One Minute Paper:

- Guest speaker not showing and letting us know
- Checking out an extra HOBO?
- What is a L-2 Orbit?
- What happens if snowing on launch day?
- When do we get reimbursed for our purchases?
- Washers for flight string?
- How far does temp probe have to extend from BalloonSat?
- How Mars on saltwater?
- Did we land on the moon for real?
- How did Tskovisky know about the cradle?
- Where do these rockets come in: Redstone, Atlas, Titan, Saturn
- Why was Oberth so important?
- How do you schedule cooler test? Do all electronics need to be inside?
One Minute Paper:

- Order film?
- Explain CoDR ranking?
- How fast does BalloonSat hit the ground?
- Condensation?
Most presentations improved from CoDR
- CDR in industry – different than what you went through
- Email issues
- All parts ordered?
- “We expect it to go fine” or “We don’t expect any problems”
- All payloads must be turned in ready to fly again and any problems understood and fixed
- Take good pictures of payload inside and out before launch in case your payload never returns
- Image/video tests are just as important as structural tests
- Practice taking data off BalloonSat before flight
CDR General Comments:

- Marv Luttges
Team Support from me…

Tuesday, October 24, 2006 – please still come to class

1. 9:00 – 9:15  Aquila
2. 9:15 – 9:30  Hubble Jr
3. 9:30 – 9:45  Cutthroat
4. 9:45 – 10:00  Wolverines
5. 10:00 – 10:15  Team 10
6. 10:15 – 10:30  BioHazard
7. 10:30 – 10:45  Echo III
8. 10:45 – 11:00  Axium
9. 11:45 – 12:00  Justice
10. 1:00 – 1:15  Cobras
Announcements:

- Movie Night Postponed
- In Class time next Tuesday
- Week from today Spacecraft Structures
- Halloween will be special orbits lecture

- Outreach form
- Budget plan

- 23 days until launch
Introducing

Dr. Kwak

a Specialist in
Family Medicine

Jennifer Kwak, M.D.
Announcements:

Great value! Young Men's urban gear

Twist your price
Buy 40% off

Savings
Starts Jan 1, 20xx
Sale 30-40%

U.S. Polo Assn.
2-pocket travel range
Reg. $60
Sale $30-40

Tickets are available at the door.

For more information, please contact the event coordinator at 555-1234.

Thank you for your support!
Announcements:

[Image with text: Announcements: ...]
COLUMBUS LASER VISION

$746 PER EYE
NO ADDITIONAL FEES

WILLIAM E. COLUMBUS, M.D.
Cornell Fellowship trained, certified LASIK specialist.
Over 5000 procedures performed since FDA approved in 1995.
98% of our patients no longer require distance eyewear.

Premier Quality at an Affordable Price

1-866-600-

Locations in Phila., Harrisburg & Wilkes-Barre, PA.
Before we get started...

In Class Exercise
Building a Rocket on Paper:

- Please wait, everyone will be opening your envelopes in a minute

- Not every rocket design will work...

- **YOU ARE A ROCKET ENGINEER:**
  You make $70,000.00 a year and you have a masters degree and drive a company Viper
Building a Rocket on Paper:

1.) Build a rocket with the right people. You will need...

- Payload Specialist
- Thruster Specialist
- Fuel Expert
- Structural Engineer
2.) Calculate total mass of your rocket, must include everything.

Total mass = mass of fuel + payload + structure + thrusters
Building a Rocket on Paper:

3.) Calculate the thrust needed to lift your rocket off the launch pad

\[ \text{Needed thrust} = \text{total mass} \times \text{gravity} \]

\[ F = m \times a \text{ [Newtons, N]} \]

1 N = 1 kg * m/s²

1 pound-force = 4.45 N

a = gravity = 10 m/s²
Building a Rocket on Paper:

4.) Calculate the total lift (thrust) capability of your rocket's thrusters

5.) Does your structure support the total weight of the rocket?

6.) Do you lift off the ground or did you crash and burn?

7.) Could you lift off the surface of the moon?
   
   \[ g_{\text{moon}} = \frac{1}{6} g_{\text{earth}} \]
## Ion Engine:

**Max Thrust** = 200 N

**Engine/Fuel Mass** = 9,000 kg (90,000 N)

**Max Thrust** (minus Engine/Mass) = -82,000 N

**Remaining Mass** = -8,200 kg

<table>
<thead>
<tr>
<th>Material</th>
<th>Ashes (2 kg)</th>
<th>Professor (180 kg)</th>
<th>Stamps (2K kg)</th>
<th>Water (20K kg)</th>
<th>Tires (200K kg)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood = 5K kg (200 kg)</td>
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<td>NO</td>
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<td>NO</td>
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<td>Composite = 9K kg (20 kg)</td>
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<td>NO</td>
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<tr>
<td>Iron = 500K kg (20,000 kg)</td>
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<tr>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Titanium = 5M kg (2,000 kg)</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
# Cold Gas Engine:

- **Max Thrust** = 22,000 N
- **Engine/Fuel Mass** = 1,700 kg (17,000 N)
- **Max Thrust (minus Engine/Mass)** = 5,000 N
- **Remaining Mass** = 500 kg

<table>
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<th>Professor (180 kg)</th>
<th>Stamps (2K kg)</th>
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<tr>
<td>Titanium = 5M kg (2,000 kg)</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
Propane Engine:

Max Thrust \(= 100,000\) N
Engine/Fuel Mass \(= 8,000\) kg \((80,000\) N\)
Max Thrust \((\text{minus Engine/Mass})\) \(= 20,000\) N
Remaining Mass \(= 2,000\) kg

<table>
<thead>
<tr>
<th>Material</th>
<th>Ashes ((2) kg)</th>
<th>Professor ((180) kg)</th>
<th>Stamps ((2K) kg)</th>
<th>Water ((20K) kg)</th>
<th>Tires ((200K) kg)</th>
<th>Comments</th>
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<tbody>
<tr>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
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<tr>
<td>Iron (= 500K) kg ((20,000) kg)</td>
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<td>NO</td>
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</tr>
<tr>
<td>Aluminum (= 3M) kg ((2,000) kg)</td>
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</tr>
<tr>
<td>Titanium (= 5M) kg ((2,000) kg)</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
Liquid Engine:

Max Thrust $= 1,500,000 \text{ N}$

Engine/Fuel Mass $= 103,000 \text{ kg (1,030,000 N)}$

Max Thrust (minus Engine/Mass) $= 470,000 \text{ N}$

Remaining Mass $= 47,000 \text{ kg}$

<table>
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<th>Material</th>
<th>Ashes (2 kg)</th>
<th>Professor (180 kg)</th>
<th>Stamps (2K kg)</th>
<th>Water (20K kg)</th>
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</tr>
</thead>
<tbody>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Structural Failure</td>
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<tr>
<td>Composite $= 9K \text{ kg (20 kg)}$</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Structural Failure</td>
</tr>
<tr>
<td>Iron $= 500K \text{ kg (20,000 kg)}$</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td></td>
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<tr>
<td>Aluminum $= 3M \text{ kg (2,000 kg)}$</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Titanium $= 5M \text{ kg (2,000 kg)}$</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
### Solid Engine:

**Max Thrust**: $3,000,000 \text{ N}

**Engine/Fuel Mass**: $52,000 \text{ kg} \ (520,000 \text{ N})

**Max Thrust (minus Engine/Mass)**: $2,480,000 \text{ N}

**Remaining Mass**: $248,000 \text{ kg}

<table>
<thead>
<tr>
<th>Material</th>
<th>Ashes (2 kg)</th>
<th>Professor (180 kg)</th>
<th>Stamps (2K kg)</th>
<th>Water (20K kg)</th>
<th>Tires (200K kg)</th>
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<tbody>
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<td>NO</td>
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<tr>
<td>(200 kg)</td>
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<tr>
<td>Composite =</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<td>9K kg</td>
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<tr>
<td>(20 kg)</td>
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<tr>
<td>Iron = 500K k</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td></td>
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<tr>
<td>(20,000 kg)</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>M kg</td>
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</tr>
<tr>
<td>(2,000 kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Titanium = 5</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>M kg</td>
<td></td>
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<tr>
<td>(2,000 kg)</td>
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</tbody>
</table>
Launch Vehicles
Past, Present, Future & Sci-Fi Future
Outline:

- Fine Print
- Background & Rocket Types
- Past
- Present
- Future
- Sci-Fi Future
Rocket Types:

- I don’t know everything about Launch Vehicles
- I may not be able to answer your questions
- This lecture is to expose you to all the different types of launch vehicles
- I can quit at any time
Background:

- Thrust = the force that moves

- Impulse = force over period of time

- Specific Impulse = Isp = ratio of impulse to fuel used

- Higher Isp usually indicates low thrust but very little fuel used

- Will learn more in Propulsion Lecture

- Rocket Types include: Solid, liquid, hybrid
Past/Present:

**Scout**

**Thrust:** 464,700 N (104,500 lb)

**Fueled Weight:** 21,750 kg

**Payload to Orbit:** 270 kg LEO

**# of Flights:** 188, 105 successful
Past:

Jupiter C

Thrust: 334,000 N (75,090 lb)
Fueled Weight: 29,030 kg
Payload to Orbit: 9 kg LEO (14 kg)

# of Flights: 6, 4 successful

Explorer I
Past:

**Mercury Redstone**

- **Thrust:** 347,000 N (78,000 lb)
- **Fueled Weight:** Not Found kg
- **Payload to Orbit:** 9 kg LEO
- **# of Flights:** 5, 5 successful

Chimp “Ham”, Shepard, and Grissom
Mercury Redstone Video
Go to the Moon Video
Past:

Saturn V

Thrust: 34,500,000 N (7,760,000 lb)
Fueled Weight: 2,910,000 kg
Payload to Orbit: 127,000 kg LEO
The F1 Engine Video
Past:
Lunar Rover Video
Saturn V:

Can it be built today? Not really…

According to Prof. Jesco von Puttkamer, Program Manager of Future Planning at NASA in 1999…

- The blue prints still exist, however only on microfilm.

- All the subcontractors and suppliers are no longer around.

- The technology is old. We can build much smaller and lighter rockets today.
Present
Present:

United States
- Shuttle
- Atlas
- Titan
- Delta
- Pegasus
- Athena
- Taurus

Foreign
- France (Ariane)
- Japan (H-series)
- China (Long March)
- Russia (Proton, Buran)
Present:

Space Shuttle

Thrust: 28,200,000 N (6,340,000 lb)
Fueled Weight: 2,040,000 kg
Payload to Orbit: 24,400 kg LEO
Cost per launch: $245,000,000
Cost per kg: $10,040

SRB Recovery

External Tank
First Shuttle Flight Video
SRB Separation Video
External Tank Video
Present:

Atlas IIAS

Thrust: 2,980,000 N (670,000 lb)
Fueled Weight: 234,000 kg
Payload to Orbit: 8,390 kg LEO
Cost per launch: $78,000,000
Cost per kg: $9,296
Present:

Titan IV

Thrust: 4,800,000 N (1,080,000 lb)

Fueled Weight: 860,000 kg

Payload to Orbit: 21,645 kg LEO

Cost per launch: $248,000,000

Cost per kg: $11,457
Titan IV Video
Present:
Present:

Delta II

Thrust: 2,630,000 N (591,000 lb)
Fueled Weight: 230,000 kg
Payload to Orbit: 5045 kg LEO, 17,000 kg
Cost per launch: $60,000,000
Cost per kg: $11,892
Present:

Pegasus

Thrust: 486,000 N
       (109,000 lb)
Fueled Weight: 24,000 kg
Payload to Orbit: 455 kg LEO
Cost per launch: $9,000,000
Cost per kg: $19,800
Present:
Present:

Pegasus Video
Present:

Ariane 44L (France)

Thrust: 5,380,000 N  
(1,210,000 lb)

Fueled Weight: 470,000 kg

Payload to Orbit: 9,600 kg LEO

Cost per launch: $110,000,000

Cost per kg: $11,458
Present:

Ariane 5 (France)

Thrust: 11,400,000 N (2,560,000 lb)
Fueled Weight: 737,000 kg
Payload to Orbit: 18,000 kg LEO
Cost per launch: $120,000,000
Cost per kg: $6,666
Present:

H-2 (Japan)

Thrust: 3,959,200 N
        (890,060 lb)

Fueled Weight: 260,000 kg

Payload to Orbit: 10,500 kg LEO

Cost per launch: $190,000,000

Cost per kg: $18,095

Video
Present:
Present:

**Long March CZ2E (China)**

- **Thrust:** 5,922,000 N
  (1,331,000 lb)
- **Fueled Weight:** 464,000 kg
- **Payload to Orbit:** 8,800 kg LEO
- **Cost per launch:** $50,000,000
- **Cost per kg:** $5,681
Present:

Proton D-1 (Russia)

Thrust: 9,000,000 N (2,000,000 lb)
Fueled Weight: 689,000 kg
Payload to Orbit: 20,000 kg LEO
Cost per launch: $70,000,000
Cost per kg: $3,500
Present:
Present:
Present/Past:
Energia (Russia)

Thrust: 34,800,000 N (7,820,000 lb)
Fueled Weight: 2,400,000 kg
Payload to Orbit: 90,000 kg LEO
Cost per launch: $764,000,000?
Cost per kg: $Not Known
Present/Past:

Buran “Snowstorm” (Russia)
First and only launch
November 15, 1988
No one on board
- Life support not tested
- CRT’s did not have software
Only 2 orbits
- This was limited because of computer memory
Landed by autopilot
Aero Buran was test unit

Had 24 test flights

3 others were being built
- Pitchka (Little Bird)
- Baikal (Typhoon)

All dismantled in 1995
Present/Past:
Present/Past:
Present/Past:
Present/Past:
Present/Past:
Present/Past:

BURAN - ENERGIA
A COMPARISON

PROTON  ARIANE - V  U.S SHUTTLE SYSTEM  BURAN - ENERGIA
Future
Future/Past:

<table>
<thead>
<tr>
<th></th>
<th>Falcon 1</th>
<th>Falcon 5</th>
<th>Falcon 9</th>
<th>Falcon 9-S5</th>
<th>Falcon 9-S9</th>
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<tr>
<td>LEO</td>
<td>570 kg</td>
<td>4,100 kg</td>
<td>9,300 kg</td>
<td>8,700 kg</td>
<td>16,500 kg</td>
</tr>
<tr>
<td>GTO</td>
<td>--</td>
<td>1,050 kg</td>
<td>3,400 kg</td>
<td>3,100 kg</td>
<td>6,400 kg</td>
</tr>
<tr>
<td>Fairing diameter</td>
<td>1.5 m</td>
<td>3.6 m</td>
<td>3.6 m</td>
<td>5.2 m</td>
<td>5.2 m</td>
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<tr>
<td>Price in millions *</td>
<td>$6.7</td>
<td>$18</td>
<td>$27</td>
<td>$35</td>
<td>$51</td>
</tr>
</tbody>
</table>

* Prices are all inclusive of launch range, third party insurance and standard payload integration costs.
Future/Past:
Future/Past:
Future/Past:
Sci-Fi Future:

- $10 Billion

[Images of futuristic scenes with the Virgin logo.]
When Can I Go?

The first flights are planned to begin in 2008. We are now starting to take reservations and deposit commitments for the first year of operations. The ticket price has been set at US$200,000 and the minimum, fully refundable deposit to secure your spaceship seat is US$20,000.

If you're ready to talk to us about making a firm reservation and paying a deposit, or would just like to be kept up to date with the Virgin Galactic space tourism programme, fill in the form below.

Mandatory fields are marked with *

*Email address: 
*Type email address again to confirm: 
Title: Mr
*First Name: 
*Surname: 
*Would you consider putting down a deposit for a ride when we're ready for you to do so? - Select -

☐ Market Research - If you are happy for us to contact you for research purposes, tick this box.
Future/Past:

- Crew Return Vehicle
- X-38
Future/Past:
Future/Past:

- X-33
- VentureStar
Future/Past:
Future/Past:
Future/Past:
Future:

- Delta IV Heavy
Future:

- Delta IV Heavy
Future:

- Shuttle Fly-back boosters
Future:

- Hyper-X
Future:

- X-37
Future: Ion Drive Video
Sci-Fi Future
Sci-Fi Future:
Sci-Fi Future:
Sci-Fi Future:
Sci-Fi Future:

- Anti-matter
Sci-Fi Future:

- Boussard Ramjet Fusion Propulsion
Sci-Fi Future:

- Electrodynamic Tether
Sci-Fi Future:

- Jovian Electrodynamic Tether
Sci-Fi Future:

- Laser Propulsion
Sci-Fi Future:

- Beamed Energy Propulsion
Sci-Fi Future:

- Pulsed Detonation Rocket
Sci-Fi Future:

- Space Based Laser Re-boost
Sci-Fi Future:

- Plasma Rocket
Sci-Fi Future:

- Plasma Rocket
Sci-Fi Future:

- Space Elevator
  - Original concept as old as Mesopotamia: Biblical “Tower of Babel” and “Jacob’s Ladder”
- Five Critical Technologies (Source: MSFC Study)
  - High Strength Materials
  - Tension Structures
  - Compression Structures
  - EM Propulsion
  - Supporting Infrastructure
- May Lower Launch Costs to <$10/kg!
Sci-Fi Future:

- $10 Billion
- To LEO or GEO?

  - LEO: Possible Today
    - Lower end just inside atmosphere
    - Space plane flies to lower end for cargo
    - 10-12 times the cargo lifted by SSTO
  - GEO: YR 2050+

- Time Frame:
  - 10-20 Years for enabling technologies
  - YR 2050 + for actual construction