS from the right hand drop down. The transponder frequency is listed after XPDR. It should be 131.30 kHz. Scroll down and find the frequency for Port 1. It's frequency is 137.4. ***After some practice you will probably choose the port that allows for the easiest***

approach. We'll just dock with Port 1 so we don't have to change frequencies on-the-fly.



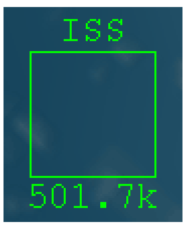
Tune your receiver to these frequencies by opening the COM/NAV MFD in the left panel (Left Shift + C). Use the SL- and SL+ buttons to change to the current frequency you want to adjust. Use the << and >> buttons to make major changes to the selected frequency and < and > to make minor changes. **Tune NAV1 to 131.3 (ISS's transponder) and NAV2 to 137.4 (ISS Dock 1).**



Turn on the Docking HUD by pressing the H key until the word "Dock" displays in the upper left hand corner or your screen. The Docking Hud will display information based on the radio frequency currently tuned. It should be currently tuned to NAV1. You can change the frequency using Control + R. Cycle through the frequencies until Nav 1 is displayed in the upper left hand corner. It will indicate XPDR ISS to show that it is tuned to the ISS's transponder.

Continue your current orbit while closely monitoring the Docking HUD and the Sync Orbit MFD. Once you get closer to the ISS, you'll begin receiving a radio signal from it's transponder and the Docking HUD will become active. It displays two pieces of vital information. The first is the distance and direction of the ISS. This is indicated with "ISS" text and your distance from the ISS. If the ISS is not directly in your field of view, the arrow will point to where the ISS is located.

If the ISS is within your field of view, the arrow is replaced with a box. The ISS is located in the middle of this box.



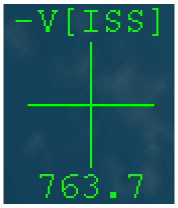
In this shot, the ISS is still 501.7 km away, and thus too small to be seen within the box.

The second piece of information is your velocity relative to the ISS and your velocity vector. This is indicated with "V[ISS]" text and the speed of the ISS relative to your ship (in meters per second). If the number is positive, this means that you are getting closer to the ISS. If it's negative, the ISS is getting further away.

The arrow points to the direction of the velocity vector, which is the direction that you must thrust to match speeds with the ISS. If the relative velocity direction is within the your field of view, it will display with the following indicator.

This marker indicates that my ships speed relative to the ISS is moving FROM this direction at 699.3

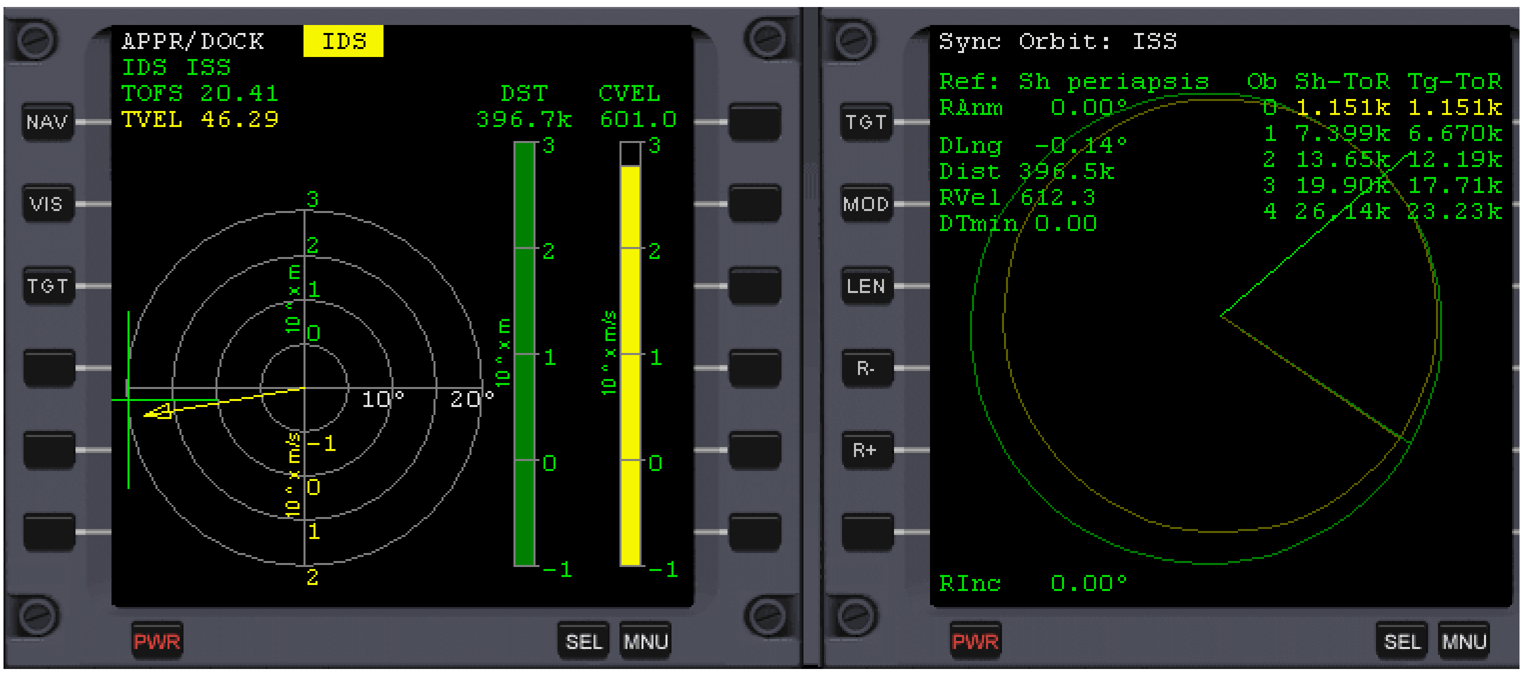
meters per second. In other words, if I thrust toward this indicator until relative velocity is 0, then I'll be going the same speed as the ISS. Just opposite (180 degrees away) from the velocity vector is the negative velocity vector (indicated by the -V[ISS] text). It indicates the direction your ship is traveling in relation to the ISS or the direction you must thrust away from in order to match speeds with the ISS.



We will use both of these indicators to make a stepped approach to the ISS.

Open the Docking MFD in the left panel (Left Shift + D). Select Left Shift + T and then enter ISS 1 to display information about Dock 1.

The DST and CVEL numbers are the distance from and relative velocity of the space station. They will be very similar to the numbers seen in the docking HUD.



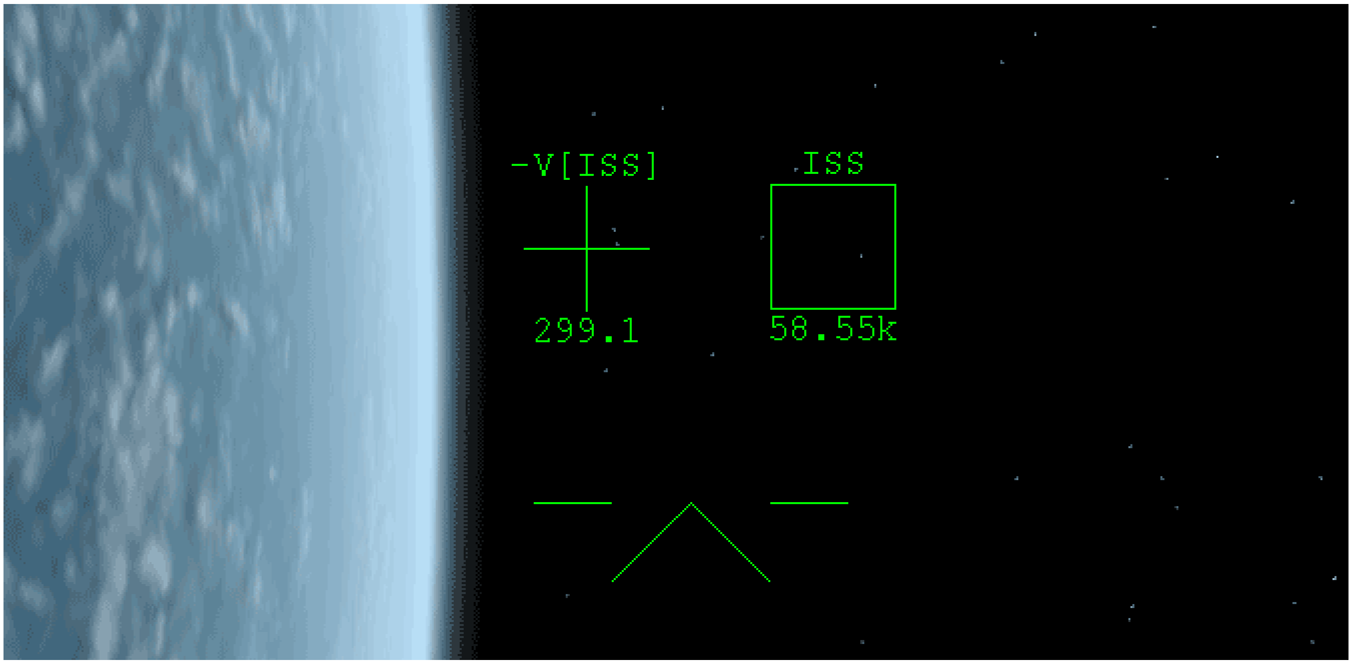
In the picture above, you can see that my ship is 396.7 kilometers from the ISS and my relative velocity is 601 meters/second. The Sync Orbit MFD on the right indicates that I am quickly approaching the intersection (my periapsis). The orbit indicators for my ship and the ISS are nearly overlapping.

Continue to monitor these two panels. If everything is properly aligned and synchronized, then your relative velocity and distance should be at their minimums very close to the intersection point.

Turn off the Prograde Autopilot and select rotational thrusters (NumPad /) and rotate your ship to face the ISS by rotating slowly toward the ISS arrow until the box displays. Hit the Kill Rotation button (killrot) on the panel or press NumPad 5 to stop all rotation once the ISS box is roughly centered. It is often helpful to cycle between rotating and killrot so that you aren't constantly trying to cancel out your rotation manually. Just hit killrot, then try to center the ISS box again, then killrot again, and so forth until you are satisfied. Depending upon your accuracy, the ISS should may begin to come into view as you approach the intersection. Enjoy the view!

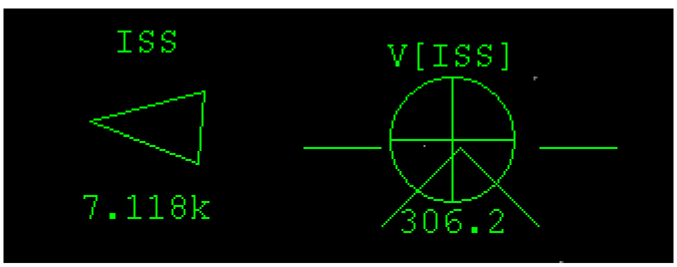
Approaching the ISS

As the intersection approaches, watch your distance and relative velocity indicators in the HUD or Docking MFD.



In this image, the ISS is 58.55 kilometers away. My ship is heading toward the -V indicator at 299.1 meters per second relative to the ISS. It looks like I'm lined up for a very close approach.

The key to this portion of the docking sequence is to get as near as we can to the ISS, then to cancel out our relative velocity so that we can match speeds with the ISS and then move in even closer. **Once you're within around 100 kilometers, quickly rotate your ship to align your nose indicator in your HUD (-^-) to point directly at the velocity vector.** This will be in the exact opposite direction of the -V indicator. Use killrot and rotational thrusters to point your nose directly at this indicator.

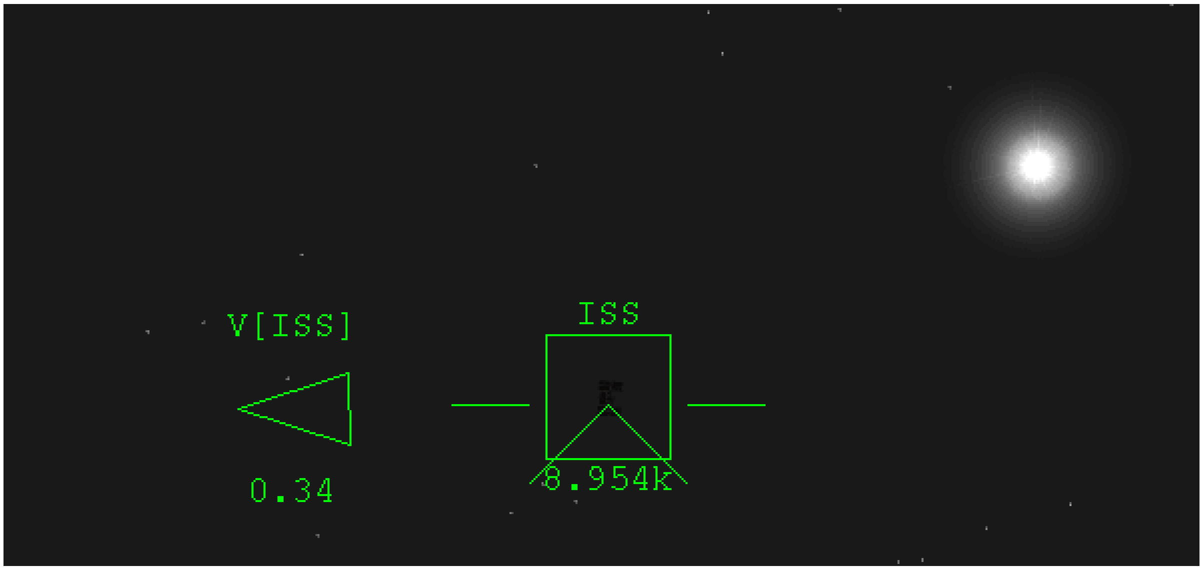


In the above shot, I have rotated my nose to point at the velocity indicator. The relative speed is 306 meters per second. The ISS is just 7.1 kilometers away!!! My precision during aligning and synchronizing orbits has paid off.

Watch the distance indicator. As soon as it begins to increase (or if it is increasing already), this means that we have just passed the intersection and our closest approach and are now drifting farther away from the ISS. **Fire your main thrusters until the relative velocity is close to 0.** Use rotational thrusters and killrot to try and keep the nose of your ship aligned with the velocity vector. Depending upon your relative velocity, the burn should take between a few and perhaps 60 seconds. As relative velocity approaches 0, the velocity vector will become more sensitive and may quickly move out of HUD's field of view. Stop thrusting at this point. You've now cancelled out most of the relative velocity and are traveling at around the same speed as the ISS. With practice, you will learn to watch the distance indicator to time this burn so that it begins shortly before you've reached your closest approach, rather than just afterward.

You are now traveling along side of the ISS. You might be within a few kilometers or a long ways away, but at least we're a lot closer than we were when we started.

Point your nose directly at the ISS by rotating toward the ISS arrow. You'll want to center the nose indicator within the ISS indicator box. Use rotational thrusters and killrot to get it close.



In the above shot, I have rotated my ship to point at the ISS. I overshot my closest approach by a little ways and the ISS is now 8.9 kilometers away (still very close). The relative velocity is .34 meters per second. Luckily the sun is not as bright in Orbiter as it is in real life!

You may notice that the relative velocity may be slowly increasing. This is due to the fact that your ship is slightly lower in orbit (faster) or higher in orbit (slower) than the ISS. As your orbits slowly separate, the relative velocity between your ships will increase. As you get closer to the ISS and your altitudes are more similar, relative velocity will become more stable.

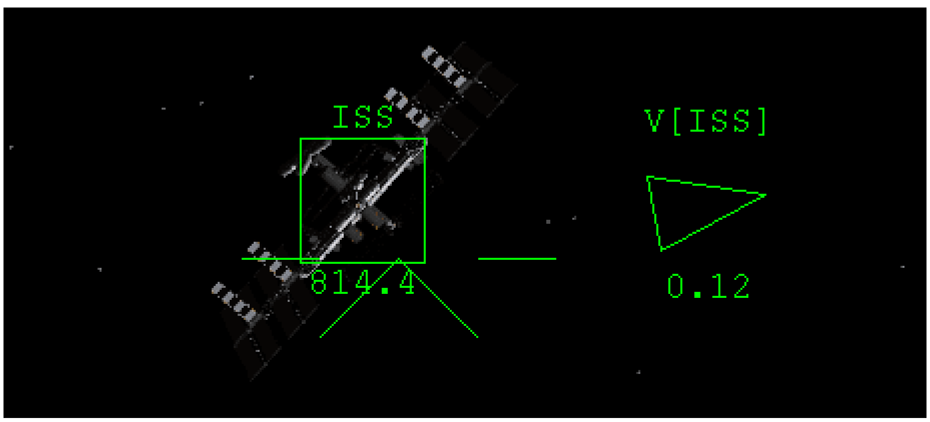
We are now going to reduce the distance between our ship and the ISS. **With our nose pointed at the ISS, engage your main thrusters.** The length of this burn will be determined by the distance between your ships. Remember that you will have to cancel out this thrust in a minute, so you're better off making it very short. If you are within 10 kilometers, a burn of perhaps one second will probably suffice. If you are tens of kilometers away, then several seconds may be required. The key is to slowly approach the ISS without overshooting or running into it. You will likely have to do this in several steps, especially if you are further away.

As soon as the burn is completed, quickly align your nose with the velocity vector indicator. We will need to burn again in a few moments to cancel out the relative velocity. As before, watch the distance indicator closely - as soon as it begins to increase or you are within 1 kilometer or so, **burn toward the velocity vector and zero out your relative velocity.** If you watch the rate of change of your distance, you can anticipate when it will begin to increase and can time your burn to cancel relative velocity before you begin to separate again.

Repeat this process of canceling relative velocity then thrusting straight at the ISS until you are within 1 kilometer. It may take several iterations. Do not get impatient. NASA usually takes 2 or 3 days to get the Space Shuttle this close to the ISS and we just did it in a few minutes. As you get closer to the ISS, shorter burns are required. Do your best to cancel out all of your relative velocity each time. You may have to 'chase' the velocity vector a little bit using rotational thrusters, but doing so allows you to more accurately burn toward the ISS the next time. You can use the retro thrusters to help you if you 'overshoot' your velocity cancellation burn. Alternatively, you can point your nose at the -V[ISS] indicate and use retro thrusters to cancel out relative velocity. This is often easier once you are within around 10 kilometers because it does not required you to turn 180 degrees for every burn - instead, the -V indicator should be in the general vicinity of the ISS and you can keep your nose pointed in that general direction all of the time. Be aware though that the retro thrusters are much weaker than the main thrusters, so it will take longer to decrease your relative speed.

This stepped approach to the ISS is not the most accurate or fuel efficient, but works very well with the tools we have. There is a custom Approach MFD that will complete this in one burn if you are willing to approach the ISS VERY slowly. The procedure we are using works very well and is often much quicker, though it is not necessarily the most realistic. The problem lies in the fact that when you thrust toward the ISS, your ship initially is headed right at it, but because of the slight differences in your orbits, your direction will be effected by the differences in your speeds (which is based on your altitudes), eventually resulting in your course deviating from your intended target. Unless you are in a ship with tremendous thrust, you can never get to anything in space by simply pointing at it and firing up the engines. As you get closer to the ISS, burning directly toward it works much more effectively because your altitudes are much more similar.

As soon as you are within around 1 kilometer, cancel out your relative velocity. Tapping the thruster and retro thruster keys (or using a joystick with a throttle control) will allow you more fine control. Once you are within 1 kilometer, the approach alert system will begin playing 'ping' sounds. The more frequent these sounds are, the closer you are to the ISS.

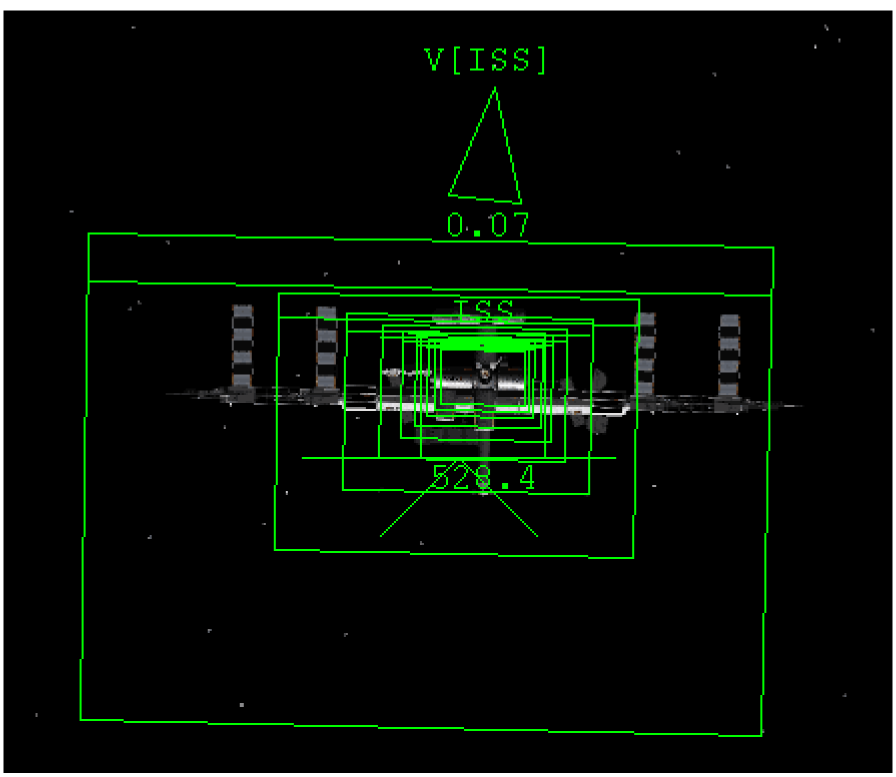


The ISS is less than a kilometer away. Relative velocity is very low (.12 m/s).

Change the HUD frequency to that of Dock 1 (NAV 2), using Control + R. If the ISS is within your field of view, you will now see docking approach markers displayed on the HUD. These markers expand outward from the docking port you have selected. They provide a visual approach path for you to use to get roughly aligned with the docking port.

I got very lucky and happened to end up with the docking port pointing roughly toward me. The rectangles you see might extend away on the far side of the ISS.

Rotate your ship and point your nose at the outermost rectangle. We want to position our ship so that it is within the approach path and then we'll begin orienting our ship for the actual docking procedure. **Continue the process of thrusting and canceling out relative velocity until you are positioned very close to the approach path.** It will only take VERY small amounts of thrust to get you there. External view may help you to orient yourself. The -V[ISS] indicator on the HUD will indicate the point your ship is heading to. Be careful not to run into the space station (though doing so does nothing in Orbiter). You may have to do this in several steps, cancelling out relative velocity each time you begin to drift off target. **Once you are positioned within or very near the approach path rectangles, again cancel out all relative velocity.** Take some time to get the relative velocity very close to 0.



I'm now lined up within the approach path and the ISS 528 meters away. My relative velocity is very low (.07 m/s).

Point your nose once again directly at the space station. Aim toward the center of the space station where the docking port is located. **Hit killrot (NumPad 5) to cancel out all rotation.**

Tune the HUD back to NAV 1 by selecting Control + R until NAV 1 displays in the upper left hand corner. This will turn off the approach rectangles, which at this point will just clutter the display.

Turn on linear translation mode (Numpad /). Now that we are this close, it might be dangerous to use our main thrusters, so we are going to use the linear thrusters to perform very small maneuvers.

Now thrust forward (Numpad 6) down the approach path and through the rectangles until you are between 100 and 300 meters away. As you thrust toward the space station you will see the -V indicator near the space station. Use your directional thrusters - Numpad 8 (up), 2 (down), 1 (left), and 3 (right) - to position the -V indicator directly over the docking port. Keep your relative velocity less than 2 or 3 meters per second. Use the reverse thruster (Numpad 9) to slow down or stop. Slowly approach the space station while keeping the -V indicator exactly centered. I call this "chasing the cross". If you start to drift in one direction, thrust to position the -V indicator opposite of the direction you are drifting to cancel out the drift. For instance, if you are drifting high, position the -V indicator below the ISS to move downward. Try to keep the -V indicator centered on the docking port to eliminate all drift.

Once you are around 100 meters away, fire your reverse thrusters until relative velocity is VERY close to 0. Don't be alarmed if the -V indicator leaves the field of view as it approaches 0 or continues to drift slightly. The amount of drift should be very small. You can use your directional thrusters to minimize drift if you need to. We're going to be setting up our docking maneuver for a few minutes and don't want to drift away from the approach path in the meantime.

The Docking Procedure

We've likely traveled millions of kilometers by this point and are now just a stone's throw (which is an interesting thing to think about when you're in space) from the space station. The final task is to successfully dock.

Killrot to stop all rotation.

Open your nose cone (K key).

Tune the Docking MFD to NAV 2 by clicking the NAV button to the left of the MFD. The Docking MFD now displays additional information about your position and orientation with the docking port.

As before, distance and relative velocity are displayed on the right hand side of the MFD. The large target is used for orienting our ship. In order for us to successfully dock, there are three elements that have to be correctly oriented.

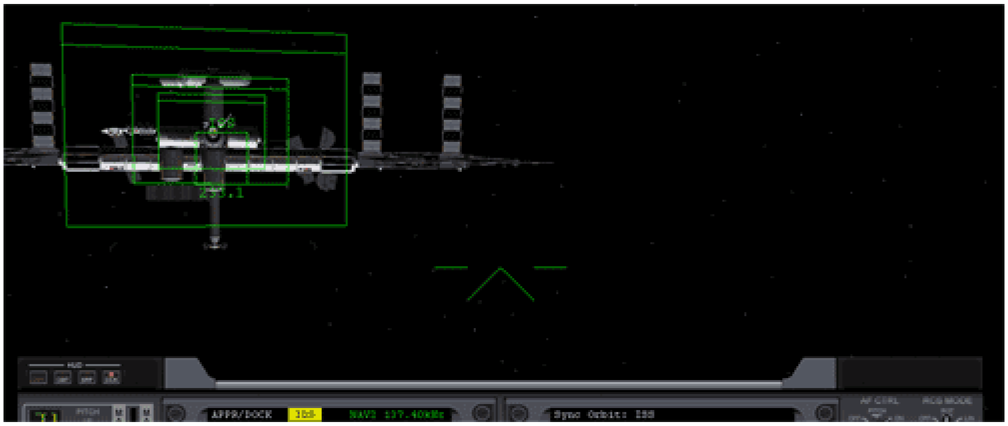
The first is that our ship has to be oriented so that the docking port on our ship connects squarely with the docking port on ISS. If you were to draw a line down the longitudinal (front to back) axis of our ship and project that line straight out from the nose cone of our ship, this line must be exactly perpendicular to the plane of the docking port. If our ship is turned so that the planes of the two docking ports are not parallel, then we cannot dock.

The second element is that our docking port must be oriented correctly so that the locking mechanisms correctly grapple the two ships together. In other words, each port has an 'up' and the 'up' on our docking port must match with 'up' on the ISS's docking port. ***In Orbiter, this element is not required, but for realism, we will be integrating it.***

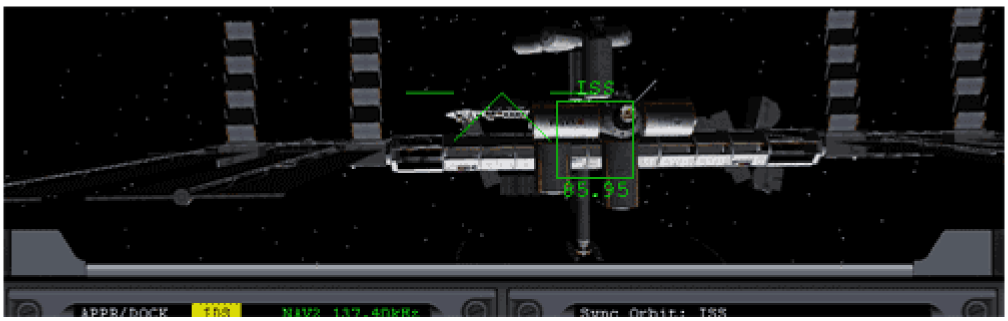
The third element is that we must actually follow the approach path and meet with the docking port. Putting our nose cone through the front window of the ISS, isn't going to make the people onboard very happy. We must directly align and then connect our circular nose cone with the circular dock of the ISS.

In short, in order for us to dock, we must be:

- **Correctly aligned longitudinally (the planes of the docking ports are the same)**
- **Correctly aligned rotationally (the docking ports meet in the correct orientation - up=up)**
- **Correctly aligned on the approach path (our ship meets the ISS where the docking port is located)**



This is what an approach looks like for a ship that is not aligned longitudinally. Although the ship is on the correct approach path (middle of the rectangles), the nose is not pointing directly at the docking port. The ISS is being approached at an angle. In order to successfully dock, your ships longitudinal axis (a line extending directly out from your docking port) must be perpendicular to the plane of the docking port. Or in other words, the planes of the two docks must be parallel.



This is what an approach looks like that is not aligned directionally. Although my nose might be pointed directly at the station and my ship may be aligned longitudinally, if I continue straight forward I will connect with the dock.

Align Longitudinally

The red (or perhaps white) X in the Docking Panel indicates longitudinal alignment. When the X is directly over the center of the target, then we are aligned longitudinally. We want to align longitudinally first.

Turn on rotational thrusters (Numpad /).

Rotate your ship to align the X to the center of the target in the Docking MFD. If the X is not displayed at all, then rotate your nose so that it is pointed at the ISS. If you are close to the approach path, the X will appear. If the X is currently to the right of center, then rotate your nose to the right. If the X is too high, then rotate your nose up. You must EXACTLY align the X over the center of the target. As the X approaches the center of the target, it will turn white and will become more sensitive. Use killrot (Numpad 5) to cancel out all rotation (i.e., stop movement of the X).

The X is aligned over the center of the target. My ship is aligned longitudinally. My ship is rotated about 20° from the correct rotational orientation, as seen by the red arrow near the top of the Docking panel and by the skew of the space station out the window.

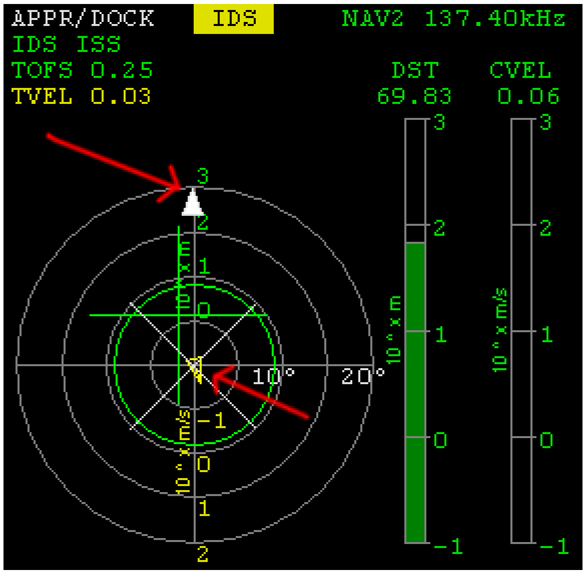
Once you are aligned longitudinally, you must not apply any thrust that will affect your longitudinal axis.

Align rotationally

Let's now orient the docking port rotationally with the docking port of the ISS. The Docking MFD displays a rotational alignment triangle that points outward along the outermost ring of the target indicator. This triangle points toward the up position of the target dock. Also, if you tune the HUD to the docking port frequency, the approach indicator rectangles will display a double line on the side that indicates the up orientation of the docking port.

Using rotation thrusters (Numpad 6 and 4), rotate your ship so that the rotational alignment triangle is pointing directly up (at the 12 o'clock position) on the Docking MFD. Killrot when you are aligned. Be very careful that you do not thrust incorrectly and change your longitudinal axis.

Docking with rotating space stations
If the ship you are docking with is rotating (such as the lunar wheel), you must use the rotational thrusters to match the rotation speed of the station. This takes some



patience and skill because you cannot use killrot to stabilize your rotation. Ensure that the rotational alignment triangle does not drift for at least one minute before continuing. In order to dock with a rotating station, your nose cone must be centered along the longitudinal axis of your ship. This is not the case with the default Delta Glider or the Space Shuttle, but does apply to the Delta Glider III, Shuttle A, and Dragonfly. Because rotational alignment is ignored in Orbiter, you can simply ignore this and dock normally pretending that the docking port of the space station is rotating to counteract the apparent rotation of the space station.

The longitudinal indicator is centered and the rotational alignment indicator is centered at the top of the MFD.

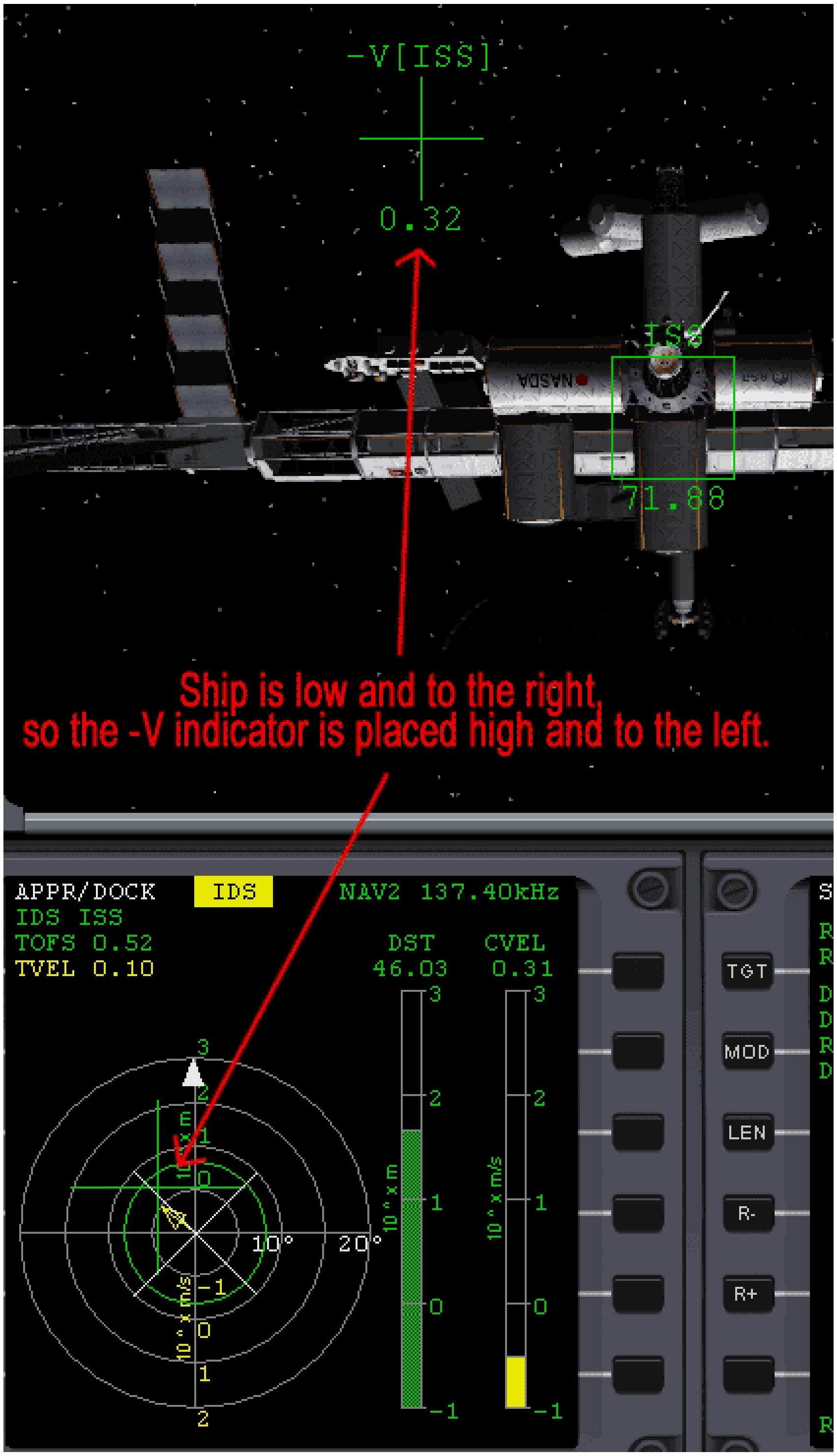
Align the approach paths

Our ship is now oriented for proper docking. We now must roughly center ourselves on the approach path, thrust forward, and complete the docking procedure. From this point on, no thrusting should be done with rotation thrusters. If the above steps were done correctly, the elements we have already aligned should not change over time.

The green + on the Docking MFD indicates our position relative to the approach path. **Turn on linear translation thrusters (Numpad /)**.

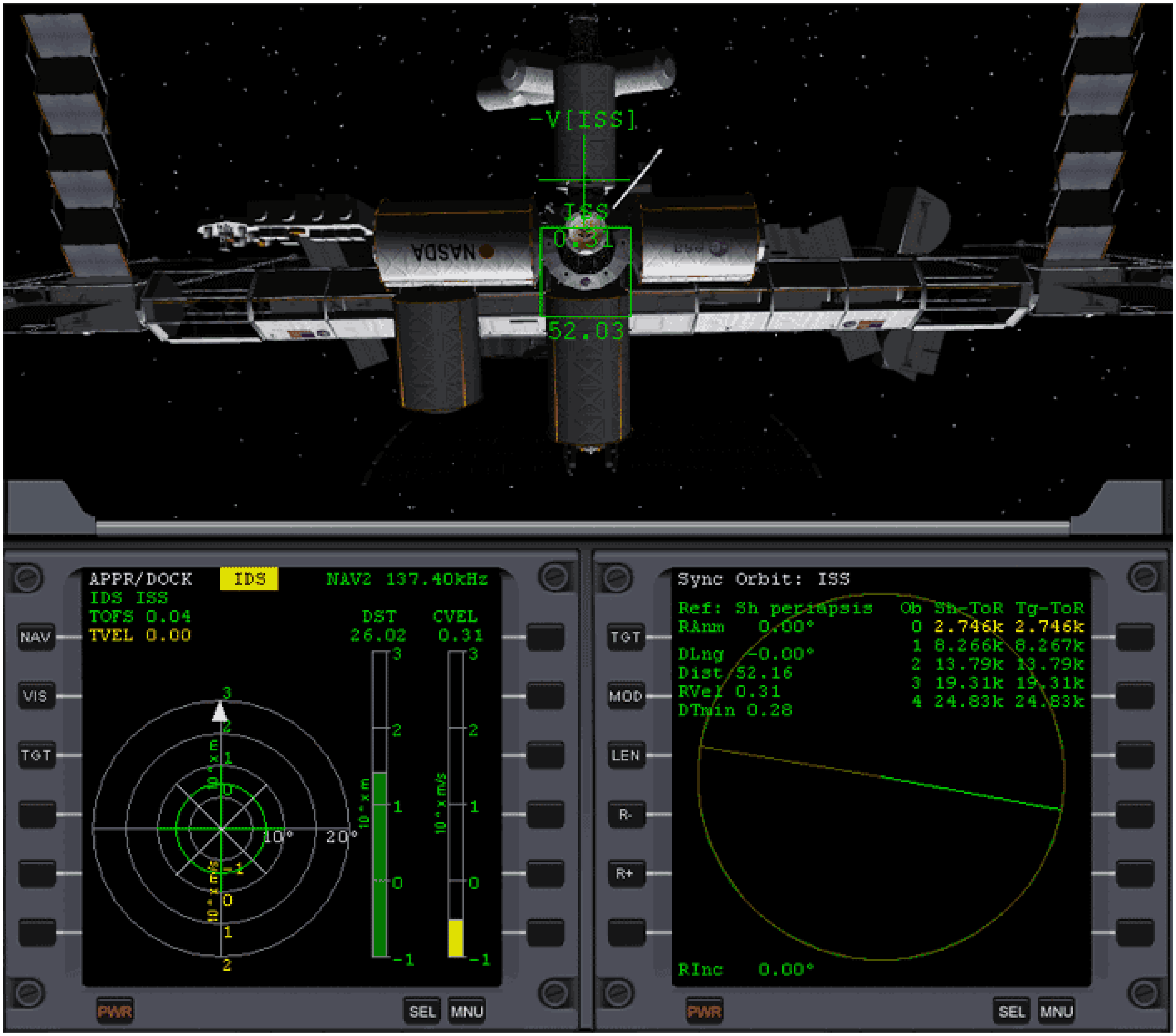
Thrust forward slightly (Numpad 6) so that your relative velocity is between .3 and .5 m/s.

Thrust linearly - Numpad 8 (up), 2 (down), 1 (left), and 3 (right) - to align the + in the Docking panel over the center of the target. As before, the -V indicator will display near the ISS. It indicates the direction you are heading relative to the ISS. Use it to help you center along the approach path. If the + in the docking panel is high and to the left (as in the image above), this means that your ship is below and to the right of the approach path. If you thrust linearly to place the -V in the same position relative to the docking port as the + is positioned in the docking panel (above and to the left), then you will move in that direction and the + in the docking panel will drift toward the center.



As the + begins to center, thrust linearly to position the -V indicator closer to the docking port. As soon as you have eliminated all drift and the + is centered, the -V indicator should be centered just above the docking port on the window (because the docking port on the default Delta Glider is a little bit below the centerline of the ship). At this point, you should glide right into a perfect docking. You may need to make MINOR adjustments to keep the + centered. Approach the ISS very slowly (use Numpad 9 to slow down). If you are traveling faster than .5 meters per second, you will not dock (but will travel right through the ISS).

Watch your distance indicator. If you are not properly aligned when you are within a few meters of the space station, back up a little bit or slow WAY down (Numpad 9), realign, and try again. The key here is to be very patient. It takes a little practice to figure out how to keep from chasing the + around. Use the -V indicator (chasing the cross) to help.



My ship is aligned longitudinally, rotationally, and along the approach path. My relative velocity is less than .5 m/s and the -V indicator is centered directly above the docking port. I am set up for a perfect dock.

Keep everything centered and continue your slow approach until docking occurs. Congratulations, you have completed a great trip and reached the end of this tutorial.

If you have any recommendations, fixes, or compliments on this tutorial, please send them to me.

Thanks, Jared "Smitty" Smith

P.S. - I'm working on a interplanetary operations manual that will cover leaving Earth and traveling to other planets, including entering a stable orbit and slingshots (gravitational assists) to other planets using TransX. You can read about my Solar System tour here.