Shuttle Landing and Flight Information

In Orbiter, landing the Space Shuttle takes significant practice in that it operates as a glider therefore there is very little room for error. When practicing landing select "Atlantis Landing Preparation" to practice the actual approach to the Kennedy Space Center for the competiton. If the Mission Commander would like to just practice their landing approach select the "Atlantis Final Approach" file which brings you directly to the final approach to runway 33 at Cape Canaveral.

I. Landing Controls

Reaction Control System (RCS) - this is found in the upper left corner of the HUD display in the "Engine Information" area. The RCS must be turned **off** to transfer controls to terrestrial flight and enable the yoke and rudder to operate properly. This is normally done at 35,000 meters.

Joystick (yoke)–the joystick will operate as the control yoke of the aircraft, it governs the aircraft's roll and pitch by moving the ailerons left and right, and moves the elevators backwards or forward.

Rudder pedals- the rudder pedals control yaw and move the rudders left or right. If your joystick does not come with a rudder control you can use the [1] and [3] key on the number pad for left and right rudder control.

Trim Control - trim tabs are small surfaces connected to the trailing edge of a larger control surface on an aircraft. The trim control is used to manage aerodynamic forces and stabilize the aircraft in a particular desired attitude without the need for the operator to constantly apply a control force. As the desired position of a control surface changes (corresponding mainly to different speeds), an adjustable trim tab will allow the operator to reduce the manual force required to maintain that position to zero, if used correctly. This is done by adjusting the angle of the tab relative to the larger surface. In orbiter the [Insert] or [Delete] button is used to adjust the trim tabs up or down.

Landing Gear – this is the support arms and wheels that are deployed just before landing. To lower the landing gear in Orbiter uses the [G] key.

Speed brake – speed brakes are a type of flight control surface used on an aircraft to increase drag or increase the angle of approach during landing. In flight the air brake will rapidly decrease the speed of an aircraft. On landing the speed brake helps transfer the weight of the aircraft from the wings to the undercarriage, allowing the wheels to be mechanically braked with much less chance of skidding while assisting the braking effect. In Orbiter the speed brake is activated by using [Ctrl] B.

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Wheel brakes – the wheel brakes are used in conjunction with the tail chute to slow down the orbiter after touchdown. In orbiter the (comma) and the (period) keys pressed down simultaneously activate the breaks.

II. Landing Aids

The Shuttle Landing Facility (SLF) at the Kennedy Space Center has two visual approach indicators to aid in shuttle landings. These indicators are the Precision Approach Path Indicator and the Visual Approach Slope Indicator.

Precision Approach Path Indicator-the PAPI consists of an array of 4 lights, which appear white or red to the pilot depending on his position above or below the glide slope. At the correct slope there will be 2 white and 2 red lights. In Orbiter there are 2 PAPI units per approach direction at the SLF, located about 2000 meters in front of the runway threshold.

Visual Approach Slope Indicator - The VASI consists of a red bar of lights, and a set of white lights in front of them. At the correct slope, the white lights are aligned with the red bar. At the SLF, the VASI is located about 670 meters behind the runway threshold.

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III. Horizontal Situation Indicator (HSI)

The horizontal situation indicator (3) combines the directional gyro and the NAV indicator into one instrument that provides heading, course reference, and course deviation and glide slope information. The HSI makes it easier to visualize the aircraft's position with reference to the selected course.

- **VOR:** surface-based omnidirectional radio beacons (1), typically with a range of several hundred kilometers. VOR signals can be fed into the HSI (horizontal situation indicator) to obtain direction and distance to the designated runway. In Orbiter the VOR for the Kennedy Space Center is used.

- **ILS:** Many runways are equipped with Instrument Landing Systems (2) to provide heading and glide slope information and are provided by the HSI. In Orbiter the ILS for Cape Canaveral runway 33 is used.

- **NAV –** The frequency at which the navigation indicator is broadcasting, it is specific to individual locations.(Kennedy Space Center- 112.70 KHz; Runway 33 at Cape Canaveral 134.20 kHz)**.**In the orbiter, when programmed, the VOR for KSC will be received immediately. The ILS for Runway 33, when programmed, will be received 30 kilometers from the runway.

- **DST-** Distance to the <u>NAV</u> selected.

- **CRS** – Course is the direction you are currently navigating in

- **BRG**- Bearing is the direction (relative to true north) in which your destination lies.

- **Compass Card / Compass Rose -** The Compass Card (4) is driven by the internal gyro and shows the magnetic heading of the aircraft.

- **Lubber Line -** The number on the Compass Card (4) under the Lubber Line (5) shows the current aircraft magnetic heading.

- **Course Deviation Indicator Bar -** The CDI (6) shows how far the aircraft is off the selected course. When the bar is in line with the yellow arrow head and tail the aircraft is exactly on the selected course. When the bar moves to the right when looking in the direction of the arrow, the desired course is on the right (with respect to the aircraft's heading). The scale under the bar shows how far off course the aircraft is. In VOR navigation, each line corresponds to a deviation of two degrees, allowing a total of +/- 10 degrees. The advantage to a standard CDI is that the entire indicator rotates with the Compass Card, giving the pilot a pictorial symbolic view of the relationship of the aircraft's heading, the selected course and the current position.

- **DEV-** Numerical course deviation for the deviation bar located at (6).

- **Course Select Pointer/Cursor -** The Course Select Pointer (7), often simply called Cursor, is set to the desired VOR course which is shown under the head of the arrow while the tail marks the reciprocal course. This is also referred to as the Omni Bearing Selector or OBS.

- **Glide slope Line -** The Glide slope Line (8) come into view when a glide slope signal is being received during an ILS approach and the aircraft's position is within the defined range and slope of the glide slope signal. This is a very sensitive display. A full deflection corresponds to a 1.4 degrees difference in the glide slope.

- **FROM**-In the lower left corner of the instrument is the TO/FROM indicator. If you see "TO" displayed it means that you are working with a bearing from you to the ground station. If you see "FROM" displayed it indicates a radial from the ground station to you.

IV. Programming the HSI for Orbiter

When using the "Atlantis Final Approach" program in Orbiter, the VOR for the Kennedy Space Center and Runway 33 will be already inputted into the HSI. In the orbiter when running the "Atlantis Landing Preparation" program (competition landing scenario) neither the VOR or ILS has been programmed into the HSI.

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When properly programmed, the VOR for KSC will be received immediately and the ILS for Runway 33will be received 30 kilometers from the runway. In the competition this has been set up for you in the simulator therefore it is recommended you practice with it under similar conditions. Orbiter does allow you to program your HSI and save the scenario so that it will be pre-programmed each time you practice your competition level landings.

Programming the HSI:

1. Select "Atlantis final approach"
2. Once the program opens immediately hit the F4 key
3. Quickly select **[Time Warp**] and a "Time Acceleration" window will appear.
4. Select [**0.1x**] time acceleration. This will slow the program down so you can modify the HSI without losing too much altitude.
5. Turn on the Left MFD by selecting [**PWR**]
6. Then hit the [**SEL**] until you see the COM/NAV mode on the right side of the panel.
7. Select [**COM/NAV**]
8. Navigation 1(NAV1) will be in yellow showing 108.00 MHz, use the arrow key on the left side of the MFD to change the receiver to 134.20 kHz which is runway 33 at Cape Canaveral:
9. The **[<< or >>]** keys change by +/- 1.0 kHz and the **[< or >]** keys change by +/- 0.10
10. Select [**SL**+] to switch to navigation 2 (NAV2). Using the arrow keys, on the left side of the MFD, change the receiver to 112.70 KHz which is the frequency at which the Kennedy Space Center is broadcasting.
11. Select the [**SEL**] and then when the Mode screen returns, select [**HSI**].
12. Select the [**LR**] and then [**NAV**] on the left side of the HSI- MFD to ensure you have both NAV's visible. NAV 1 will have no signal but will show 134.20 kHz, NAV 2 will show VOR KSC at 112.70 kHz.
13. Immediately hit [**Exit**] (it is not necessary to exit time warp)
14. When the Orbiter host screen returns select the [**Save Current**].
15. Under Scenario name type in **"Landing"**. This will allow you to return to the landing scenario each time with the correct HSI already set up.

You may have to practice several times until you get the hang of the settings. Once you complete it and have sufficient altitude to practice you will save it. If you make a mistake after saving just repeat the procedure and save with the same name format and it will over-write the last saved program.

V. Surface Earth Multi-function display

The Surface Earth MFD assists in flight close to planetary surface. It provides the pilot with information for operating the aircraft when it is in the earth's atmosphere. The most important component is the "Artificial Horizon" which is a pictorial representation of the earth. The blue

portion represents the sky and the green or brown portion represents the ground. The horizon line represents the aircraft. The pitch ladder and sky pointer move in relation to it, providing the indications of pitch, roll, and "which way is up". The Sky Pointer is the white triangle in the middle of the bank indicator hash marks, this simply points up at all times.

- Artificial horizon (1)
  - Pitch
  - Bank
- Heading indicator (2)
- Altitude (3)
- Vertical speed (4)
- Vertical acceleration in m/sec^2 (5)
- Ground Speed (6)
- Acceleration in m/sec^2 (7)
- Angle of attack (8)
- Atmospheric data (9)
  - OAT: Outside Air Temperature in Kelvin
  - M: Mach number M=v/a, with airspeed v and speed of sound a.
  - DNS: Atmospheric density [kg m^{-3}]
- Equatorial position (longitude and latitude, and rate of change (10)

VI. Heads up Display

Head-up display or heads-up display (also known as a HUD) is any transparent display that presents data without requiring users to look away from their usual viewpoints. The origin of the name stems from a pilot being able to view information with the head positioned "up" and looking forward, instead of angled down looking at lower instruments. The heads up display provides the important data from the Surface Earth Multi-function display and provides essential information for landing.

When landing, the HUD should be set to "Surface Earth" mode to ensure the proper information for landing is being used. Two important aspects are the "direction indicator" and the "velocity vector". The "direction indicator" is the fixed forward point that shows the up orientation of the craft or the nose of the aircraft. The "velocity vector" is the flight path based on current heading, velocity and rate of descent. The "velocity vector" will continuously change as the pilot changes any of the three flight aspects.

The "pitch ladder" corresponds with the "pitch ladder" in the artificial horizon. This depicts the pitch angle of the aircraft in relation to the horizon. It consists of horizontal lines above and below the neutral "zero-pitch" line, which is a thin white line stretched across the entire screen, the ladder rungs are in 10 degree increments. Small horizontal lines below the zero-pitch line are found on the artificial horizon. This is done to provide for precise pitch control during landing approach and is not reproduced on the HUD.
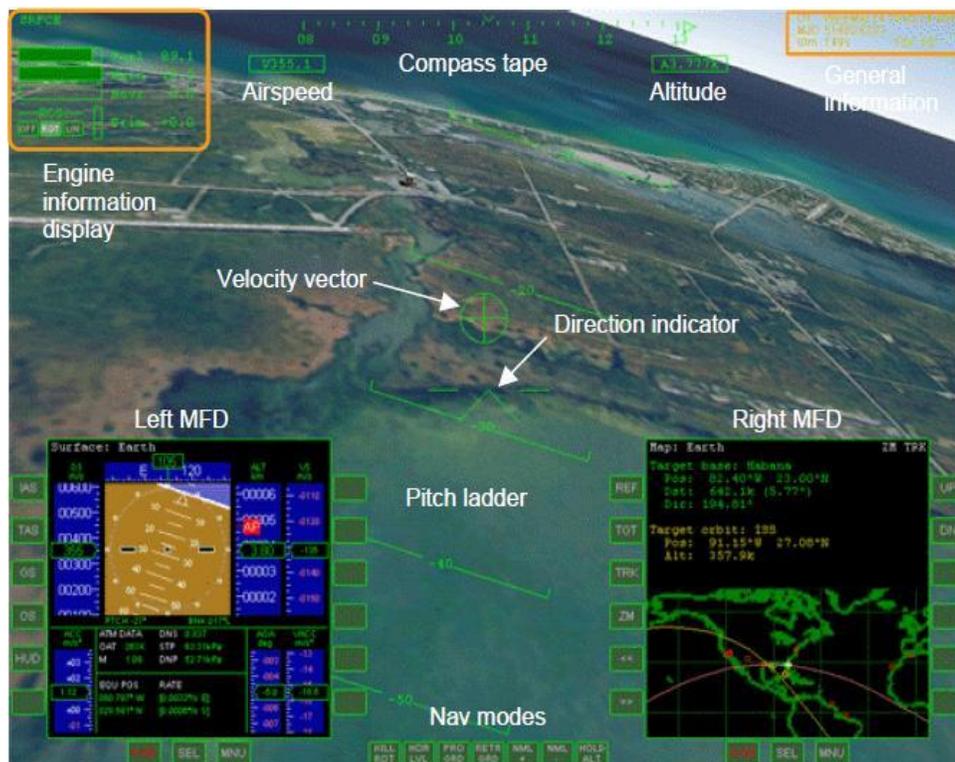
VII. Landing Recommendations

There are two runways at Cape Canaveral that can be seen in the Orbiter program. The first runway is the military airport located on the southern end of Merritt Island; it is referred to as the Air Force Skid Strip. The 'Skid Strip" is 10,000 feet by 200 feet and is used by USAF and NASA to land transport and training aircraft. The second runway is the shuttle landing facility (known as SLF or Runway 15/33) located on the northern end of Merritt Island. This runway is designated as the Space Shuttle landing site in Florida. The SLF is 15,000 feet long and 300 feet wide with an extra 1,000 feet of paved overruns at each end. There are two additional landing areas for the space shuttle; Edwards Air Force Base in California and White Sands Space Harbor in New Mexico.

1. Initial Approach

a. Ensure that the Reaction Control System (RCS) found in the upper left corner of the HUD display in the "Engine Information" area is turned off to transfer controls to terrestrial flight and enable the yoke and rudder to operate properly. This is normally done at 35,000 meters, however the full effects of lift and control over the shuttle's flight path will not occur until 28,000 meters is reached.

b. Use the VOR to locate the Kennedy Space Center which should be to your left of center. This will help you orient towards runway 33 which is at Cape Canaveral.

c. Maneuver your "Direction Indicator" using the yoke and rudder.

d. The "Velocity vector" will slowly orient to the correct position, this will help you judge you flight path.

e. To increase airspeed you push the yoke forward, however this will decrease your altitude rapidly. To increase altitude you pull the yoke back, but this will decrease airspeed.

f. Remember, you are flying a very heavy glider that relies on its descent speed to provide lift.

g. The Orbiter Shuttle stalls between 100 and 125 m/s, however if the pitch is above + 20 degrees this may occur as high as 150 m/s.

2. Final approach

a. When performing an ILS approach to runway 33 at the Kennedy Space Center, initially pitch to -15° and use the PAPI indicators ahead of the runway for glide slope adjustment.

b. Use the split rudder speed brake (Ctrl-B) to bleed off airspeed if necessary during your approach.

c. On approach, slowly raise the nose to touch down with an AOA of approx. +10°.

d. Lower your gear during the final flare-up, about 10 seconds before touchdown.

e. Touchdown speed is approximately 180-200 m/s., anything below 150 m/s can damage the landing gear and tires.

VIII. In Space Flight Operation

When operating in a zero atmosphere condition (outer space) ensure that the Reaction Control System (RCS) is turned **on**. The RCS is found in the upper left corner of the HUD display in the "Engine Information" area. Turning on the RCS allows the yoke and rudder controls to operate the "Reaction Control Engines" (RCS). In this mode the pilot can use the yoke and rudder to manually orient the space shuttle. If your joystick does not come with a rudder control you can use the [1] and [3] key on the number pad for left and right rudder control.

The Reaction Control System (RCS) is composed of 44 small liquid-fueled rocket thrusters and a very sophisticated computerized (fly-by-wire) flight control system. This control system provides attitude control along the pitch, roll, and yaw axes so as to allow manual orbital maneuvers.

In order to operate the shuttle in space the HUD should be in "**Orbit Earth Mode**" to provide the necessary information for positioning the shuttle in either a pro-grade or retro-grade orientation.

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When the HUD is in "Orbit Earth" mode your flight path ladder is aligned with the orbital plane instead of the horizon plane, and there is a ribbon showing your orbital azimuth angle. It also shows indicators for pro-grade (the direction of your orbital velocity vector) and retrograde (the opposite direction). When in pro-grade your orbital plane is 000 degrees and the azimuth angle is 000 degrees, when in retrograde your orbital plane is 180 degrees and the azimuth angle is 00 degrees.

The HUD will also provide your Orbital Speed data in K/sec. (OS) and "Eccentric Anomaly in the Nominal Orbit" (rad.) data. To demonstrate the maneuver and place the shuttle in either pro-grade or retro-grade select the computer directed maneuver icons on the bottom of the HUD screen. The flight computer will automatically position the shuttle to the correct position for pro-grade and retro-grade.