Announcements:

- Community Service forms back to you – all approved

- HW 9 Due after spring break
Ready For Flight Cards:

Ready for Flight Cards
- Don’t lose this only copy
- Must turn in on 11/8
- Use as a checklist
- Follow it exactly
- Fully completed, your team flies
- Not completed, your team does not fly
- Somewhat redundant back side
# BalloonSat Launch Acceptance Checklist

## Connection/Installation Verifications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino 9V</td>
<td>Connected? Y/N</td>
</tr>
<tr>
<td>BGA0011 board installed</td>
<td></td>
</tr>
<tr>
<td>Temp2 connected to shield &amp; cut-out box</td>
<td>Connected? Y/N</td>
</tr>
<tr>
<td>Camera SD card installed and locked</td>
<td>Connected? Y/N Locked? Y/N</td>
</tr>
<tr>
<td>Orange LED connected to D4 on shield</td>
<td>Connected? Y/N</td>
</tr>
<tr>
<td>Blue LED connected to D3 on shield</td>
<td>Connected? Y/N</td>
</tr>
<tr>
<td>Arduino shield/balloon shield fully sealed</td>
<td>Minimal Gap Between Shield? Y/N</td>
</tr>
</tbody>
</table>

## Resource Verifications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGA0011 board installed</td>
<td>Erased? Y/N</td>
</tr>
<tr>
<td>Pictures in DCM Folder on Camera</td>
<td>Deleted? Y/N</td>
</tr>
<tr>
<td>Battery Voltage</td>
<td>Record Voltage</td>
</tr>
<tr>
<td>Heater Battery 1 Voltage</td>
<td>Record Voltage</td>
</tr>
<tr>
<td>Heater Battery 2 Voltage</td>
<td>Record Voltage</td>
</tr>
<tr>
<td>Heater Battery 3 Voltage</td>
<td>Record Voltage</td>
</tr>
<tr>
<td>Camera battery charged</td>
<td>Charged? Y/N</td>
</tr>
</tbody>
</table>

## Visual Verifications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Switch Power LED (GREEN)</td>
<td>Working &amp; Visible? Y/N</td>
</tr>
<tr>
<td>Arduino ON LED (ORANGE)</td>
<td>Working &amp; Visible? Y/N</td>
</tr>
<tr>
<td>Arduino SD Card LED Visible (BLUE)</td>
<td>Working &amp; Visible? Y/N</td>
</tr>
<tr>
<td>Heater Switch Power LED (RED)</td>
<td>Working &amp; Visible? Y/N</td>
</tr>
<tr>
<td>Balloon shield switches all ON</td>
<td>Visible? Y/N</td>
</tr>
</tbody>
</table>

## Date Verifications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>Two spikes beginning and end</td>
</tr>
<tr>
<td>Temp 1</td>
<td>Increase</td>
</tr>
<tr>
<td>Temp 2</td>
<td>Great increase than Temp 1</td>
</tr>
<tr>
<td>Pressure</td>
<td>1 or 2 Gps</td>
</tr>
<tr>
<td>Accel X</td>
<td>Flat at 1 G and -1 G</td>
</tr>
<tr>
<td>Accel Z</td>
<td>Flat at 1 G and -1 G</td>
</tr>
<tr>
<td>Camera script runs</td>
<td>Run script until 1 to 2 pictures (tail if self timer starts or flashed)</td>
</tr>
</tbody>
</table>

## Mechanical Verifications:

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>&gt; 864 grams</td>
</tr>
<tr>
<td>Balloon Attachment Tube</td>
<td>Through center</td>
</tr>
<tr>
<td>Washers on top and bottom</td>
<td>Secured with hot glue</td>
</tr>
<tr>
<td>All components secured inside box</td>
<td>Velocone tape and/or hot glue</td>
</tr>
<tr>
<td>All External taped in off position and/or covered with foam core cover</td>
<td>(YN)</td>
</tr>
</tbody>
</table>

## Authorized by:

| IT#1 | ____________________________ |
|------|_____________________________
| IT#2 | ____________________________ |

This document is for verification of the Team #____ flight unit prior to BalloonSat Check-in.
Tuesday (3/29)...

Guest Lecture - ADCS

HW 9 Due
Thursday (3/31)…
In-Class Mission Simulation + Spider

Colorado Space Grant Consortium
Mission Sim Day:

- One person per team come up with BalloonSat
- Line up like launch
- Turn them on when I tell you
- Let them run (at your table) until end of class

- I don’t expect it to be fully operational
- I do expect it to do something
- It must do everything by the following week
Tuesday (4/5)…

Launch Readiness Reviews - Live

Presentations due 7 AM

Colorado Space Grant Consortium
Thursday (4/7)...

Launch Logistics

DD Rev C due 4 PM
Friday (4/8)…

BalloonSat Check-In

Colorado Space Grant Consortium
Saturday (4/9)...

Launch!

Colorado Space Grant Consortium
Questions?

Colorado Space Grant Consortium
Orbits and Mission Design – Part 1

ASEN 1400

Class #20

Colorado Space Grant Consortium
Orbit Introduction:

• What is an orbit?
**Orbit Introduction:**

- How fast would it have to be going?

  - Let’s figure it out…

  \[
  v = \sqrt{\frac{GM}{R}}
  \]

  - \( v \) is velocity
  - \( G \) is Universal Gravitational Constant
  - \( M \) is mass of planet or satellite
  - \( R \) is radius of planet or satellite

  \[
  G = 6.67 \times 10^{-11} \text{ m}^3 \text{ (kg s}^2)\)
  \]

  \[
  M_{\text{Earth}} = 5.974 \times 10^{24} \text{ kg} \quad R_{\text{Earth}} = 6367000 \text{ m}
  \]

  \[
  v_{\text{Earth}} = 7910 \text{ m/s} = 17694 \text{ mph}
  \]
Gravity and Weightlessness:

• When in space why do you float? i.e. Weightlessness
Universal Gravitation, Applied:

• When in space why do you float? i.e. Weightlessness

\[
\frac{mV^2}{r} = \frac{MmG}{r^2}
\]

\[
V = \sqrt{\frac{MG}{r}}
\]
Orbit Introduction:

What is an orbit?
- Path of a satellite around any central body

What shape is it?
- Orbits are conic sections
- Circles
- Ellipses
- Parabolas
- Hyperbolas
Orbit Introduction:

How are orbits described?
- **Position and Velocity** at any one time
- **Keplerian Elements** (from Kepler’s Laws)

**Position and Velocity**
- Given *position* and *velocity* of a satellite at time *t*, you can calculate the position and velocity at any other time

**Keplerian Elements**
- Size, Shape, Inclination (easy)
- Right Ascension of Ascending Node, Argument of Perigee, True Anomaly (hard)
Orbit Definition:

Keplerian Elements

- Semi major axis (a)
  - Size
- Eccentricity (e)
  - Shape
Orbit Definition:
**Orbit Definition:**

**Keplerian Elements**

- Inclination (i)
  - **Angle** to the Equator
**Orbit Definition:**

**Keplerian Elements**

- Right Ascension of Ascending Node (RAAN, Ω)
- **Rotation** about the Earth’s Spin Axis
Keplerian Elements

- Argument of Perigee ($\omega$)
- **Rotation** of the conic section in the plane
Keplerian Elements

- True Anomaly (θ)
  - Defines the position of a body in orbit
  - Angle between the Position Vector and the vector to Perigee
  - Elliptical only
Orbit Definition:
Types of Orbits:

- Geosynchronous/Geostationary (equator)
Types of Orbits:

Geostationary VS. Geosynchronous
Types of Orbits:

- Critical Inclination
Types of Orbits:

- Repeating Ground Trace
Types of Orbits:

- Polar/ Sun Synchronous
Types of Orbits:

- Molniya
Earth, the Moon, Mars, and the Stars Beyond

A Brief Discussion on Mission Design
Universal Gravitation, Applied:

• When in space why do you float? i.e. Weightlessness

\[
\frac{mV^2}{r} = \frac{MmG}{r^2}
\]

\[
V = \sqrt{\frac{MG}{r}}
\]
Orbit History:

- **1665 A.D.**
  - Isaac Newton
  - At 23, plague while at Cambridge
  - Went to be one with nature
  - He studied gravity
  - Discovered “Newton’s Laws of Motion”
  - 1666, he understood planetary motion
  - Did zip for 20 years until Edmund Halley
Newton’s Laws:

1st Law…

*Body at rest stays at rest, a body in motion stay in motion*

2nd Law…

*\( F = m \times a \)*

3rd Law…

*For every action, there is an equal and opposite reaction*
Newton’s Laws:

Newton Continued...

• 1687, Principia Published
• Law of Universal Gravitation (Attraction)

\[ F = \frac{m_1 m_2 G}{r^2} \]
Newton’s Laws:

Newton Continued...
- 1687, Principia Published
- Law of Universal Gravitation (Attraction)

\[ F = ma = \frac{m_2 V^2}{r} \]

\[ F = \frac{m_1 m_2 G}{r^2} \]
Universal Gravitation, Applied:

• When in space why do you float? i.e. Weightlessness

\[ \frac{mV^2}{r} = \frac{MmG}{r^2} \]

\[ V = \sqrt{\frac{MG}{r}} \]
Orbit History:

- **1600 A.D.**
  - Johannes Kepler
    - Used Tycho’s careful Mars observations to smash Aristotle theories
    - Presented 3 laws of planetary motion
    - Basis of understanding of spacecraft motion
    - However, “Why was not understood”
    - Calculus?
Kepler’s 3 Laws of Planetary Motion:

1. All planets move in **elliptical orbits**, sun at one focus
Kepler’s 3 Laws of Planetary Motion:

2. A line joining any planet to the sun, sweeps out equal areas in equal times.
Kepler’s 3 Laws of Planetary Motion:

3. The square of the period of any planet about the sun is proportional to the cube of the planet’s mean distance from the sun.

\[ T^2 \propto R^3 \]

\[ \frac{4\pi^2}{T^2} = \frac{GM}{R^3} \]

\[ T = 2\pi \sqrt{\frac{R^3}{\mu}} \]

<table>
<thead>
<tr>
<th>Planet</th>
<th>P (yr)</th>
<th>a (AU)</th>
<th>T²</th>
<th>R³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.24</td>
<td>0.39</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Venus</td>
<td>0.62</td>
<td>0.72</td>
<td>0.39</td>
<td>0.37</td>
</tr>
<tr>
<td>Earth</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Mars</td>
<td>1.88</td>
<td>1.52</td>
<td>3.53</td>
<td>3.51</td>
</tr>
<tr>
<td>Jupiter</td>
<td>11.9</td>
<td>5.20</td>
<td>142</td>
<td>141</td>
</tr>
<tr>
<td>Saturn</td>
<td>29.5</td>
<td>9.54</td>
<td>870</td>
<td>868</td>
</tr>
</tbody>
</table>

If you can observe the period of rotation, you can determine the distance.
Orbit History:

Gottfried Leibniz

Isaac Newton
Kepler and Newton BFFs:

Kepler’s Laws...Orbits described by conic sections

Velocity of an orbit described by following equation

\[ v = \sqrt{\frac{2\mu}{r}} - \left(\frac{\mu}{a}\right) \]

\[ \mu = GM \]

For a circle (a=r):

\[ v = \sqrt{\frac{\mu}{r}} \]

For an ellipse (a>0):

\[ v = \sqrt{\frac{2\mu}{r}} - \left(\frac{\mu}{a}\right) \]

For a parabola (a=∞):

\[ v = \sqrt{\frac{2\mu}{r}} \]
Orbit Introduction:

• Let’s figure it out…

\[ v = \sqrt{\frac{GM}{R}} \]

- \( v \) is velocity
- \( G \) is Universal Gravitational Constant
- \( M \) is mass of planet or satellite
- \( R \) is radius of planet of satellite

\[ G = 6.67 \times 10^{-11} \frac{m^3}{(kg \cdot s^2)} \]

\[ M_{Earth} = 5.974 \times 10^{24} \text{ kg} \quad R_{Earth} = 6367000 \text{ m} \]

\[ v_{Earth} = 7910 \frac{m}{s} = 17694 \text{ mph} \]
Orbit Introduction:

- On the moon?

\[ v = \sqrt{\frac{GM}{R}} \]

- \( v \) is velocity
- \( G \) is Universal Gravitational Constant
- \( M \) is mass of planet or satellite
- \( R \) is radius of planet or satellite

\[ G = 6.67 \times 10^{-11} \frac{m^3}{(kg \cdot s^2)} \]

\[ M_{\text{Earth}} = 5.974 \times 10^{24} \text{ kg} \quad R_{\text{Earth}} = 6367000 \text{ m} \]

\[ M_{\text{Moon}} = 7.350 \times 10^{22} \text{ kg} \quad R_{\text{Moon}} = 1738000 \text{ m} \]

\[ v_{\text{Moon}} = 1679 \frac{m}{s} = 3756 \text{ mph} \]

\[ v_{\text{Earth}} = 7910 \frac{m}{s} = 17694 \text{ mph} \]
Circular Orbit:

For a 250 km circular Earth Orbit

Orbital Velocity

\[ v = \sqrt{\mu \over r} \]

\[ v = \sqrt{(398600.4) \over (250 + 6378.14)} \]

\[ v = 7.75 \, \text{km/sec} = 17,347 \, \text{mph} \]
Circular Orbit:

Orbital Period

\[ P^2 = a^3 \]

\[ P = \frac{\text{circumference}}{\text{velocity}} \]

\[ P = 2\pi \sqrt[3]{\frac{r^3}{\mu}} \]

\[ P = 2\pi \sqrt[3]{\frac{(250 + 6378.14)^3}{398600.4}} \]

\[ P = 5370 \text{ sec} = 89.5 \text{ min} \]
Circular Orbit:

For a **500 km** circular Earth Orbit

**Orbital Velocity**

\[
v = \sqrt{\frac{\mu}{r}}
\]

\[
v = \sqrt{\frac{398600.4}{(500 + 6378.14)}}
\]

\[
v = 7.61 \, \frac{km}{sec} = 17,028 \, mph
\]
Circular Orbit:

For a 500 km circular Earth Orbit

Orbital Period

\[ P = 2\pi \sqrt{\frac{r^3}{\mu}} \]

\[ P = 2\pi \sqrt{(500 + 6378.14)^3} \]

\[ P = 2\pi \sqrt{\frac{(500 + 6378.14)^3}{398600.4}} \]

\[ P = 5,676 \text{ sec} = 94.6 \text{ min} \]

Conclusions???
Changing Orbits:

How about 250 km to 500 km

How would you do it?
Changing Orbits:

Changing orbits usually involves an elliptical orbit or Transfer Orbit

Perigee = close
Apogee = far

\[ \Delta v_1 = v_{per} - v_i \]
\[ \Delta v_2 = v_f - v_{apo} \]
Changing Orbits:

1) Velocity of initial orbit
   \[ v_i = 7.75 \frac{km}{sec} \]

2) Velocity of final orbit
   \[ v_f = 7.61 \frac{km}{sec} \]

3) Velocity at perigee

4) Velocity at apogee

\[ \Delta v_1 = v_{per} - v_i \]
\[ \Delta v_2 = v_f - v_{apo} \]
Changing Orbits:

Since orbit is elliptical at $V_{per}$ and $V_{apo} a > 0$, so

$$v = \sqrt{\frac{(2 \mu)}{r} - \left(\frac{\mu}{a}\right)}$$

where

$$a = \frac{(r_1 + r_2)}{2}$$

$$a = \frac{((250 + 6378.14) + (500 + 6378.14))}{2}$$

$$a = 6753 \text{ km}$$
Changing Orbits:

So back to our $\Delta V$’s

3) **Velocity at perigee**

\[
v_{\text{per}} = \sqrt{\frac{2\mu}{r}} - \left( \frac{\mu}{a} \right)
\]

\[
v_{\text{per}} = \sqrt{\frac{2 \times 398600.4}{(250 + 6378.14)}} - \left( \frac{398600.4}{6753} \right)
\]

\[
v_{\text{per}} = 7.83 \ \frac{km}{sec}
\]
So back to our $\Delta V$’s

4) Velocity at apogee

$v_{per} = \sqrt{\frac{(2\mu)}{r} - \left(\frac{\mu}{a}\right)}$

$v_{per} = \sqrt{\frac{(2 \times 398600.4)}{(500 + 6378.14)}} - \left(\frac{398600.4}{6753}\right)$

$v_{per} = 7.54 \frac{km}{sec}$
Changing Orbits:

1) Velocity of initial orbit

\[ v_i = 7.75 \, \frac{km}{sec} \]

2) Velocity of final orbit

\[ v_f = 7.61 \, \frac{km}{sec} \]

3) Velocity at perigee

\[ v_{per} = 7.83 \, \frac{km}{sec} \]

4) Velocity at apogee

\[ v_{apo} = 7.54 \, \frac{km}{sec} \]

\[ \Delta v_1 = v_{per} - v_i \]

\[ \Delta v_2 = v_f - v_{apo} \]
Changing Orbits:

Therefore:

$\Delta V_1$ is to start transfer

$\Delta v_1 = v_{per} - v_i$

$\Delta v_1 = 7.83 - 7.75$

$\Delta v_1 = 0.08 \frac{km}{sec}$

$\Delta v_1 = 178.9 \text{ mph}$
Changing Orbits:

$\Delta V_2$ is to circularize orbit

$\Delta v_2 = v_f - v_{apo}$

$\Delta v_2 = 7.61 - 7.54$

$\Delta v_2 = 0.07 \frac{km}{sec}$

$\Delta v_2 = 156.6 \text{ mph}$
Changing Orbits:

What if we did the whole thing in reverse?

Go from 500 to 250 km?

What happens to the answer?

\[
\Delta v_1 = v_{apo} - v_i
\]

\[
\Delta v_2 = v_f - v_{per}
\]
Changing Orbits:

1) Velocity of initial orbit

\[ v_i = 7.61 \text{ km/sec} \]

2) Velocity of final orbit

\[ v_f = 7.75 \text{ km/sec} \]

3) Velocity at perigee

\[ v_{per} = 7.83 \text{ km/sec} \]

4) Velocity at apogee

\[ v_{apo} = 7.54 \text{ km/sec} \]

\[ \Delta v_1 = v_{apo} - v_i \]

\[ \Delta v_2 = v_f - v_{per} \]
Changing Orbits:

Therefore:

$\Delta V_1$ is to start transfer

\[
\Delta v_1 = v_{apo} - v_i
\]

\[
\Delta v_1 = 7.54 - 7.61
\]

\[
\Delta v_1 = -0.07 \text{ km/sec}
\]

\[
\Delta v_1 = -156.5 \text{ mph}
\]
Changing Orbits:

$\Delta V_2$ is to circularize orbit

$\Delta v_2 = v_f - v_{per}

\Delta v_2 = 7.75 - 7.83 \, \text{km} \, \text{sec}^{-1}

\Delta v_2 = -0.08 \, \text{km} \, \text{sec}^{-1}

\Delta v_2 = -178.9 \, \text{mph}$
Changing Orbits:

Time to do transfer is the same

\[ P = 2\pi \sqrt{\frac{a^3}{\mu}} \times .5 \]

\[ P = 2\pi \sqrt{\frac{(6753)^3}{398600.4}} \times .5 \]

\[ P = 2,761 \text{ sec} \]

\[ P = 46 \text{ min} \]
How well do you understand Hohmann Transfers?

• 1 to 2?
• 2 to 3?
• 3 to 1?
• 1 to 3?
At end of Class:
Changing Orbits:

Also something called “Fast Transfer”

• It is more direct and quicker

• However it takes more fuel

• $\Delta V_1$ and $\Delta V_2$ are much bigger
From Earth Orbit to the Moon:

Same as changing orbits but....
- At apogee you **don’t have empty space**
- Instead, you have a large and massive object

Gravity from this object can **act as a ΔV** against your spacecraft

When going to the Moon the following could happen:
1) Gravity will cause your spacecraft to **crash** into the surface
2) Gravity will cause your spacecraft to **zip** off into space for a long time
Getting to the Moon:

• Gravity Assist
Cassini's speed related to Sun
Moon Video
Apollo XIII:

1. Liftoff, April 11, 1970, 1:13 p.m. CST
2. Saturn V third stage propels Odyssey and Aquarius toward moon, April 11, 3:48 p.m.
3. Odyssey docks with Aquarius, pulling it from third stage, April 11, 5:14 p.m.
4. Odyssey fires engine to leave free-return trajectory, April 13, 7:23 p.m.
5. Oxygen tank two in Odyssey explodes, April 13, 5:07 p.m.
6. Aquarius fires engine to return to free-return trajectory, April 14, 2:43 a.m.
7. Aquarius fires engine for PC-2 speed-up burn, April 14, 8:40 p.m.
8. Aquarius fires engine to correct trajectory, April 15, 10:31 p.m.
9. Damaged service module jettisoned, April 17, 7:14 a.m.
10. Aquarius jettisoned, April 17, 10:43 a.m.
11. Odyssey splashes down, April 17, 12:07 p.m.
Apollo XIII:

1. Liftoff, April 11, 1970, 1:13 p.m. CST

2. Saturn 5 third stage propels Odyssey and Aquarius toward moon, April 11, 3:48 p.m.

3. Odyssey docks with Aquarius, pulling it from third stage, April 11, 5:14 p.m.

4. Odyssey fires engine to leave free-return trajectory, April 12, 7:53 p.m.
Apollo XIII:

8. Aquarius fires engine to correct trajectory, April 15, 10:31 p.m.

6. Aquarius fires engine to return to free-return trajectory, April 14, 2:43 a.m.

5. Oxygen tank two in Odyssey explodes, April 13, 9:07 p.m.

7. Aquarius fires engine for PC+2 speed-up burn, April 14, 8:40 p.m.
Apollo XIII:

1. Lift off, April 11, 1970, 1:13 p.m. CST

9. Damaged service module jettisoned, April 17, 7:14 a.m.

10. Aquarius jettisoned, April 17, 10:43 a.m.

11. Odyssey splashes down, April 17, 12:07 p.m.
To the Moon for Money:
To the Moon for Money:

- Post lunar fly-by
  - Earth perigee (42,000 km)
  - May 16
- Trans-lunar injection
  - May 7
- Final geosynchronous orbit (36,000 km)
  - late May
- (214,000 km)
  - April 28
- (321,000 km)
  - May 4
- 5 ¾ days to moon
- 3 ¼ days return to Earth
- Perilune (8000 km)
  - May 13
To the Moon for Money:
Earth to L1:

Lagrangian Points are orbits about an equilibrium point
There are 5 Lagrangian Points
Earth to L1:

- Solar wind collection in halo orbit about L1 (2 yrs.)
- Return leg (5 mos.)
- Outward leg (3 mos.)
- Lunar orbit
- Parking orbit (optional)
- Positioning for daylight reentry

Diagram shows the trajectory from Earth to L1, including various orbital phases and distances.
Earth to Mars:

- Initial Orbit
- Earth Orbit
- Transfer Orbit
- Mars Orbit
- Final Orbit

$\Delta v_1$

$\Delta v_2$
Earth to Beyond:

Say you are in a 250 km orbit...

Orbital Velocity:

\[ v_i = 7.75 \frac{km}{sec} \]
\[ v_i = 17,336 \text{ mph} \]
Earth to Beyond:

Velocity on parabolic (a=∞) escape trajectory:

\[ v = \sqrt{\frac{2 \mu}{r}} \]

\[ v_{esc} = \sqrt{\frac{2 \times 398600.4}{(250 + 6378.14)}} \]

\[ v_{esc} = 10.97 \text{ km/sec} \]

\[ v_{esc} = 24,539 \text{ mph} \]

\[ \Delta v_{esc} = 3.22 \text{ km} \]
Earth to Beyond:

$\Delta V$ needed is...

$$\Delta v_{esc} = v_{esc} - v_i$$
$$= 10.97 - 7.75$$

$$\Delta v_{esc} = 3.22 \frac{km}{sec}$$

$$\Delta v_{esc} = 7,202 \text{ mph}$$
At end of Class:
Questions?

Colorado Space Grant Consortium

T-23
Orbits: 
_A Brief Historical Look_

Arthur C. Clarke

Discovered This Orbit
Ancient Orbit History:

“ORBIT” from Latin word “orbita”
orbitus = circular; orbis = orb

• 1800 B.C.
Stonehenge
- Study of the vernal equinox
1500 B.C.: Egyptians and Babylonians

- Written evidence of stellar observations
- Solar Calendar of 365 days
- Time divided into 60 even units
350 B.C.: Greek Thoughts

Aristotle

• Said earth is center of the universe
• Dominated scientific thought for 1800 years
Start of the Heliocentric Model:

1543 A.D.

Nicholas Copernicus
- Said Sun-centered rotations
- Measurements crude but thinking shifts
- Didn’t release findings until the end of his life
Orbit History:

- **1580 A.D.**
  
  **Tycho Brahe**
  
  - Accurate measurements of planets (Mars) as a function of time
  
  - Even though telescope had not been invented
Orbit History:

- **1610 A.D.**
  - Galileo Galilei
  - Good friends with Copernicus
  - Observations with TELESCOPE reinforced
  - Discovered Venus has phases