

# "From the Earth to The ISS" an Orbiter 2016 Stock Atlantis(STS-101) Full Mission Tutorial -Part 1

Document Title: "From the Earth to The ISS" an Orbiter 2016 P1 Stock Atlantis Full Mission Tutorial Part-1

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Document Information: A Space Shuttle to ISS.scn Tutorial for a nominal launch to rendezvous for docking with the ISS using no external addons besides Sound 5.0. This tutorial must be used with the scenario provided in order to view the same conditions and procedures that are automated in the default Space Shuttle to ISS.scn scenario in Orbiter 2016. This tutorial will teach a new user to Orbiter 2016 how to complete this mission manually in order to better understand the concepts behind the provided playback tutorial that usually accompanies this scenario in Orbiter 2016 and how to use the tools provided to complete this mission.

Scenario Name: Space Shuttle to ISS-0005-0010.scn

Original Scenario: Space Shuttle to ISS.scn

File Location: ..\Orbiter 2016\Scenarios\2016 Edition\

Scenario Description:

Space Shuttle to ISS

Space Shuttle to ISS.scn without the automated tutorial provided in the original scenario.

Launch the Space Shuttle Atlantis (STS-101) to orbit using the AscentAP MFD then follow my tutorial to rendezvous with the ISS and dock.

Mission starts on Tue Mar 23, 2010 at 11:57:04 (T-80s to lift off). The Autopilot is pre-configured for launch with the correct settings if you launch at T+80s from the start of this flight.

Although the date of this flight does not correspond to any historic flight done by NASA, the ISS is on a descending orbit near the Cape and in a perfect position for launch to intercept.

Press the "L" button in the L-MFD at Sim: 80s to liftoff at Tue Mar 23 11:58:24 2010 (MJD: 55278.4989).

Good Luck!!

Scenario Initial Parameters and Preflight Analysis:

State: (Paused)

Initial View: External Camera

Tgt: Atlantis

Cam track: (rel-pos)

FoV: 50°

Dst: 78.40

View: Cockpit

Tgt: Atlantis

Cam Cockpit

FoV: 50°

Hud: Surface Earth

Azimuth: 180°

Pitch: +90°

TAS: 5.42

R: 47.38 ALT

Date: Tue Mar 23 11:57:04 2010

MJD: 55278.4980

Sim: 0

#### Engines:

Main Prop: 719k

Main Eng: 0.00

Hover Eng: 0.00

RCS: ROT

Trim: 0.0

L-MFD: AscentAP MFD

Ascent P1/4

MET: 00:00:00.0

Launch azimuth: 137.1°

Orbit inc: 51.6°

Orbit altitude: 350.0km

OMS2 scheduled: yes

R-MFD: Map

Map: Earth

SHP: Atlantis [80.62°W 28.63°N, Alt 52.36, Crs 270.0°]

TGT: ISS [121.97°W 49.59°N, Alt 372.2K]

## Tutorial:

### Flight Director's Forward:

The NASA Mercury Program was designed to put a man into space, assess human capabilities in space, and ensure safe recovery. The Space Race began with the 1957 launch of the Soviet satellite Sputnik 1 and then after many trials and errors, America achieved its goal and even leapfrogged the Soviets by being first to put a man into orbit. The Gemini Project's key achievements included long-duration missions, **rendezvous and docking techniques**, spacewalks, and perfecting re-entry and landing methods.

The Gemini program was pivotal in developing and testing rendezvous and docking techniques, crucial for future lunar missions. Gemini missions demonstrated the ability to maneuver spacecraft into the same orbit and then achieve a controlled docking, a process involving two separate spacecraft joining together in space.

Some missions require that the ORBITER meet, or rendezvous with, a satellite in orbit. If this satellite, or "TARGET," is in orbit prior to the launch of the shuttle, the rendezvous is called a "ground-up rendezvous."

Space rendezvous and docking with a "TARGET" traveling in orbit at 7.684km/s and an altitude 372.2km above the Earth is no small feat. Docking with the International Space Station or ISS(ZARYA), which has limited control thrusters for stabilizing its orientation, makes it even harder. We will take the information available from various sources and join them into this tutorial in order to achieve these two goals -**space rendezvous and controlled docking** in the Stock Space Shuttle Atlantis (STS-101) Atlantis.

We will be using a scenario provided in Orbiter 2016 that has been stripped of its playback tutorial so that you can follow the steps in that tutorial yourself using this tutorial manually instead. We will also show you how to use an online YouTube video of STS-1's actual launch to sync your simulation with that video's launch and then conduct your launch while watching the video (windowed mode required).

This scenario that we will use is from the playback tutorial Space Shuttle to ISS.scn. As it turns out there was no actual Space Shuttle flight with a launch date of March 23, 2010. But this is an Orbiter 2016 tutorial scenario that shows how to fly the Space Shuttle to ZARYA and then modified to remove the playback aspect of that scenario.

The original scenario is located in the ..\Orbiter 2016\Scenarios\2016 Edition\ folder. When you play that scenario, a tutorial takes over your flight and shows you information and instructions on the screen in purple on what is being done to launch the stock Space Shuttle into orbit using the AscentAP

MFD. But only to a certain point. You are left contriving the rest of the mission yourself. So, here at Mission Control Houston we have made it our mission to complete this flight using this scenario without the playback tutorial aspect. It was quite easy to tear out the playback part of this scenario(see [Appendix B. - Scenario Creation](#)).

This tutorial will show you how to strip that automated playback from the scenario and the instructions/information from your screen and allow you to take control of the flight yourself.

And this tutorial will provide this stripped scenario as a downloadable \*.scn file so you don't have to create it yourself. You simply need to paste it into your Scenarios folder and then run it in your Orbiter Launchpad.

When you run it you will need to do all the procedures to get to ISS(ZARYA) yourself using only default MFDs provided in the Orbiter 2016 install, and complete all the steps and info provided in this tutorial to be mission complete. But you will not have any problem with this tutorial.

#### Complete Mission Objectives:

To launch the Space Shuttle Orbiter into a nominal orbit for rendezvous with the ZARYA then proceed to dock. After this, the deployment and addition of the Leonardo module to ISS(ZARYA) if possible then to return safely to Earth at either the Shuttle Landing Facility at Kennedy Space Center in Florida or Edwards Air Force Base in California. While Edwards Air Force Base served as a frequent backup landing site, the Kennedy Space Center was the preferred location for most landings due to its proximity to the launch site. For this tutorial we will only cover the launch to Low Earth Orbit(LEO) and the rendezvous and docking procedures.

#### Mission Duration:

Approximately 8 to 12 days Mission Elapsed Time (MET).

#### Scenario Understanding:

To start with you will need to get the scenario ready to use. To achieve this see section below, [Appendix C. - Scenario for Use With This Tutorial](#)

#### Original Scenario Time:

The scenario's mission start time was chosen by I assume Dr. Martin Schweiger. The scenario starts on Tue Mar 23, 2010 at 11:57:04. I also assume that the time of liftoff he has chosen to launch is the correct time for a nominal launch so we will mirror that launch time.

The liftoff turns out to be Tue Mar 23 11:58:24 2010, T+80s after un pausing the scenario. This is what we will use as well.

We know that it takes us roughly 870 seconds to the first phase of our orbit. 870s plus our 80s to launch is 950 seconds from the beginning of the scenario. 950s with a Launch azimuth of 137.11°. We will conduct calculations for how this was determined in a later tutorial but the information is here for your knowledge.

#### MFDs Needed for This Flight:

MapMFD  
AscentAP MFD  
OrbitMFD  
Sync Orbit MFD  
Docking MFD  
Attitude RCS MFD

#### Mission Launch to Orbit:

Video Syncing during launch for [STS-1 - The Launch - Complete Day 1 \(40th Anniversary\)](#)

1. Start your scenario and at Sim 20 Tue Mar 23 11:57:24 2010 (MJD 55278.4982) you can start the video at: 02:52:35 (T-1:00 to liftoff)

#### I. Launch to the ISS

- A. Un-pause the simulation and watch the "Sim" amount increase to launch at the proper launch time.
  1. Press Ctrl+P to un-pause the simulation.
  2. After unpausing at Sim 20s, start the above [video](#) at timestamp: 02:52:35 (T-01:00).
  3. At Sim 40 seconds Development Flight Instrumentation Recorders ON
  4. At Sim 56 seconds Go for Auto Sequence Start

5. Now watch either the "Sim" amount until it gets to 80s or watch the time for this time: Mar 23 11:58:24 2010 to launch.
  6. At Sim 80, press the "L" button in the L-MFD (AscentAP MFD) to start the autopilot launch (MET 00:00:00.00).
  7. LIFTOFF
- B. A series of automated processes happen during Liftoff  
(Note: Do not move your ship or save your scenario during liftoff or after the OMS-1 cutoff or try to replay a saved scenario expecting the AscentAP MFD to burn again at OMS-2. It will not).
1. Liftoff at Tue Mar 23 11:58:24 2010 MET 00:00:00.00. (You can see your MET in the top right corner of your AscentAP MFD).
  2. Roll Program at MET 00:00:15.00
  3. Roll Complete at MET 00:00:19.00.
  4. Max Q (Maximum dynamic Pressure) at around MET 00:00:54.00.
  5. Go at throttle up at MET 00:01:14.00.
  6. Negative C at MET 00:01:47.00.
  7. Go for SRB Sep at 00:01:59.00.
  8. SRB (Solid Rocket Booster) Separation (Sep) at MET 00:02:07.00 (MET 126s)
  9. Begin PEG 1 guidance.
  10. Press to MECO at MET 00:04:07.00.
  11. Negative return at MET 00:04:21.00.
  12. Gimbal Roll maneuver starts at MET 00:05:46.00.
  13. At MET 00:06:20.00 pitch to +30° and Single Engine Rodda.
  14. Single Engine Press to MECO at MET 00:07:16.00.
  15. At MET the crew is up to 3Gs.
  16. **MECO at MET 00:08:28.00 (508s)** (Sim 593s from start of scenario).
  17. Tank Separation and Nominal OMS-1 Ignition at **MET 00:08:58.00**.
  18. **OMS-1 Cutoff at MET 00:14:30.60 (870s)** (Sim 953s) an orbit of about 22.62 x 350.0k. No dV residuals hopefully. Your remaining fuel should be about 15881kg with a current vehicle mass of 256.012klbm and an empty vehicle mass of 229.999klbm.
  19. Coast to OMS-2 burn.
  20. (A Plane Alignment opportunity occurs during this wait at about MET 00:31:13.00 but we must forgo this burn at this time due to the Ascent AP MFD program already in progress).
  21. Please follow Section II Procedure for Opening the Cargo Bay Doors below then return to monitor the rest of this list.
  22. **Nominal OMS-2 Ignition at MET 00:37:59.00** [at a Time to Apoapsis (ApT) of 69.87s with a burn duration of 00:03:48.35 (229s)].
  23. **OMS-2 Cutoff at MET 00:41:47.35** (Sim 2592 with an orbit of about 332.6 x 352.3k (yours may be slightly different)).
  24. **At this time switch to your external view (F1) and save your scenario state for later.** (Mine is titled: "Space Shuttle to ISS-0005-0010 0001.scn").
  25. Your remaining fuel should be around 11.9kg to 12.0kg (1195kg). You are now in space. Traveling at over 18,000 miles per hour (28968.192 km/hour).
  26. **Keep your AscendAP MFD open!!** so we can keep an eye on the Mission Elapsed Time (MET) as it will be useful for our flight and syncing up with this tutorial.
  27. Please follow all the procedures below with Section III Conduct a Plane Change Maneuver and Burn.

## II. Procedure for Opening the Cargo Bay Doors

### A. Procedure: Open Shuttle Bay Doors

1. Press CTRL+Space bar - Then press Payload Door Operation.
2. The Atlantis Payload Bay Operation panel appears
3. Set PL BAY DOOR, SYS 1 and 2 to ENABLE.
4. Turn on PL BAY MECH PWR, SYS 1 and 2 to ON.
5. Unlatch both bay doors under LATCH CONTROL by setting SYS A and SYS B to RELEASE
6. When the readout says "REL" on both, turn both LATCH CONTROL, SYS A and B to OFF.
7. Set payload bay doors to deploy by setting PL BAY DOOR switch to OPEN
8. When they are deployed you will see under PL BAY DOOR will read OP.
9. Set PL BAY DOOR setting switch to STOP.
10. Deploy both radiators under RADIATOR CONTROL, SYS A and B to DEPLOY.
11. When both displays read "DPL" then set SYS A and B to OFF.
12. Set the KU ANTENNA from GND to DEPLOY.
13. When the KU ANTENNA display reads DPL, set KU ANTENNA switch to GND.
14. Disable PL BAY DOORS and PL BAY MECH PWR to DISABLE and OFF respectively.
15. Close the Atlantis: Payload Bay Operation panel by clicking the red "X".

16. Close the Atlantis Control panel.

### III. Plane Change Burn (NPC)/NC-1 Burn

(Nodal Crossing 1): This burn aligns the shuttle's orbital plane with that of the ISS. The timing is crucial to minimize the need for costly plane changes.

- A. After your OMS-2 Cutoff you will want to adjust your orbital plane to be closer to the ISS's orbital plane.
  1. Open up Align Planes MFD on page 1 of your MFD list.
  2. Press the "TGT" button and scroll to "Spacecraft" with your arrow buttons then to "ISS" for your target.
  3. For this flight you should be approaching the Descending Node (DN) from your position (P) in about 1.7k seconds (Tn 1.7xx seconds and about 00:29:45.00) from OMS-2 cut off. This means you must set up a burn using the NML + direction.
  4. We will use the Attitude RCS MFD to accomplish a +15° OMS burn. The Orbital Maneuvering System (OMS) is a system of hypergolic liquid-propellant rocket engines used on the Space Shuttle.
  5. At about MET 01:01:00.00 or 12:59:30 UTC you can begin set up of this burn
  6. Open Attitude RCS MFD in another MFD or an external MFD screen.
  7. Press "BAS" to select the Basemode to "normal" and then press R+ to add a pitch function.
  8. Press +V button until the + pitch reads +15.
  9. **At Time to Node (Tn) 120.0 seconds (MET 01:04:45.5) in Align Plane MFD, please conduct an external view save** at this point prior to the alignment burn in case anything goes wrong.  
I have called my save "Space Shuttle to ISS-0005-0010 0002.scn"
  10. At Tn 90s (around MET 01:05:15.10) in Align Plane MFD, you are now ready to press GO to start your RCS Attitude change to prograde +15°. Do not do this earlier because it can use up fuel holding that attitude and you will want to cancel this hold attitude program after the burn below for the same reason.
  11. Once Attitude RCS MFD points you at +15° NML +, you can either wait until Align Plane "Tn" is half of the estimated (Est) thrust T (time) needed for TthD, or you can let Align Plane MFD tell you when to burn (You will see "Engage Thrust" in red), and cut your OMS thrust
  12. As you burn, watch the relative inclination (RInc) slowly dropping down to zero.
  13. When the Align Plane MFD tells you to "Kill Thrust", you will kill all thrust.  
Note: This can be a little glitchy at times so when you see TthD at 00.00 or close to it then this is when to cut engines. If "Engage Thrust" stays on after your cutoff, just click on SEL to select a different MFD and then click back on and the issue should be fixed.
  14. After that you can use RCS thrusters to further fine tune your alignment but you will need to set the RCS Attitude to END and then make a new "normal" attitude but with out the + pitch amount since the RCS thrusters are not at a 15° incline to your Shuttle's forward axis. You can use the LIN mode for RCS thrusters to adjust it further using your numpad's 9 and 3 buttons.
  15. Once this is done you will want to also stop the Attitude RCS from holding attitude by pressing RTN, then END. You are now in near perfect alignment with the orbital plane of the ISS.
  16. Your remaining fuel should be about 11356kg out of 21600kg. You should see 11.3kg next to MAIN PROP in the top left of your cockpit view.
  17. **After the align plane burn and adjustment I recommend another save** in the external view to save your progress. My save is called "Space Shuttle to ISS-0005-0010 0003.scn"

### IV. Sunlit Orbital Burn to Increase the Orbital Period and Create our Rendezvous Point - This was referred to as the Terminal Phase Initiation (TI) burn.

- A. **At MET 01:27:02.00** you should start to see the sunrise on your ship in an external view.
- B. Now is a good time to prepare for increasing your orbital period and create your rendezvous point.
  1. Press PRO GRD in your hud to start the Prograde Autopilot. Once it finds it and stabilizes, press KILL ROT to save fuel.
- C. Once the sun is up and you can see the Earth well underneath you (crossing the Earth's terminator), you can begin the next step C.
- D. **At approximately MET 01:33:18.50** you will cross the Earth's terminator.
- E. Sunset happens at about MET 02:19:10.00. This gives a half period of about 00:45:52.00 (2,752s). Half of that or when the sun will be as high as it can be is about 00:22:56.00 after sunrise.

- F. This would mean that if you want to choose the exact middle of the day period of your orbit, you would want to shoot for about MET 01:33:18.00 + 00:22:56.00 = MET 01:56:14.00 to start the below process.
- G. Also for your records you can see that your orbit period is about 01:31:44.00 (5,504s). You can check this with a seconds to hours calculator located here: <https://www.inchcalculator.com/seconds-to-time-calculator/>.
- H. OrbitMFD's T = 5.473k seconds = 01:31:13.00. We were close. It's good to know these things.
- I. You will now set your intersection point as your PeA and in sunlight using Sync Orbit MFD.
- J. You can also choose to burn as close to ISS's PeA as possible if you like; however this will make your rendezvous happen mostly in the dark. This is not recommended.
- K. I have chosen an early intersection point but you can choose any point you like in this orbit's sunlit time.
  1. To conduct an OMS Prograde Burn and create our new PeA I will use RCS Attitude and Sync Orbit MFD to set the rendezvous orbit.
  2. My burn time choice will be about MET 01:40:00.00
  3. At about T-2 min (120s) to OMS burn open the Sync Orbit MFD.
  4. Press TGT to set the target to the ISS.
  5. Press the MOD button until it shows a list of times on the right side of the MFD screen.
  6. You should see "Ref: Sh periapsis" in the top left.
  7. Press the LEN button and enter 15.
  8. Open in another MFD window the RCS Attitude MFD.
  9. Press the SET button until it shows "prograde" in the "Basemod:" area.
  10. Press the "+R" button to see the "+ pitch" subsection underneath "Basemode:"
  11. Press the "+V" button until it reads +15.
  12. At about MET 01:38:00.00 save your sim in the external view before you conduct your attitude and burn.
  13. At about MET 01:39:00 press the "GO" button to engage a prograde burn +15° for the OMS burn.
  14. Once the attitude is stable for this maneuver, make another external save point. Mine is called "Space Shuttle to ISS-0005-0010 0004.scn"
  15. After the save point is created you can engage your OMS thrust by pressing and holding the num pad "+" on your keyboard.
  16. Watch the list of times in Sync Orbit MFD and the two times (Sh-ToR and Tg-Tor) in yellow move.
  17. When the yellow numbers move to the bottom of that list then you can cut engines anywhere from #14 orbit to #10 orbit (Ob). Any of these orbits will suffice. I usually choose #14 orbit to save on fuel and because it is when the DTmin goes close to 0.
  18. Once you have reached the orbit # you are happy with, or if you see the DTmin reach 0.00 you can CUT your OMS thrust by letting go of the num pad "+".
  19. At this point it would be wise to do another external view and save your scenario. "Space Shuttle to ISS-0005-0010 0005.scn".

#### V. Note ISS's RAD at your PeA

- A. You have now set your intersection point for rendezvous with the ISS in a daylight part of your orbit. Now it is time to note the radial and normal altitude of the ISS while it passes over your periapsis (PeA). You want your radial altitude to be about the same and as close to that as possible. To see this altitude you will need two MFDs. OrbitMFD and Sync Orbit MFD. Follow the steps below:
  1. Open OrbitMFD if you do not already have it open and set the Form (FRM) to "Equatorial" EQU (Frm ECL).
  2. Set the Projection (PRJ) to SHP.
  3. Now ensure that the distances are set to view everything in radials from the center of the Earth.
  4. This means that you will see your PeA as PeR and your Alt will show as RAD.
  5. Press TGT to select the ISS as the target.
  6. You will be looking at two things. In Sync Orbit MFD you will notice that the column on the right "Tg-ToR" is counting down. This the time the ISS is to your Periapsis.
  7. When this number Tg-ToR reaches 120.00 you will want to make an external save point. Mine is called "Space Shuttle to ISS-0005-0010 0006.scn"
  8. When the Tg-ToR reaches 0.00 you can pause your sim, and then make a note of the reading in Orbit MFD of what the IIS's yellow RAD amount is. You can also switch to Altitude mode by pressing the DST button in OrbitMFD to see the ISS's Altitude in km above the Earth's surface. Both amounts will be needed later.

9. Once they are written down you can change or keep your Orbit MFD's view back to Altitude in kilometers by pressing the "DST" button to toggle the two views.
10. Keep both the Sync Orbit MFD and the OrbitMFD open and move on to the next section.

#### VI. Match your PeA to ISS RAD/Alt at our own ApA

- A. You can wait around or fast forward until your own ApT is about 180 (seconds). This is your time to Apoapsis.
- B. At this time it is a good idea to save your sim in the external view in case you mess this burn up. I have named my save point as "Space Shuttle to ISS-0005-0010 0007.scn"
- C. This gives you some time to set up another RCS Attitude +15° OMS burn.
- D. You will want to see if your PeR is currently higher or lower than the amount you wrote down from the ISS's RAD when it passed your periapsis.
  1. If it is higher, then you will burn your OMS retrograde to lower your PeR.
  2. If it is lower then you will burn your OMS prograde to raise your PeR.
- E. For this example we will be raising our PeR because my PeR was 6.723M and it needs to be what I wrote down which was 6.739M.
- F. So we will burn OMS prograde at +15°.
- G. If your burn requires a retrograde burn you can do everything below the same except choose retrograde in RCS Attitude MFD.
- H. You will be using the Sync Orbit MFD again so keep it viewable.
  1. Set up your RCS Attitude for a +15 prograde burn by pressing GO at about your 80s Time to Apoapsis (ApT).
- I. Burn **EXACTLY** at your ApR (ApT 0.000) to set our PeR to ISS's RAD (radial) altitude so as not to change your intersection point too much.
  1. At precisely ApT 0.0 you must burn prograde keeping an eye on your PeR until it comes up to the RAD that ISS had at our PeR.
  2. You can now cancel your RCS Attitude MFD hold on prograde pitch +15° by hitting RTN then END.
  3. Once you're done with the burn you can save your sim in an external view. I have called mine: "Space Shuttle to ISS-0005-0010 0008.scn"
  4. By doing this my orbit in Sync Orbit MFD has moved my intercept up a few orbits from where it was. This is good. I had chosen a fairly late intercept orbit earlier when raising our ApA to minimize the fuel needed when getting close enough to dock with the ISS.
  5. The earlier your numbers (in yellow) are (lower the number of orbits), the more fuel you will need to rendezvous with the ISS. I chose a cheaper intercept but longer rendezvous time.
  6. All other burns from here on will ONLY be at your periapsis. Do not change your PeA/PeR from your Apoapsis from here on.
  7. Hopefully our remaining fuel will be about 9.82kg (9823kg) at this point in the mission.
- J. There are two numbers that you will now want to keep near 0 in Sync Orbit MFD -The RInc and the DTmin for the remaining burns or RCS maneuvers.
  1. These are the main rendezvous maneuvers needed using the OMS engines. The rest should be small adjustments using the Space Shuttle's RCS thrusters.

#### VII. Small Align Plane Adjustments If Needed

- A. In Sync Orbit MFD you will be keeping an eye on your orbit position and the Dtmin amount as well as the relative inclination RInc between the two orbits in degrees.
- B. If everything has been done correctly, this should still be very close to 0°. If it is more than 0.50° then you will need to reload your saved scenario "Space Shuttle to ISS-0005-0010 0002.scn" and realign your planes again, and then readjust your apoapsis to match the ISS's altitude again by following the steps above. If RInc is more than 1.00°, the Sync Orbit MFD will not work.
- C. If it is less than 0.05° then you are good but if it goes near 0.05° then it is a good idea to wait until the correct time and then conduct a small RCS adjustment in Normal + or Normal - directions.
- D. In Align Plane MFD you may see that there is a small amount of thrust needed to align. This can be done using your RCS thrusters without any pitch +/- and if it is small enough (i.e. < 10.00 seconds or so), you can do this quickly and easily.
- E. Ensure that your RCS configuration is in LIN (or linear mode).
  1. When the Align Plane MFD shows the Tn value of about 120.0s, you will note the node (AN or DN) line that you are closest to. You are the intersection line (green line with P near the circumference of the circle)
    - a) If you are close to the DN position (in yellow), you will set up the attitude using the NML + autopilot.

- b) If you are close to the AN position (in yellow), you will set up the attitude using the NML - autopilot.
2. After the autopilot points you at the correct Node, you will then want to burn **exactly** 1/2 the time listed under Est thrust T for TthA or TthD. TthA is only for the Ascending Node (AN) pointing alignment and TthD is for the Descending Node (DN) pointing alignment.
3. Whichever you are pointing in is the number in seconds you will need to use your RCS or OMS thrusters to burn for.
4. You will need to start at 1/2 that time to begin burning and cutoff when the time runs out for the node you are burning towards.
5. In other words if you (P) are closest to the AN yellow line, you will use the NML - autopilot to point in the correct attitude and look at the TthA amount in seconds. If it is say 5.00 seconds, then you will need to begin your burn at 2.50 seconds and end when it reaches 0.00.

#### VIII. Small to Medium DTmin and Period Adjustment Burn at Your Periapsis

- A. On the first orbit after completing part VI Match your PeA to ISS RAD/Alt at our own ApA of this tutorial, you may need to adjust your period to be closer to the ISS's period. This can be done **ONLY** at your Periapsis. As you approach your first Periapsis after part VI, your DTmin in Sync Orbit MFD might be a bit large (i.e > 5.00). If it is you may need to complete the steps below:
  1. Check your OrbitMFD's PeT. When it reaches 120s, hit pause and **create an external save point** in preparation for the RCS adjustments you will be making soon. My save is called "Space Shuttle to ISS-0005-0010 0009.scn"
  2. When your PeT gets to 80s, set the RCS Attitude MFD to a prograde with a + pitch of +15\*
  3. Once you are pointed prograde, you may need to do an OMS burn when your PeT goes to 0.00.
  4. When your PeT goes to 0.00 then set up your RCS Attitude MFD to do a +0\* pitch attitude in the prograde direction and use your RCS thrusters to thrust forward (Numpad 6) or backward (Numpad 9) to bring your Sync Orbit MFD's DTmin to 0.00. You can use the left CTRL key on your keyboard to make even smaller adjustments to get it exactly at 0.00. It is ok if after that, it starts to go up.
  5. After this adjustment burn **you should choose to save your progress**. My save is called "Space Shuttle to ISS-0005-0010 0010.scn" It is a good habit to save in external view mode only so you can keep the camera angle you want. Otherwise if you save in cockpit mode, your external camera view will default to a view behind the Space Shuttle.
  6. If you wish and things look good in Sync Orbit MFD (RInc stays below 0.50° per orbit, and your period DTmin stays below 5.00 per orbit, you can continue to fast forward until either of these amounts go above these tolerances.
  7. Continue to keep an eye on these while fast forwarding until you are at Orbit (Ob) #2. (Note: your orbit # may jump around as you fast forward. This is normal as your relative velocity to the ISS will go up and down as you can see in Docking MFD).

#### IX. Get To Orbit #2

- A. After your orbit goes to the No. 2 position in Sync Orbit MFD wait until you are about T-200s before your PeA and then you should **make an external save point**. My save point is called: "Space Shuttle to ISS-0005-0011.scn".
- B. At this point you should make some observations in Sync Orbit MFD. First note where you are in relation to the intersect point.
  1. Since you are before your intersection point, then you will want to check your DTmin.
    - a) If your DTmin is less than 1.00 then you will not need to do anything on this orbit and you can go on to part D below.
    - b) If your DTmin is more than 1.00 then you will need to make a short OMS burn and possibly an RCS thruster burn to keep your DTmin burn low. This is important to do now because you are getting close to your rendezvous.
  2. Begin your attitude to prograde at pitch +15\* using Sync Orbit MFD at T-80s to PeA.
  3. At **EXACTLY** PeT 0.000 you will make your OMS burn until DTmin reaches 0.00
  4. After you make the burn, **make an external save point**. Mine is called: "Space Shuttle to ISS-0005-0012.scn"
  5. From here on -every time you get close to your Periapsis, you will need to adjust this unless it is 0.00. It needs to be as close to 0.00 as possible for the rendezvous to be successful.
  6. In some cases doing this burn may change your orbit from 2 to 1 and/or 0. This is ok. Either way, when you get near Orbit 2, 1, or 0 you need to be keeping a closer eye on the numbers of your rendezvous.

X. Get To Orbit #1 or #0

- After your orbit goes to the No. 1 or No. 0 position in Sync Orbit MFD wait until you are about T-400s before your last Pe before rendezvous point (PeT 400.000).
- You should **make an external save point**. My save point is called: "Space Shuttle to ISS-0005-0010-0013.scn".
- You are now close to the intersection, you can begin your prep for rendezvous.
- Here are the stock MFDs you should have open when you get to the last orbit. In the glass cockpit I like to have Ascent AP MFD in L-MFD, Sync Orbit MFD in the R-MFD, OrbitMFD set with the ISS as the target above the L-MFD, Align Plane MFD (target ISS) covering the Ascent AP MFD (accept for the MET info), Dock MFD (target ISS) next to the L-MFD, and RCS Attitude MFD above the R-MFD. As seen below, you are now set for your rendezvous.

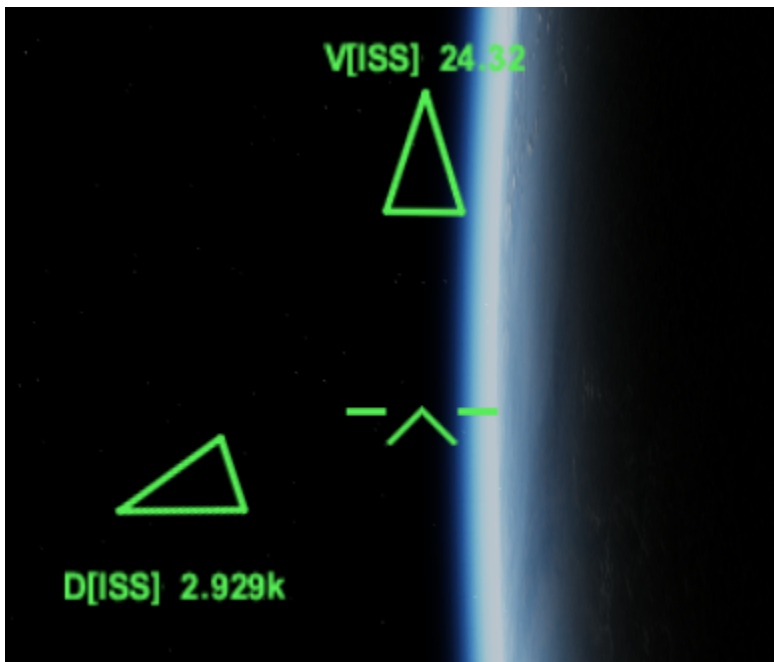


XI. Rendezvous Burn with OMS

- After making the save you will want to look at Docking MFD and select TGT to select ISS from the list.
- Press the HUD button and begin to search for the ISS using your Rotation RCS jets. You may see something that looks like the below image.



- C. In the image below you can see a triangle on your screen that is titled “D[ISS]” That is the direction to the ISS and your distance to the ISS.



- D. It is easier to use your pitch and yaw thrusters to find the ISS by rolling to where the bottom of the arrow to the ISS is flat at your top, bottom, left, or right.



- E. In the image above you can see that it is much easier to yaw to the port (left) direction to find the ISS now that it is directly to the port.

- F. Use the RCS in rotation (ROT) mode to turn toward that arrow until you can see a square. In this case you would use the Numpad 1 to yaw to port.
- G. It should have a D[ISS] under a square where the ISS is. Next to the D[ISS] should be a number which is the distance to the ISS from your current location.



- H. Once you find it you should also see a triangle labeled "V[ISS]" somewhere on your screen. If you don't, it is because the relative velocity vector **target** is somewhere on your screen already in the view you are already facing. Look for it. It looks like this:



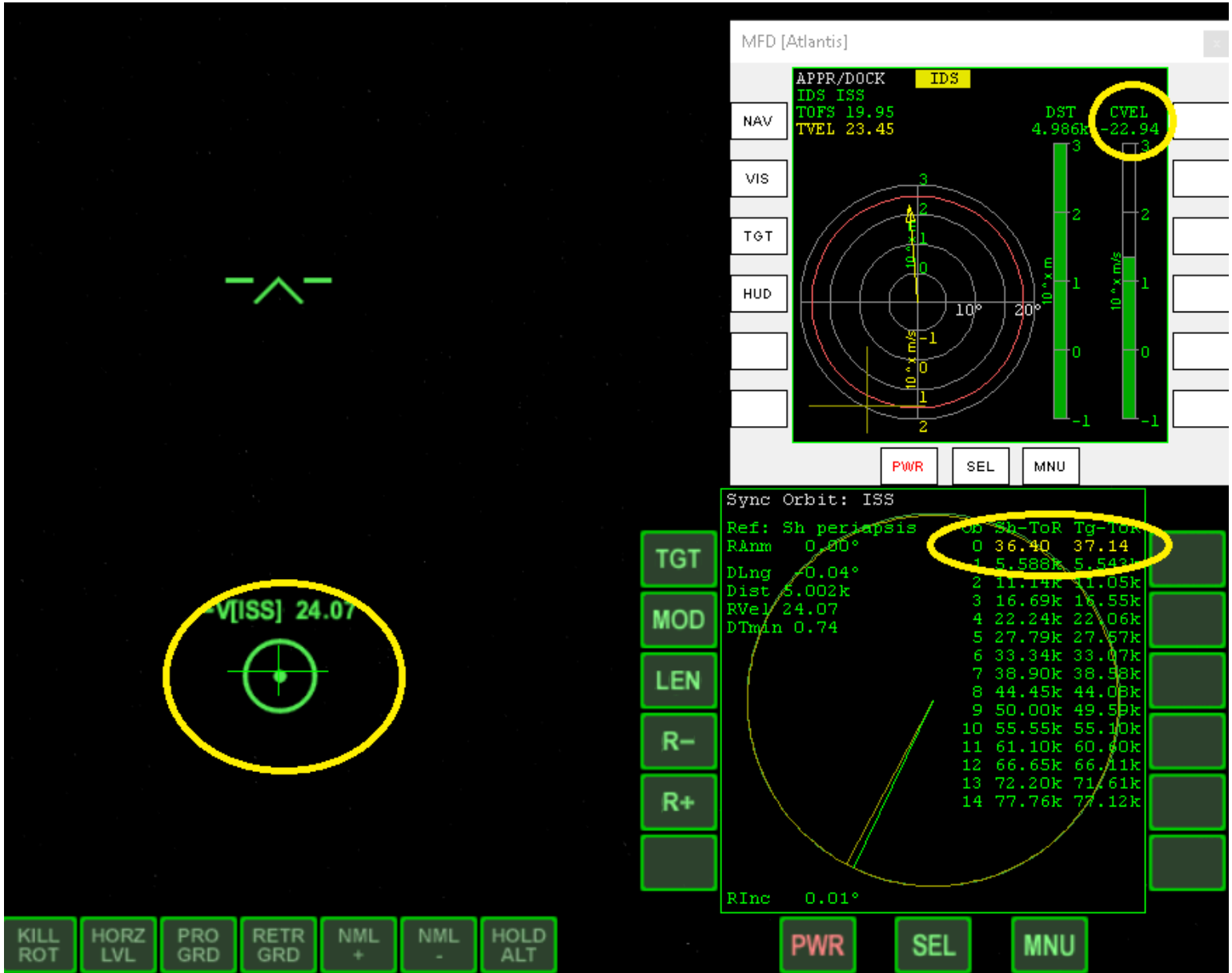
- I. If you don't see the target, find it by following the arrow toward the V[ISS] until you are pointing toward it like the image above.
- J. Once you have found the V[ISS] target we will now look for the **negative** relative velocity vector. It is 180° opposite of the direction of the V[ISS] now you can rotate 180° until you find the -V[ISS].
- K. If you see the -V[ISS] on your screen simply go to part I below.



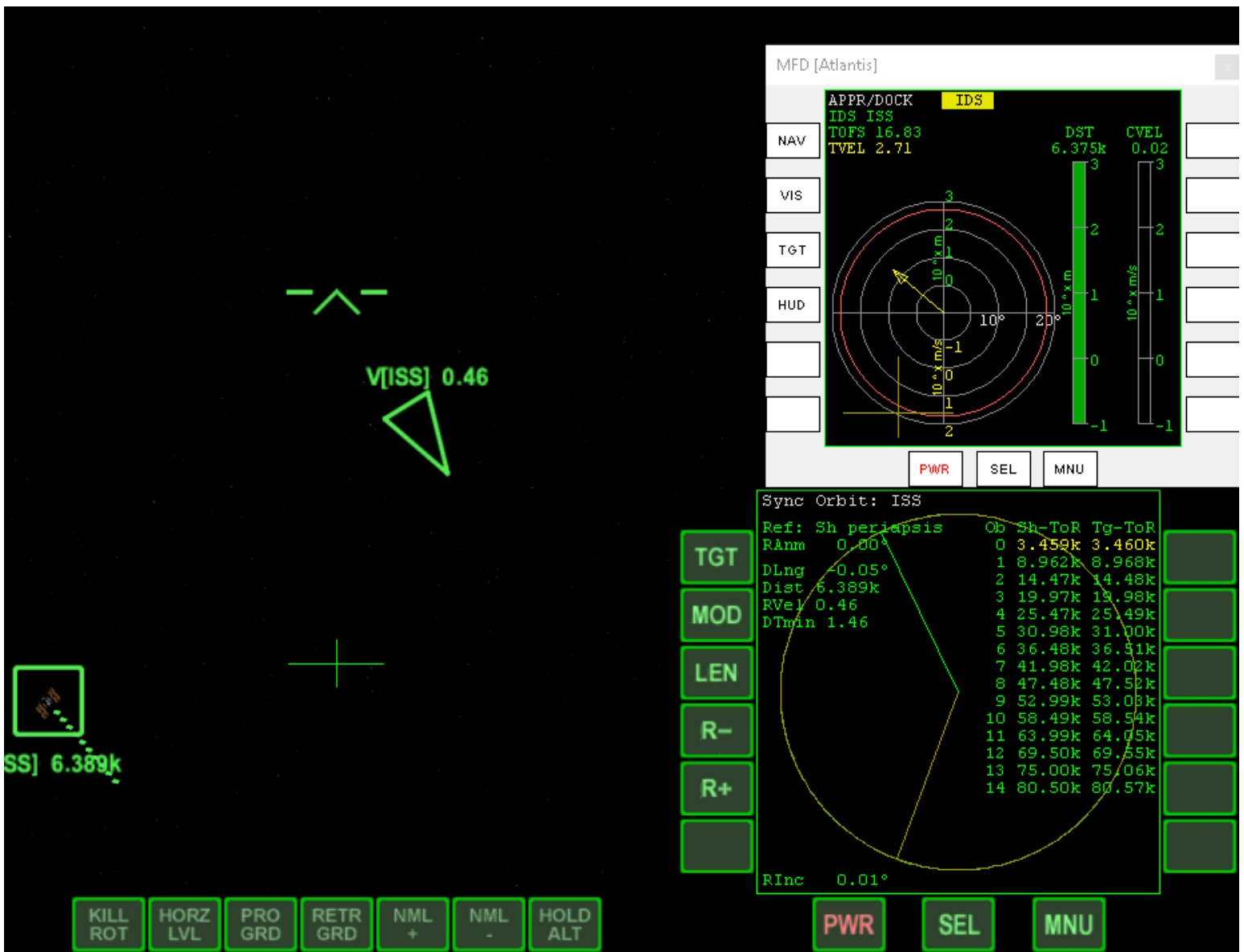
- L. Rotate up, down or sideways to find the -V[ISS] target by pitching or yawing away from the "V[ISS]" arrow/target until you find the target and put your -15° mark on top of the "-V[ISS]" target as seen below.



- M. Now check to see if you are near your PeA as viewed in OrbitMFD or Sync Orbit MFD. If you are getting close, then wait until the time gets to 0.00s and then look to see if your CVEL is positive or negative (it should be negative but in case it is not):
1. If the CVEL is negative then burn your OMS at full throttle until your CVEL goes to 0.00.
  2. If your CVEL is not negative yet wait until it is and then burn OMS to null your relative velocity until CVEL gets to 0.00.
  3. The image below shows you are ready to thrust with your OMS to null the relative negative velocity and you have roughly -22.94 velocity and you have 36.4 seconds to throttle up.



- N. When this is done you can **make an external save point**. I called mine "Space Shuttle to ISS-0005-0010-0014.scn"
- O. The image below shows the relative velocity has been effectively nullified.



XII. You are Go for Rendezvous and Docking

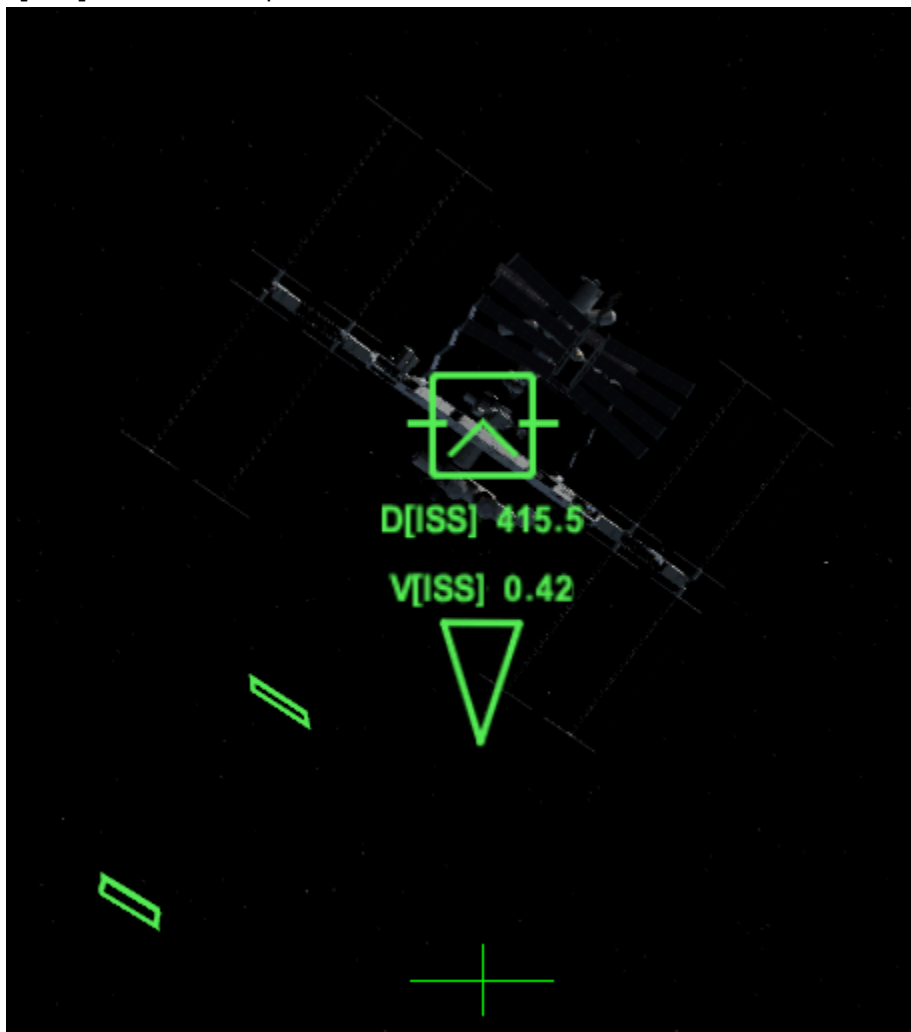
- When your CVEL in DockMFD goes to 0.00 then cut your engines. Your relative velocity with respect to the ISS is now 0.00. This will change over time but don't worry.
- You will now point your nose "↖" directly at the ISS.
- Note the position of the V[ISS] arrow in relation to your nose. Whichever direction it is pointing to V[ISS], you will want to use RCS in LIN mode to thrust in the arrow direction to bring the V[ISS] to line up directly on top of the D[ISS] target.
- So if the arrow is pointing down then press Numpad 2 to make it go up. If it points to the left, use the thruster on Numpad 3 to make it come to the right.
- Once the V[ISS] target is on top of the ISS, you may use your Numpad 6 to thrust toward the ISS.
- Hold your RCS thruster toward the ISS until your CVEL goes to about  $1 \times 10^x$  m/s or ten meters per second. If you prefer you can choose a smaller amount. It depends on how far you are away from the ISS.
- As you're thrusting toward the ISS try and keep your velocity vector on the ISS as you reach 10 m/s.



- H. You should add about 2.00 m/s if the ISS is less than a kilometer away. If you have a distance of about 1-10km then 5 m/s is more appropriate. Remember you do need to rendezvous when it is daylight.
- I. Note that however much thrust you use to get to the ISS you will need the same amount to stop once you're there. Also, you may not rendezvous when the sun is lighting your two vessels. This is why it is very helpful for these HUD icons to be on your screen as you will not need to see the target to rendezvous using your HUD.
- J. You may have to do the above process (steps A - I) several times if you are a good distance away until you close the distance to the ISS.
- K. When you reach the ISS and are about 700 m away, you will point at the ISS and thrust in reverse (Numpad 9) in LIN mode until you are back at CVEL 0.00.
- L. you can **make an external save point**. I called mine "Space Shuttle to ISS-0005-0010-0015.scn"
- M. When you arrive at the ISS, you will want to set your Docking MFD to show you the docking port approach vector.
- N. Select TGT in Docking MFD and choose the ISS, then use your right arrow key to select ISS, dock 1.
- O. Now click HUD again on Docking MFD.
- P. 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.
- Q. If all goes well you should be at about 7.22kg of fuel when you arrive near ISS at 500m distance.
- R. You will need about 3.00 kg of fuel to de-orbit burn so do not let your fuel go below 3.00 kg.
- S. You must maneuver the Space Shuttle into that docking vector path using your RCS jets. This tutorial will show you an easy way.

### XIII. Docking with the ISS

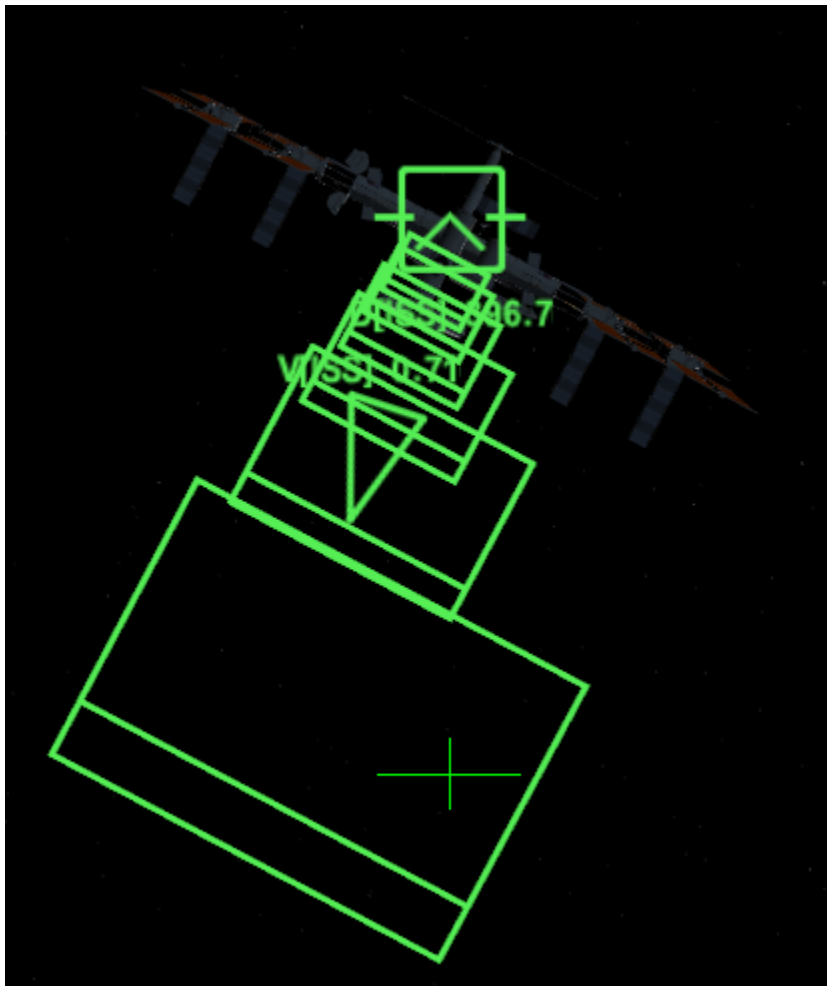
- A. First face the ISS.
- B. Rotate until the V[ISS] is directly below, above, or to either side. The image shows the V[ISS] below our Space Shuttle.



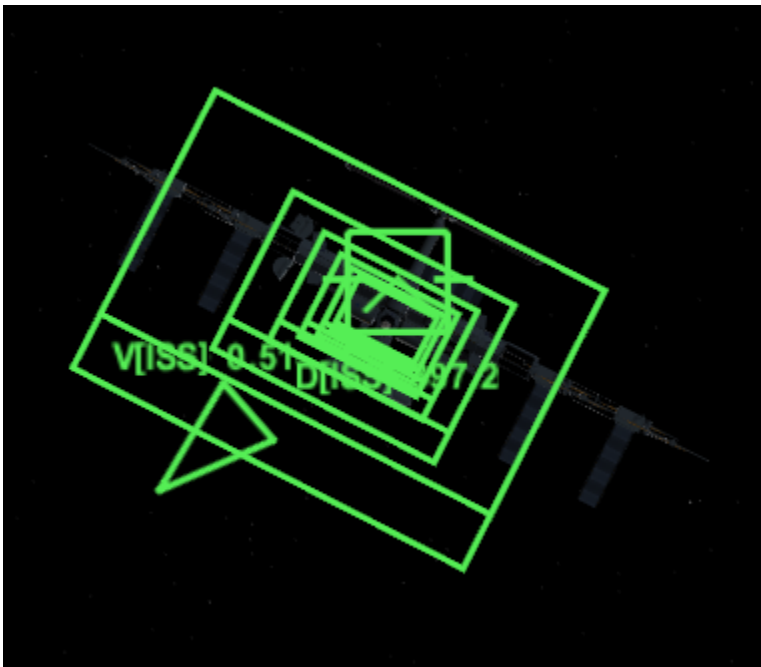
- C. Once rotated, you will use RCS in linear mode (LIN) to bring the V[ISS] to the ISS and on top of the square as we did earlier.



- D. Now you will want to put yourself inside the path leading to the docking collar Dock 1.



- E. As seen above we are almost inside the docking path until it looks like the image below.



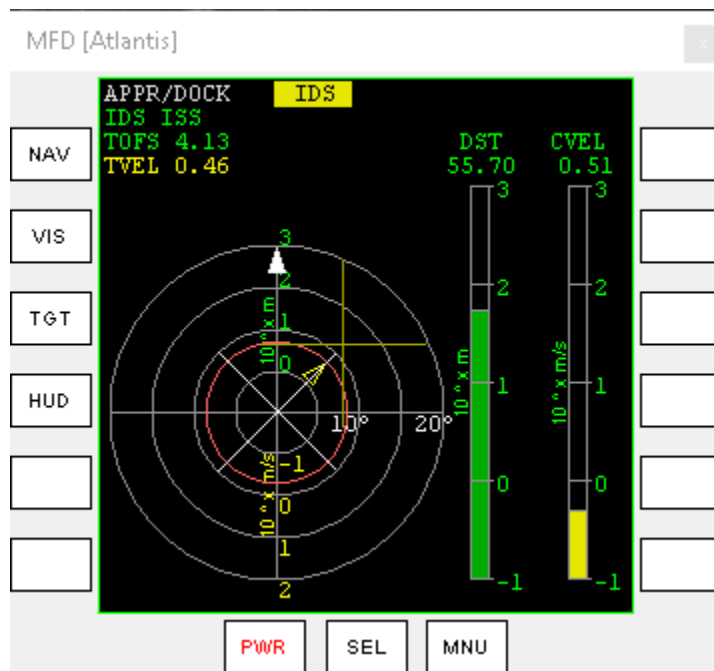
- F. Once your view looks like the above image, you can open up your RCS Attitude MFD and make sure your KILL ROT is not currently ON and then press the DCK button. It should already have NAV 1 131.30MHz as the transponder (XPDR) for the ISS. We want to set it to the docking port we have targeted.
- G. Click the NAV button until you see NAV2 108.05MHz IDS D-01 ISS in the top right corner of RCS Attitude MFD.
- H. Now press ACT to activate the alignment feature of this MFD. The RCS Attitude MFD will align your docking port with dock 1 of the ISS.
- I. Now all you have to do is thrust upward to dock. Use Numpad 2 to move upward toward the ISS dock 1.
- J. Watch your CVEL that it goes up to 1.00 to 2.00 or so as you begin your approach. You will notice that RCS Attitude has aligned your docking port to be the correct rotational direction to dock as the white arrow will show as being straight up in the 12:00 position. See below image:



- K. Now that you are heading upward to the ISS dock, you need to control your vertical and horizontal alignment to dock 1. This is seen by the yellow cross. As you can see above, the yellow cross/plus indicator is too far to the top right area. You need to have that directly in the middle of your target. There is also a yellow arrow near the center of your docking target. That arrow shows which direction along the horizontal plane you are

heading. As you move upward, you simply need to aim that arrow toward the yellow cross and have it stable on your center by the time you reach the docking port on ISS.

- L. Start by making the yellow arrow point to the center of your yellow cross as seen below:



- M. It takes some getting used to but know that to control the forward, back, left and right directions (which is all you need for this segment of docking), you only need these Numpad keys: forward = 6, backward = 9, left = 1, and right = 3. Only use these four directions to get the yellow cross onto your center target. If your CVEL starts to go into the negative simply press Numpad 6 to begin to go back toward the ISS's dock 1 port.
- N. After this just keep your yellow cross at the center and your movement toward dock 1 and you should dock with little problem. It very much beats doing the alignment all manually.
- O. After you dock you should pat yourself on the back and realize that you have done something that is not easy to do AT ALL in Orbiter 2016. Celebrate and then save an external save point. I named mine "Space Shuttle to ISS-0005-0010-0016.scn"

#### Appendix A. - List of Saved Scenarios:

1. Space Shuttle to ISS-0005-0010 0001.scn is the Orbit Complete save point.
2. Space Shuttle to ISS-0005-0010 0002.scn is the Before Align Plane save point.
3. Space Shuttle to ISS-0005-0010 0003.scn is the After Align Plane save point.
4. Space Shuttle to ISS-0005-0010 0004.scn is before setting up your sunlit Periapsis rendezvous point.
5. Space Shuttle to ISS-0005-0010 0005.scn is after setting up your sunlit Periapsis rendezvous point.
6. Space Shuttle to ISS-0005-0010 0006.scn is 120s before the ISS passes your Periapsis to take note of.
7. Space Shuttle to ISS-0005-0010 0007.scn is before matching your PeR to the ISS's RAD altitude.
8. Space Shuttle to ISS-0005-0010 0008.scn is after matching your PeR to the ISS's RAD altitude.
9. Space Shuttle to ISS-0005-0010 0009.scn is just before a small to medium burn to fix DTmin
10. Space Shuttle to ISS-0005-0010 0010.scn is just after a small to medium burn to fix DTmin
11. Space Shuttle to ISS-0005-0010 0011.scn in Orbit #2 just before a period adjustment burn.
12. Space Shuttle to ISS-0005-0010 0012.scn in Orbit #2 just after a period adjustment burn.
13. Space Shuttle to ISS-0005-0010 0013.scn in Orbit #0 just before your last DTmin adjustment burn.
14. Space Shuttle to ISS-0005-0010-0014.scn in Orbit #0 you have just nullified your relative velocity.
15. Space Shuttle to ISS-0005-0010-0015.scn you are 700m from the ISS.
16. Space Shuttle to ISS-0005-0010-0016.scn you have docked with the ISS docking port 1.

#### Appendix B. - Scenario Creation:

In order to create your own workable version of the original playback scenario "Space Shuttle to ISS.scn", you simply copy the original to the root Scenarios directory and rename it. This breaks the

code in system.dat located in this folder:

..\Orbiter 2016\Flights\Space Shuttle to ISS, which ties into any scenario named Space Shuttle to ISS.scn and starts the playback for that scenario named that filename. In fact you could name any scenario as "Space Shuttle to ISS.scn" and it would run the playback aspect. To that end, I have been able to "gut" the playback aspect of this scenario and use it for this tutorial as you will need to use it in order to follow this written tutorial.

I have included the code in this tutorial (see below) as well as a downloadable copy of our starter scenario in order to facilitate the use with this tutorial. You can copy and paste the code directly into another scenario using a text editor (We use [Notepad++](#)) and save your new file. We named ours "Space Shuttle to ISS-0005-0010.scn". The code is given below.

#### Appendix C. - Scenario for Use With This Tutorial <code>:

"Space Shuttle to ISS-0005-0010.scn"

```
BEGIN_HYPERDESC
<h1>Space Shuttle to ISS</h1>
<p><b>Space Shuttle to ISS.scn</b> without the automated tutorial provided in the original
scenario.</p><br><br>
<ul style="list-style-type:
square;margin-left:20px;margin-top:10px;margin-bottom:10px;margin-right:0px;padding:0px;">
<li><p>Launch the Space Shuttle Atlantis (STS-101) to orbit using the AscentAP MFD then follow my
tutorial to rendezvous with the ISS and dock.</p></li>
<li><p>Mission starts on Tue Mar 23, 2010 at 11:57:04 (T-80s to lift off). The Autopilot is
pre-configured for launch with the correct settings if you launch at T+80s from the start of this
flight.</p></li>
<li><p>Although the date of this flight does not correspond to any historic flight done by NASA, the
ISS is on a descending orbit near the Cape and in a perfect position for launch to intercept.</p></li>
<li><p>Press the "L" button in the L-MFD at Sim: 80s to liftoff at Tue Mar 23 11:58:24 2010 (MJD:
55278.4989).</p></li>
<p>Good Luck!!</p>
<div style="margin-left:40%">polaris149Tiberius - 2025<br>
<a href="https://www.orbiter-forum.com/members/polaris149tiberius.507/"
target="_blank">https://www.orbiter-forum.com/members/polaris149tiberius.507/</a></div>
END_HYPERDESC

END_DESC

BEGIN_ENVIRONMENT
  System Sol
  Date MJD 55278.4979646848
END_ENVIRONMENT

BEGIN_FOCUS
  Ship Atlantis
END_FOCUS

BEGIN_CAMERA
```

```
TARGET Atlantis
MODE Extern
POS 4.000000 -179.908748 0.000000
TRACKMODE TargetRelative
FOV 50.00
BEGIN_PRESET
  Cockpit:Atlantis:50.38
  Track:ISS:40.00:RELATIVE 1.983 -0.474 -0.522
  Ground:Atlantis:10.00:Earth -80.64956 28.58345 20.00
  Ground:Atlantis:10.00:Earth -80.62091 28.61734 13.00
  Ground:Atlantis:10.00:Earth -80.62043 28.62695 30.00 2.83 0.09
  Ground:Atlantis:15.13:Earth -80.62028 28.62644 13.00 2.27 0.24
  Ground:Atlantis:15.27:Earth -80.62036 28.62704 67.00 2.99 -0.07
  Ground:Atlantis:10.00:Earth -80.62363 28.61974 1.00
  Ground:Atlantis:10.00:Earth -80.62250 28.62220 1.00
  Track:Atlantis:50.00:RELATIVE 2.890 -0.009 -1.229
  Track:Atlantis:50.00:RELATIVE 4.317 0.000 3.063
  Track:Atlantis:50.00:RELATIVE 4.317 3.141 0.079
  Track:Atlantis:50.00:RELATIVE 2.882 0.000 3.003
  Track:Atlantis:50.00:RELATIVE 4.000 0.528 0.000
  Track:Atlantis:50.00:RELATIVE 4.000 1.479 0.000
  Track:Atlantis:50.00:RELATIVE 4.000 -0.010 0.000
  Track:Atlantis:50.00:RELATIVE 4.000 -1.604 0.000
  Track:Atlantis:50.00:RELATIVE 4.000 -0.010 -0.643
  Track:Atlantis:50.00:RELATIVE 4.000 -0.010 -1.730
  Track:Atlantis:50.00:RELATIVE 4.000 -3.140 -1.599
  Track:Atlantis:50.00:RELATIVE 4.000 -3.140 0.000
  Track:Atlantis:50.00:GLOBAL 4.000 -3.098 1.107
  Track:Atlantis:50.00:RELATIVE 4.000 -3.140 -0.717
  Track:Atlantis:22.60:RELATIVE 4.000 -3.140 -0.717
  Track:Atlantis:50.00:RELATIVE 4.000 -3.140 0.000
END_PRESET
END_CAMERA
BEGIN_HUD
  TYPE Surface
END_HUD
BEGIN_MFD Left
  TYPE User
  MODE AscentAP
END_MFD
BEGIN_MFD Right
  TYPE Map
  REF Earth
  TARGET ISS
  ZOOM 4
  DISP 62639
END_MFD
BEGIN_SHIPS
ISS:ProjectAlpha_ISS
  STATUS Orbiting Earth
  RPOS -2332086.423 6182445.211 -1345307.918
  RVEL 5336.1922 821.0606 -5467.3974
```

```
AROT -127.055 1.840 -42.434
VROT 0.1001 -0.0289 -0.0620
AFCMODE 7
PRPLEVEL 0:1.000000
IDS 0:1 100 1:2 100 2:3 100 3:4 100 4:5 100
NAVFREQ 0 0
XPDR 466
FLIGHTDATA
END
Atlantis:Atlantis
STATUS Landed Earth
POS -80.6208629 28.6270922
HEADING 180.02
ALT 47.360
AROT 151.068 -8.226 4.507
AFCMODE 7
PRPLEVEL 0:1.000000
DOCKINFO 1:0,Atlantis_ET
NAVFREQ 466 1
FLIGHTDATA
CONFIGURATION 0
GEAR 0 0.0000
ARM_STATUS 0.5000 0.0000 0.0000 0.5000 0.5000 0.5000
SAT_OFS_X 0.000000
SAT_OFS_Y 0.000000
SAT_OFS_Z 0.000000
MET 0.000 0.000 0.000 0.000
ASCENTAP 0 0 1 350000 2.3937 -1.40710 0.49964
END
Leonardo:Leonardo_mplm
STATUS Landed Earth
POS -80.6208629 28.6270886
HEADING 180.02
ALT 47.360
AROT 0.000 -0.000 0.000
ATTACHED 0:0,Atlantis
AFCMODE 7
NAVFREQ 0 0
XPDR 477
FLIGHTDATA
END
Atlantis_ET:Atlantis_Tank
STATUS Landed Earth
POS -80.6208628 28.6271639
HEADING 180.02
ALT 60.978
AROT 151.068 -8.226 4.507
AFCMODE 7
PRPLEVEL 0:1.000000
DOCKINFO 0:1,Atlantis 1:0,Atlantis-SRB1 2:0,Atlantis-SRB2
FLIGHTDATA
END
Atlantis-SRB1:Atlantis_SRB
STATUS Landed Earth
POS -80.6209264 28.6271640
HEADING 179.87
```

```
ALT 49.578
AROT 151.068 -8.226 4.507
AFCMODE 7
PRPLEVEL 0:1.000000
DOCKINFO 0:1,Atlantis_ET
FLIGHTDATA
END
Atlantis-SRB2:Atlantis_SRB
STATUS Landed Earth
POS -80.6207993 28.6271639
HEADING 180.18
ALT 49.578
AROT 151.068 -8.226 -175.493
AFCMODE 7
PRPLEVEL 0:1.000000
DOCKINFO 0:2,Atlantis_ET
FLIGHTDATA
END
END_SHIPS

BEGIN_ExtMFD
END
```

#### Appendix D. - NASA Terminology:

“Press to MECO” - a point in the Launch where the Space Shuttle Atlantis can continue the current nominal mission profile to the point of Main Engine Cutoff and still reach their planned orbit if they lose one engine.

“Negative Return” - a "negative return" meant that the Atlantis space shuttle could no longer make an emergency return-to-launch-site abort landing at Kennedy Space Center due to a problem during ascent.

“Single Engine ROTA” - Rota Spain is a naval base in Rota, Spain. Atlantis can safely land in Rota, Spain even if two of the three main engines should fail.

“Residuals”: Astronauts like Buzz Aldrin referred to Delta-V "residuals" when describing the difference between the actual velocity change (delta-v) achieved by a thruster burn and the expected, ideal delta-v. In a perfect burn, the guidance computer would display residuals of 0, 0, 0 in all three axes. However, any deviation would be shown as a small value, typically in tenths of a foot per second. During the descent, it seems engineers focused on nulling the X (vertical) and Z (fore/aft) residuals, meaning they aimed to correct any deviations in these directions to avoid landing too long or short. The Y (left to right) residual was considered less critical and was not actively corrected. These corrections were performed by firing the Reaction Control System (RCS) with the hand controller.

“S-band”: The Space Shuttle used the S-band frequency range, specifically between 2 and 4 GHz, for communication with ground stations and other spacecraft. This band was part of the Unified S-band (USB) system, which combined tracking, ranging, command, voice, and television into a single system.

“POGO on the engines”: POGO, short for Progressive Oscillation, Generated Oscillation, is a type of vibration that can occur in liquid-fueled rocket engines. It's a self-excited oscillation caused by the interaction between the engine and the rocket's structure, specifically the propellant feed lines. In the context of the Space Shuttle, POGO oscillations were a concern, particularly during ascent, and required careful mitigation strategies.

“State Vector” - In orbital mechanics, a state vector might include the position and velocity of a satellite or spacecraft, allowing calculation of its trajectory. Orbital state vectors come in many forms including the traditional Position-Velocity vectors, Two-line element set (TLE), and Vector Covariance Matrix (VCM).

#### Appendix E. - Links to useful websites:

Credits to sites that inspired this tutorial:

<https://smithplanet.com/stuff/orbiter/orbitaloperations.htm>  
<https://www.orbiter-forum.com/>  
[https://www.orbiterwiki.org/wiki/Surface\\_MFD](https://www.orbiterwiki.org/wiki/Surface_MFD)  
<https://www.satsig.net/orbit-research/orbit-height-and-speed.htm>  
<https://www.orbiterwiki.org/wiki/MFD>  
<https://live.ariss.org/tle/>

Calculators:

<https://www.calculator.net/time-calculator.html?tcday1=0&tchour1=2&tcminute1=23&tcsecond1=0&Op=-&tcday2=0&tchour2=1&tcminute2=27&tcsecond2=02&tcday3=&tchour3=&tcminute3=3&tcsecond3=49&ctype=1&x=Calculate>  
<https://www.calculatorsoup.com/calculators/time/time-calculator.php>  
<https://www.inchcalculator.com/seconds-to-time-calculator/>  
<https://ti84calc.com/ti84calc>  
<https://ti89.com/Online-Calculators/>  
<https://www.satnow.com/calculators/orbital-speed-calculation>

Other Useful Unused sites:

<https://www.satnow.com/calculators/rocket-acceleration-calculator>  
<http://orbiter.dansteph.com/forum/index.php?page=welcome>  
[https://www.rapidtables.com/calc/math/Cos\\_Calculator.html](https://www.rapidtables.com/calc/math/Cos_Calculator.html)  
<https://www.ticalc.org/basics/calculators/ti-81.html>

Articles:

<https://ntrs.nasa.gov/api/citations/20240003182/downloads/Introduction%20To%20Space%20Shuttle%20Relevance.pdf>  
[https://www.orbiterwiki.org/wiki/Launch\\_Azimuth](https://www.orbiterwiki.org/wiki/Launch_Azimuth)  
<http://orbiter.dansteph.com/forum/index.php?topic=10321.0>  
<https://xenforo.orbiter-forum.com/threads/launch-mfd-v-1-6-6-for-orbiter-2016.587/page-3>  
<https://www.orbiter-forum.com/threads/manual-launch-of-the-shuttle-in-orbiter-2016.37618/>  
<https://www.orbiter-forum.com/threads/orbiter-2016-re-launch-re-open-quick-save-scenario-causes-at-lantis-to-fly-off-the-pad-after-un-pausing-solved.42334/>  
[https://www.reddit.com/r/RealSolarSystem/comments/732q3b/how\\_to\\_launch\\_into\\_mars\\_orbital\\_plane/](https://www.reddit.com/r/RealSolarSystem/comments/732q3b/how_to_launch_into_mars_orbital_plane/)  
<https://www.orbiter-forum.com/threads/understanding-inclination-and-launch-azimuth.34033/>  
[http://orbiter.dansteph.com/downloadround/tempdgIV/doc/res/DGIV\\_Documentation\\_en.pdf](http://orbiter.dansteph.com/downloadround/tempdgIV/doc/res/DGIV_Documentation_en.pdf)  
<https://rjallain.medium.com/calculating-the-speed-to-get-to-low-earth-orbit-and-other-calculations-c4df88f4cd2e>  
<https://space.stackexchange.com/questions/64728/in-circle-orbit-give-a-delta-v-to-a-satellite-how-to-find-final-orbit-altitude>

Videos:

<https://www.youtube.com/watch?v=SS7MNPWES-E>  
<https://www.youtube.com/watch?v=xTvbJEEBS7s>  
<https://www.youtube.com/watch?v=UDJFtQGRhIo>  
  
<https://www.youtube.com/watch?v=9cGZNWkKFUc>  
[https://www.youtube.com/watch?v=fGY70H\\_F49c](https://www.youtube.com/watch?v=fGY70H_F49c)

Other Reference and Info:

<https://space.stackexchange.com/questions/64728/in-circle-orbit-give-a-delta-v-to-a-satellite-how-to-find-final-orbit-altitude>

## Appendix F. - Calculations:

Find the Launch Azimuth:

The formula for finding the Launch Azimuth (direction of launch on a compass heading)

$$\text{azimuth} = \arcsin [\cos(\text{inclination})/\cos(\text{latitude})]$$

Example:

Mir/ISS/Etc orbit at around 52 degrees inclination, and the cape is at about 28:

$$Az = \arcsin(\cos(52)/\cos(28))$$

$$Az = \arcsin(0.6594627)$$

$$Az = 41.3 \text{ degrees}$$

$$ISS = 51.59^\circ$$

$$\text{Our latitude at KSC} = 28.63$$

$$Az = \arcsin(\cos(51.59^\circ)/\cos(28.63^\circ))$$

$$Az = \arcsin(0.6594627)$$

The cosine of 51.59 degrees is approximately 0.621284551.

In a right-angled triangle, the cosine of an angle is defined as the ratio of the length of the adjacent side to the length of the hypotenuse. The formula is:

$$\cos(\theta) = \text{Adjacent} / \text{Hypotenuse}$$

It is important to ensure that your calculator is in degree mode when calculating the cosine of an angle in degrees.

To calculate  $\cos(51.59^\circ)/\cos(28.63^\circ)$

1. Calculate the cos of 51.59°

$$\text{Cos} * 51.59^\circ$$

$$\cos(51.59^\circ) = 0.621284551$$

2. Calculate the cos of 28.63°

$$\text{Cos} * 28.63^\circ$$

$$\cos(28.63^\circ) = 0.877732213$$

3. Divide the results:

$$0.621284551/0.877732213$$

$$= 0.7078292693$$

4. Take the arcsin ( $\sin^{-1}$ ) of the answer

$$\sin^{-1}(0.7078292693) = 45.05857205^\circ$$

5. azimuth =  $45.05857205^\circ + 90^\circ$  because of it being a descending node past the normal =  $135.01^\circ$

Launch MFD says we need to head at  $137.09^\circ$  Now we need to compensate for the time it takes to get in orbit. Time to Node is 415.9s. The earth spins at 408m/s at  $90^\circ$  and the height of our orbit is 350km. Which makes our speed at 350km around 7697.07m/s or 7.69707km/s.

Our launch time to a close Inclination is 870s which means the earth will have moved 408m in 870s by the time we are in the first part of our orbit.  $408\text{m/s} * 870\text{s} = 354,960\text{m}$  in the time it takes us to get basically in-line with the ISS.

Distance to ISS is 4.239M at the beginning of the simulation.

The time to lift off is 80s. At the time of our launch the ISS is traveling at an altitude of 372.2K according to MapMFD. The ISS's velocity is 4.777 according to

<https://www.omnicalculator.com/physics/earth-orbit>

HTML:

To calculate  $\frac{\cos(51.59^\circ)}{\cos(28.63^\circ)}$ : Calculate  $\cos(51.59^\circ)$ : 0.621284551 Calculate  $\cos(28.63^\circ)$ : 0.877732213 Divide the results:  $\frac{0.621284551}{0.877732213} \approx 0.70782927$  Therefore,  $\frac{\cos(51.59^\circ)}{\cos(28.63^\circ)} \approx 0.70782927$ .

$$\sin^{-1}\left(0.7078292693\right)$$

To determine the launch azimuth for Orbiter 2016, you need to calculate the angle between North and the desired launch direction, taking into account the desired orbital inclination and the

launch site's latitude. This involves using spherical trigonometry to find the launch azimuth that will result in the desired orbital inclination when combined with the Earth's rotation.

Here's a more detailed explanation:

#### 1. Understand Launch Azimuth:

Launch azimuth is the compass direction (measured clockwise from North) in which a spacecraft is launched.

It's crucial for achieving the desired orbital inclination, which is the angle between the orbital plane and the Earth's equator.

#### 2. The Relationship Between Azimuth and Inclination:

Launching eastward (azimuth of 90 degrees) from a location on Earth will result in an orbital inclination approximately equal to the latitude of the launch site.

To achieve higher inclinations, you need to launch at an angle to the east (azimuth greater than 90 degrees).

The exact relationship is defined by spherical trigonometry:

$$\cos(\text{inclination}) = \cos(\text{latitude}) \cdot \sin(\text{azimuth})$$

#### 3. Calculating Launch Azimuth:

To find the required azimuth ( $\beta$ ) for a given inclination ( $i$ ) and latitude ( $\phi$ ), you can rearrange the formula:

$$\beta = \arcsin(\cos(i) / \cos(\phi))$$

If the inclination is equal to the latitude, the azimuth will be 90 degrees (due east).

For retrograde orbits (orbiting in the opposite direction of Earth's rotation), the azimuth will be between 270 and 90 degrees.

#### 4. Using Orbiter Tools:

Orbiter 2016 provides tools like LaunchMFD to calculate launch azimuth and insertion profiles for specific orbits or targets.

You can also use TransX or BaseSyncMFD for transfer orbit insertion and deorbit burns.

You'll need to set the correct frame of reference (equatorial) in Orbiter before calculating the launch azimuth.

#### 5. Considerations:

The Earth's rotation provides a free velocity boost when launching eastward.

The amount of this boost depends on the launch site's latitude.

Vector addition is used to combine the launch velocity with the rotational velocity to achieve the desired orbital velocity and inclination.

By understanding these concepts and utilizing the tools available in Orbiter 2016, you can accurately determine the launch azimuth for your desired orbital inclination.

The Space Shuttle Atlantis primarily landed at two locations: the Shuttle Landing Facility at Kennedy Space Center in Florida and Edwards Air Force Base in California. While Edwards Air Force Base served as a frequent backup landing site, the Kennedy Space Center was the preferred location for most landings due to its proximity to the launch site.

Here's a more detailed breakdown:

Kennedy Space Center (KSC), Florida:

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This was the designated primary landing site for most missions. The Shuttle Landing Facility at KSC was a purpose-built runway designed specifically for shuttle landings.

Edwards Air Force Base, California:

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Edwards served as the primary backup landing site and was utilized when weather conditions or other factors prevented a landing at KSC.

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It is important to ensure that your calculator is in degree mode when calculating the cosine of an angle in degrees.