MODULE 8 ASSIGNMENT

1. What is a launch window?

...the period of time when we can launch a spacecraft directly into a specified orbit from a given launch site. (Sellers, Chapter 9.1, pg 291)

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2. How do mission planners specify a desired orbit so a spacecraft can do its mission?

They define a set of classical orbital elements that satisfy mission objectives. (Sellers, Chapter 9.1, pg 291)

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9. What do we mean when we say orbital planes are fixed in inertial space?

This means that the orbital plane does not move relative to the equatorial plane and that it has no angular velocity about the polar axis. This allows us to draw the ground track of the orbiting vehicle as a fixed path with the Earth rotating beneath it. By defining the orbital plane in such a manner, we only need to define the Earth's rotational velocity and couple of other angles on the auxilliary triangle in order to develop a launch window for a given orbit and a given launch site.

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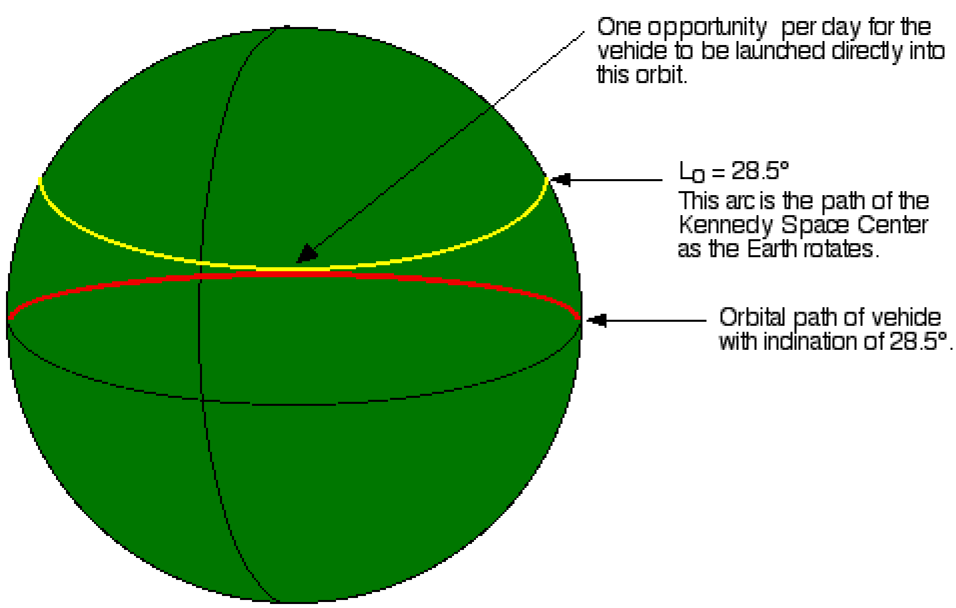
12. Mission planners want to launch the Space Shuttle from Kennedy Space Center (L_o = 28.5°) into an orbit with an inclination of 28.5°. How many launch windows will there be each day? Draw a diagram to illustrate this case. How would this change if the desired inclination were 57°? Draw a diagram to illustrate this case.

From the diagram below you can see that there is only one launch window per day from Kennedy for a vehicle desiring an orbit with an inclination of 28.5°:



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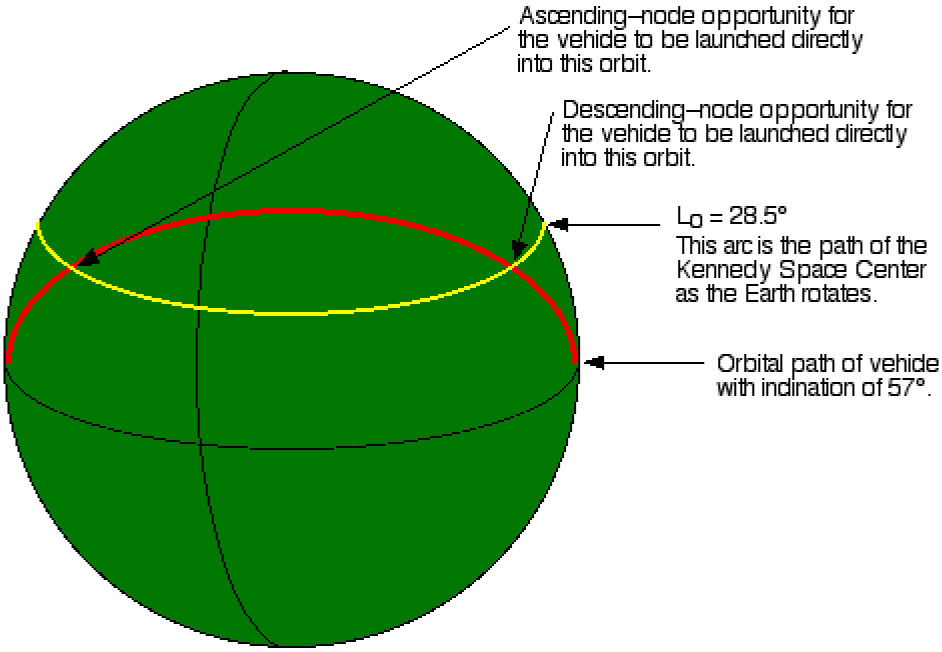
Similarly, we can see from the diagram below that there are two launch windows per day from Kennedy for a vehicle desiring an orbit with an inclination of 57°:



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20. What are the four phases of a launch vehicle ascent?

Phase one, the vertical ascent. This is where the vehicle climbs in the quickest in order to clear the Earth's atmosphere.

Phase two, the pitch over. This is where the vehicle pushes over to a slightly horizontal position in order to get some velocity downrange.

Phase three, the gravity turn. This occurs when gravity pulls the vehicle toward horizontal giving the velocity vector a more horizontal direction further increasing the velocity downrange.

Phase four, the vacuum phase. This is where the vehicle is essentially free from the Earth's atmosphere and accelerates towards burnout velocity (at which point it should be on orbital velocity and altitude).

(Sellers, Chapter 9.3, pgs 308-309)

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21. How fast is Kennedy Space Center (L_o = 28.5°N) moving?

It is moving at 0.4087 km/s. (Sellers, Chapter 9.3, pg 311)

Using the following equation we can verify this information:

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$V_{launch\ site} = (R_{Earth} \bullet \cos L_o)\omega_{Earth}$

where:
R_{Earth} = Earth's radius = 6378.14 km
L_o = Launch site latitude = 28.5°
ω_{Earth} = Earth's angular velocity (rad/sec) = 15.04107°/hr = $7.29212 \bullet 10^{-5}$ rad/s

Therefore:
$V_{launch\ site}$ = (6378.14 km•cos28.5°) • $7.29212 \bullet 10^{-5}$ rad/s
$V_{launch\ site}$ = (6378.14 km•0.887882) • $7.29212 \bullet 10^{-5}$ rad/s
$V_{launch\ site}$ = (5605.22 km) • $7.29212 \bullet 10^{-5}$ rad/s
$V_{launch\ site}$ = 0.40874 km/s

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22. Explain why eastward launches get a "head start" but westward launches don't.

In an inertial world (the one we live in), there is relative velocity as a function of position. From our perspective on the surface of the Earth, we are only moving when we actually take some action to put us in motion (walking, running, etc.). That is our "velocity" relative to the surface of the Earth. Since the Earth is rotating at roughly 15°/hr (angular velocity), from a point at the center of the Earth looking out a person on the surface of the Earth possess some velocity that is tangential to the direction of the Earth's rotation. If that person is at the Equator, their velocity is at its greatest.

Now, we take into account that the Earth rotates in an easterly direction, and we see that for any point on the face of the Earth (excepting the poles), every object has some relative tangential velocity in the easterly direction. This is the "head start".

A vehicle being launched into a prograde/direct orbit gains a "head start" velocity equal to the relative tangential velocity of its launch site. Vehicles that launch into retrograde/indirect orbits are launching against the rotation of the Earth and lose this speed advantage. They are essentially flying into a "head wind" equivalent to their launch sites relative tangential velocity. This head start or lack thereof is defined by the angular momentum for that point on the face of the Earth or the equation:

$V = Rw$

and can be further tailored to a launch site's position by defining the radius (R) relative to the latitude of the launch site.

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23. Define the following:

a) $V_{loss\ gravity}$ vector

The extra velocity needed to overcome gravity and reach the correct altitude.
(Sellers, Chapter 9.3, pg 312)

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b) $V_{burnout}$ vector

The inertial velocity needed at burnout to be in the desired orbit (Sellers, Chapter 9.3, pg 312)

c) $V_{launch\ site}$ vector

The velocity of the launch pad due to Earth's rotation (which works for us or against us depending on whether we launch east or west). (Sellers, Chapter 9.3, pg 312)

d) ΔV_{needed} vector

The total velocity change that the launch vehicle must generate to meet the mission requirements.
(Sellers, Chapter 9.3, pg 312)

e) ΔV_{losses}

The velocity losses during ascent due to drag, back pressure, and steering roughly equal to 1.5 km/s. (Sellers, Chapter 9.3, pg 314)

f) ΔV_{design}

The design velocity of the launch vehicle must deliver to reach the desired orbit. In other words, this is the velocity we must desing our launch vehicle to provide.
(Sellers, Chapter 9.3, pg 314)

g) The SEZ coordinate system

This is the south-east-zenith coordinate system and is a result of applying the right hand rule to the south and zenith direction vectors. If we choose to take the vector pointing due south from the launch site as the principal direction vector for describing the coordinate system and then select the straight up or zenith direction vector as our out-of-plane vector, the east direction vector completes the right hand rule. The end result is that we now have three reference vectors to establish a coordinate system, the SEZ coordinate system.
(Sellers, Chapter 9.3, pg 310)