Gateway To Space

ASEN 1400 / ASTR 2500

Class #17

T-25

Colorado Space Grant Consortium
Today:

- Announcements
- One minute questions/answers
- Lecture on Launch Vehicles
**Announcements:**

- Insulation – bring extra back

- Other items needed?

- Launch is 25 days away

- Time is still your enemy not your friend

- DD Rev A/B – Still haven’t read them – This Friday

- Team One on One Meetings – Who’s interested?
One Minute Report Questions:

- Compass?
- Do projects get rejected if risk is too high but rewards are also great?
- What engineering major should you obtain to become a systems engineer?
- Do comp sci majors make more in aerospace or comp sci companies?
- What is the best way to attach our internal hardware to our sat?
- Can we talk to Joe more?
- Why validation after verification?
- How does one rate risk from 1 to 5?
Systems Engineering “V” Model
Risk Management

- Risk management is done throughout the entire program life cycle
- Risk is defined in two dimensions
  - Probability of occurrence
  - Consequence if the risk occurs
- Identify risks while there is still time to react
- Put in place mitigation strategy to minimize or eliminate risks
- Sources of risks include:
  - Poorly defined technical tasks or cost estimations
  - Poorly defined requirements and interfaces
  - Low technological maturity (technical risks)
  - Unrealistic project planning or inadequate resources
  - Inadequate workforce skill level

Risk Matrix

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<td>5</td>
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</tr>
</tbody>
</table>
One Minute Report Questions:

- To late to get in SG this year?
- Worried about time because team has so many conflicts that are non-negotiable
- Is systems engineering something you learn in school or on the job?
- Solid works on a mac?
One Minute Report Questions:
Mid Semester Team Evaluations…

- Due next class

- Make sure your name is on the form
Mid Semester Team Evaluations…

- Due at the start of class on Thursday
- Team of six has 1200 points

Total = 1200 points
Mid Semester Team Evaluations…

- Say not everyone is pulling their weight

Total = 1200 points
Mid Semester Team Evaluations…

- I take everyone’s scores and do the math, taking into account how self scoring compares to team score for you.
Next Class...

Orbit and Mission Design
- Part 1

Mid Semester Team Evals DUE

Colorado Space Grant Consortium
Concept of Liftoff

Colorado Space Grant Consortium
Concept of Liftoff

- What does liftoff mean?
- Newton’s 2\textsuperscript{nd} Law?
- \( F = m \times a \)
- How much do you weigh?
- How much thrust (F)?
- Off the ground but have to keep going
Background:

- **Thrust** = the force that moves (lb, N)

- **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**
Types of Rockets
Types of Rockets

Model Rockets (Estes)
Types of Rockets

High Altitude/Amateur Rockets
Types of Rockets

Suborbital/Sounding Rockets
Types of Rockets

Orbital Rockets
Types of Rockets:
Objectives:

- Become familiar with past and present launch vehicles
- Learn the major companies

- **Rocket Classes**
  - Small Lift: < 2,000 kg
  - Medium Lift: 2,000 – 20,000 kg
  - Heavy Lift: 20,000 – 50,000 kg
  - Super Heavy Lift: > 50,000 kg
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
Building a Rocket on Paper:

2.) Calculate total mass of your rocket, must include everything.

\[ Total \ mass = mass \ of \ fuel + payload + structure + thrusters \]
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
\[ a = \text{gravity} = 10 \ m/s^2 \]
Building a Rocket on Paper:

4.) Calculate the total lift (thrust) capability of your rockets 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>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>Composite = 9K kg (20 kg)</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Iron = 500K kg (20,000 kg)</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Aluminum = 3M kg (2,000 kg)</td>
<td>NO</td>
<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>
<thead>
<tr>
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<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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</thead>
<tbody>
<tr>
<td>Wood = 5K kg (200 kg)</td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Composite = 9K kg (20 kg)</td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>Iron = 500K kg (20,000 kg)</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>Aluminum = 3M kg (2,000 kg)</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
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</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>
Propane Engine:

Max Thrust = 100,000 N
Engine/Fuel Mass = 8,000 kg (80,000 N)
Max Thrust (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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</thead>
<tbody>
<tr>
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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>(200 kg)</td>
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<td></td>
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</tr>
<tr>
<td>Composite = 9K kg</td>
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<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>Structural Failure</td>
</tr>
<tr>
<td>(20 kg)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Iron = 500K kg</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>(20,000 kg)</td>
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<tr>
<td>Aluminum = 3M kg</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<td>(2,000 kg)</td>
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<tr>
<td>Titanium = 5M kg</td>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>(2,000 kg)</td>
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</table>
**Liquid Engine:**

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

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

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

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

<table>
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<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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</thead>
<tbody>
<tr>
<td>Wood = 5K kg</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO Structural Failure</td>
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<tr>
<td>(200 kg)</td>
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<tr>
<td>Composite = 9K kg</td>
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<td>NO Structural Failure</td>
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<td>Iron = 500K kg</td>
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<td>Aluminum = 3M kg</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
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<tr>
<td>(2,000 kg)</td>
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<tr>
<td>Titanium = 5M kg</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>(2,000 kg)</td>
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</table>
## Solid Engine:

<table>
<thead>
<tr>
<th></th>
<th>Ashes</th>
<th>Professor</th>
<th>Stamps</th>
<th>Water</th>
<th>Tires</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td><strong>Max Thrust</strong></td>
<td>3,000,000 N</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engine/Fuel Mass</strong></td>
<td>52,000 kg (520,000 N)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Max Thrust (minus Engine/Mass)</strong></td>
<td>2,480,000 N</td>
<td></td>
<td></td>
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<tr>
<td><strong>Remaining Mass</strong></td>
<td>248,000 kg</td>
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<table>
<thead>
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<th>Substance</th>
<th>Mass</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Ashes</td>
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<td>NO</td>
</tr>
<tr>
<td>Professor</td>
<td>180 kg</td>
<td>NO</td>
</tr>
<tr>
<td>Stamps</td>
<td>2K kg</td>
<td>NO</td>
</tr>
<tr>
<td>Water</td>
<td>20K kg</td>
<td>NO</td>
</tr>
<tr>
<td>Tires</td>
<td>200K kg</td>
<td>NO</td>
</tr>
</tbody>
</table>

- **Wood = 5K kg (200 kg)**: NO, NO, NO, NO, NO, Structural Failure
- **Composite = 9K kg (20 kg)**: NO, NO, NO, NO, NO, Structural Failure
- **Iron = 500K kg (20,000 kg)**: YES, YES, YES, YES, NO
- **Aluminum = 3M kg (2,000 kg)**: YES, YES, YES, YES, YES
- **Titanium = 5M kg (2,000 kg)**: YES, YES, YES, YES, YES
Launch Vehicles

Past, Present, Future & Sci-Fi Future
- Grasshopper
Outline:
- Background & Rocket Types
- Past
- Present
- Future
- Sci-Fi Future
Past
Past:

**Jupiter C (1956-1957)**

- **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/Present:

Scout (1961-1994)

Thrust: 464,700 N (104,500 lb)
Fueled Weight: 21,750 kg
Payload to Orbit: 270 kg LEO

# of Flights: 188, 105 successful
Past:

**Mercury Redstone (1960-1961)**

- Thrust: 347,000 N (78,000 lb)
- Fueled Weight: Not Found kg
- Payload to Orbit: 9 kg LEO (Suborbital)
- # of Flights: 6, 5 successful

First US manned rocket
Chimp “Ham”, Shepard, and Grissom
First Mercury-Redstone Launch, Nov 1960
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
- Launches: 11/11

7 manned moon landings
Past:
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.
Past:

Lockheed Martin

Thrust: 4,800,000 N
        (1,080,000 lb)
Fueled Weight: 860,000 kg
Payload to Orbit: 21,645 kg LEO
Cost per launch: $250,000,000
Cost per kg: $11,500
# Launches: 35, 32 successful
Last Launch: 2005
Past:

Falcon 1 (Space-X)

Thrust: 454,000 N
Fueled Weight: 38,555kg
Payload to Orbit: 570kg LEO
Cost per launch: $7,000,000
Cost per kg: $12,280
Launches: 5/2

First flight March 2006, retired 2010

To be replaced with Falcon 1e (1010kg to LEO), current status uncertain.
Past:

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
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
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
Past:

Aero Buran was test unit

Had 24 test flights

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

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

BURAN - ENERGIA
A COMPARISON

PROTON  ARIANE - V  U.S SHUTTLE SYSTEM  BURAN - ENERGIA
Present
### Present:

<table>
<thead>
<tr>
<th>United States</th>
<th>Foreign</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Atlas</td>
<td>- France (Ariane)</td>
</tr>
<tr>
<td>- Delta</td>
<td>- Japan (H-series)</td>
</tr>
<tr>
<td>- Pegasus</td>
<td>- India (PSLV)</td>
</tr>
<tr>
<td>- Taurus</td>
<td>- China (Long March)</td>
</tr>
<tr>
<td>- Falcon</td>
<td>- Russia (Proton, Sea Launch, Soyuz)</td>
</tr>
</tbody>
</table>
Present:

Atlas V (2002 – Present)
Lockheed Martin/ULA

Thrust: 8,590,000 N
       (1,900,000 lb)
Fueled Weight: 546,700 kg
Payload to Orbit: 10-19,000 kg LEO
Cost per launch: $138,000,000
Cost per kg: $9,000
Launches: 27, 1 partial failure

Notable payloads:
Mars Reconnaissance Orbiter
Juno
Present:

**Atlas V 401 Vehicle**

- Atlas V Booster
- RD-180 Engine
- Short ISA
- Conical ISA
- RL 10A Centaur Engine
- Centaur
- SDO Spacecraft
- PLF
- Launch Vehicle Adapter
Present:

Delta II (1989 – Present)
Boeing/ULA
Thrust: 2,630,000 N
(591,000 lb)
Fueled Weight: 230,000 kg
Payload to Orbit: 5045 kg LEO
Cost per launch: $60,000,000
Cost per kg: $11,892

Notable Payloads:
Mars Rovers
GRAIL
Present:

Delta IV

Height 63 - 77.2 m (206 - 253.2 ft)
Diameter 5 m (16.4 ft)
Mass 249,500 - 733,400 kg (550,000 - 1,616,800 lb)
Capacity
Payload to LEO 8,600 - 25,800 kg (18,900 - 56,800 lb)
Payload to GTO 4,300-12,980 (9,480-28,620 lb)
Cost per launch: $160,000,000
Present:

Delta IV Heavy

Thrust: 8,896,443 N
Fueled Weight: 733,000kg
Payload to Orbit: 23,000kg LEO
Cost per launch: $254,000,000
Cost per kg: $11,000
Launches: 5/4
First Launch: Dec 2004

Possible launcher for MPCV
(Formerly Orion)
Present:
Present:

**Pegasus**

Orbital

Thrust: 486,000 N (109,000 lb)

Fueled Weight: 24,000 kg

Payload to Orbit: 455 kg LEO

Cost per launch: $11,000,000

Cost per kg: $19,800

Launches: 35/40
Present:
Present:

Taurus (XL) (1994 – Present)
Orbital

Thrust: 1,606,000 N
Fueled Weight: 73,000 kg
Payload to Orbit: 1,320 kg LEO
Cost per launch: $24,000,000
Cost per kg: $16,000

Launches: 9/6
Present:

**Antares (2013)**
Orbital, Wallops

Thrust: 3,265,000 N
Payload to Orbit: 6,120 kg LEO
Cost per launch: $?
Cost per kg: $?

Solid and liquid
Launches: 4

Cygnus Spacecraft
Present:
Present:

**Falcon 9 (Space-X)**

- **Thrust:** 5,885,000 N
- **Fueled Weight:** 505,846 kg
- **Payload to Orbit:** 13,150 kg LEO
- **Cost per launch:** $61,200,000
- **Cost per kg:** $4000
- **Launches:** 3/4
- **Nov 30 ‘11, Dragon RNDZ ISS**
Present:
**Dragon (Space X)**

- Fully autonomous rendezvous and docking with manual override capability in crewed configuration
- Pressurized Cargo/Crew capacity of >2500 kg and 14 cubic meters
- Down-cargo capability (equal to up-cargo)
**Dragon:**

- Launches on Falcon 9
- Supports up to 7 passengers in Crew configuration
- Designed for water landing under parachute for ocean recovery
**Present:**

**Ariane 5 (France) (1996 – present)**

- **Thrust:** 11,400,000 N (2,560,000 lb)
- **Fueled Weight:** 737,000 kg
- **Payload to Orbit:** 16-21,000 kg LEO
- **Cost per launch:** $120,000,000
- **Cost per kg:** $6,400
- **Launches:** 60/56
Present:

H-2A, H-2B (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
- H-2B Launches: 2/2
- H-2A Launches: 19/18
Present:
Present:

Long March CZ-2F (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
Sea Launch/Zenit

**Present:**

**Sea Launch/Zenit**

Thrust: 8,180,000 N
Fueled Weight: 450,000 kg
Payload to LEO: 13,740 kg
Cost per launch: $100,000,000
Cost per kg: $7,300
Launches: 32/36
Present:

**Proton-M Enhanced (Russia)**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrust</td>
<td>10,000,000 N</td>
</tr>
<tr>
<td>Fueled Weight</td>
<td>712,800 kg</td>
</tr>
<tr>
<td>Payload to Orbit</td>
<td>20,000 kg LEO</td>
</tr>
<tr>
<td>Cost per launch</td>
<td>$100,000,000</td>
</tr>
<tr>
<td>Cost per kg</td>
<td>$4500</td>
</tr>
<tr>
<td>First Flight</td>
<td>2007</td>
</tr>
</tbody>
</table>

Proton rocket family dates back to 1965, ~340 launches total.
Present:
Soyuz:

(Russia)

Soyuz-U (cargo)
Soyuz-FG (crew)

Thrust: \(10,000,000\) N
Fueled Weight: \(313,000\) kg
Payload to Orbit: \(6,900\) kg LEO
Launches: \(745/724\)

Soyuz also refers to crew capsule
Present:

Polar Satellite Launch Vehicle
(India)

Thrust: 500,000 N
Fueled Weight: 294,000 kg
Payload to Orbit: 3,250 kg LEO
Cost per launch: $15,000,000
Cost per kg: $5200
Launches: 26/28
First Flight: 1993
Worldwide launch schedule

October 7, 2011 - A regularly updated listing of planned missions from spaceports around the globe. Dates and times are given in Greenwich Mean Time. "NET" stands for no earlier than. "TBD" means to be determined. Recent updates appear in red type. Please send any corrections, additions or updates by e-mail to: sclark@spaceflightnow.com

Latest changes:
9/20: Ariane 5 scrubbed; Adding window for Sea Launch/Atlantic Bird 7; Adding window for Minotaur 4/TacSat 4
9/22: Sea Launch/Atlantic Bird 7 delayed; Adding timeframe for Long March 2F/Tiangong 1; Adding time for Proton/QuetzSat 1
9/24: Updating launch times for Progress 45P, Soyuz 28S and Soyuz 29S
9/26: Long March 2F/Tiangong 1 delayed; Soyuz/Globalstar delayed
9/28: Adding time for Long March 2F/Tiangong 1
9/29: Adding time for Soyuz/Glonass; Adding date for Zenit/Intelsat 18; Proton/Glonass delayed
9/30: Adding Proton/SES 4 launch
10/04: Land Launch/Intelsat 18 scrubbed; Delta/NPP delayed; Adding date for Long March/W3C
10/05: Adding date for Proton/ViaSat 1
10/08: Adding time for PSLV/Mega-Tropiques; Adding Long March 2F/Shenzhou 8; Next Falcon 9 delayed; Taurus 2 demo delayed; Progress 46P delayed; Adding date for Atlas 5/AEHF 2

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Launch Log


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ASTRONAUT AUTOGRAPH & MEMORABILIA SHOW

Final Shuttle Mission Patch

Free shipping to U.S. addresses!

The crew emblem for the final space shuttle mission is now available in our store! Atlantis is scheduled for launch in June.

- U.S. STORE
- WORLDWIDE STORE

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Oct. 12  PSLV ● Mega-Tropiques

Launch time: 0530 GMT (1:30 a.m. EDT)
Launch site: Satish Dhawan Space Center, Sriharikota, India

India's Polar Satellite Launch Vehicle (PSLV) will launch the Mega-Tropiques research satellite. Jointly managed by India and France, the mission will study the water cycle and climate in the tropics. Delayed from Sept. 25. [Oct. 8]

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Oct. 19  Proton ● ViaSat 1

Launch time: 1848 GMT (2:48 p.m. EDT)
Launch site: Baikonur Cosmodrome, Kazakhstan

---
Future
**Falcon 1e:**

- Length: 24.7m (81 ft)
- Width: 1.7 m (5.5 ft)
- Mass: 38,180 kg (77 klbs)
- Thrust on liftoff:
  - 512 kN (115 klbf)

Falcon 1 (5/2) with modified 1st stage.
Falcon Heavy:

Thrust: 17,000,000 N
Weight: 1,400,000 kg
Payload LEO: 53,000 kg
Launch cost: $125,000,000
Cost per kg: $2300!
First Flight: 2015, planned
Future:

Vega (ESA)

Thrust: 3,040,000 N
Fueled Weight: 124,300 kg
Payload to Orbit: 1,500 kg LEO
First Flight: Planned Jan 2012

Development began 1998
**Building on a Foundation of Proven Technologies**

**Launch Vehicle Comparisons**

- **Space Shuttle**
  - Height: 184.2 ft
  - Gross Liftoff Mass: 4.5M lb
  - 55k lbm to LEO

- **Ares I**
  - Height: 321 ft
  - Gross Liftoff Mass: 2.0M lb
  - 48k lbm to LEO

- **Ares V**
  - Height: 358 ft
  - Gross Liftoff Mass: 7.3M lb
  - 117k lbm to TLI
  - 144k lbm to TLI in Dual-Launch Mode with Ares I
  - 290k lbm to LEO

- **Saturn V**
  - Height: 364 ft
  - Gross Liftoff Mass: 6.5M lb
  - 99k lbm to TLI
  - 262k lbm to LEO

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**Crew Lander**

- **Core Stage**
  - (5 RS-68 Engines)
  - 3.1M lb LOx/LH₂

- **Upper Stage**
  - (1 J-2X)
  - 280k lb LOx/LH₂

- **5-Segment Reusable Solid Rocket Booster (RSRB)**

- **Orion CEV**

- **Lunar Lander**

- **Earth Departure Stage (EDS) (1 J-2X)**
  - 499k lb LOx/LH₂

- **Two 5-Segment RSRBs**

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**Building on a Foundation of Proven Technologies**

- **Launch Vehicle Comparisons**

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**Crew Lander**

- **S-IVB**
  - (1 J-2 engine)
  - 240k lb LOx/LH₂

- **S-II**
  - (5 J-2 engines)
  - 1M lb LOx/LH₂

- **S-IC**
  - (5 F-1 engines)
  - 3.9M lb LOx/RP

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**Height (Space Shuttle):** 184.2 ft

**Gross Liftoff Mass (Space Shuttle):** 4.5M lb

**55k lbm to LEO**

---

**Height (Ares I):** 321 ft

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**Height (Ares V):** 358 ft

**Gross Liftoff Mass (Ares V):** 7.3M lb

**117k lbm to TLI**

**144k lbm to TLI in Dual-Launch Mode with Ares I**

**290k lbm to LEO**

---

**Height (Saturn V):** 364 ft

**Gross Liftoff Mass (Saturn V):** 6.5M lb

**99k lbm to TLI**

**262k lbm to LEO**
Future:

Space Launch System (SLS)

Congressionally mandated, 2010
Mission “Explore deep space and provide NASA-owned access to ISS”

Planned LEO payload capability:
70,000 – 129,000 kgs

Test flight 2017
1st crewed flight 2021

Based on Shuttle and Ares programs
Future:

Space Launch System (SLS)

Thrust: 16,000,000 N
Weight: 979,542 kg
Payload LEO: 130,000 kg
Launch cost: $500,000,000
Cost per kg: $3846
First Flight: 2015, planned
Future:

Space Launch System (SLS)
Future:

Space Launch System (SLS)
Future: Liberty

ATK and Astrium

Based on Shuttle/Ares boosters and Ariane 5 upper stage

Not selected for Commercial Crew Development (CCDev), but is still in work

Planned LEO payload: 22,000 kg
**Future: Dream Chaser**

CU highly involved
- Displays, controls, human rating

7 crew members to ISS

Planned launch vehicle: ULA Atlas V
(must man-rate)

Based on HL-20 lifting body

Drop tests planned Summer 2012 on WhiteKnightTwo

Runway landing, 1.5 g

(Soyuz ~5 g)
Future: Dream Chaser
Future: Orion (LMCO)

- For crewed missions to the Moon, asteroids and Mars.
- Formerly for constellation program Ares rocket (Cancelled program)
- Test on ULA Delta IV DEC 4th, 2014
- To be used with Space Launch System vehicles
- 21 Days of life support
- Includes Crew Module and Service Module
- 2017: Circumlunar mission
- 2021: Rendezvous with captured asteroid in lunar orbit
Future: Orion (LMCO)
Future: Orion (LMCO)
Future: CST-100 (Boeing)

(C)rew (S)pace (T)ransportation, 100 km is considered the boundary of space

Larger than Apollo capsule, smaller than MPCV

Atlas 5 planned launcher

Possibly operational by 2015
**Future: New Shepard (Blue Origin)**

Based off DARPA/McDonald Douglas’ DC-X
Vertical takeoff and landing
Suborbital tourism/research (100km alt, 10 min)
August 2011, test vehicle failure at mach 1.2, 45k ft
“Flight instability, range safety terminated thrust”

NASA’s commercial crew development:
- Awarded Launch Abort System contract
- Working on crew capsule with own funds
Future: New Shepard (Blue Origin)

Succeeds the Charon (2005), and Goddard (2006)

Suborbital

Thrust for 2.5 minutes

Reusable propulsion module

Separates from crew capsule, autonomous vertical landing

Crew capsule lands with parachutes

Available for manned crew or experiments
Future: SpaceShipTwo

Virgin Galactic and Scaled Composites

SpaceShipOne won the Ansari-X prize in 2004

SpaceShipTwo

- Six passenger
- Launches off WhiteKnightTwo at 50,000 ft
- Hybrid motor
Future: Spaceport America
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? 

- [ ] Market Research - If you are happy for us to contact you for research purposes, tick this box.
Future/Present: X-37

- Unmanned, classified
- Launches on Atlas V
- 2 Flights
  - April – Dec 2010
  - March 2011 - ?
Sci-Fi Future
Sci-Fi Future:

- Plasma Rocket
Sci-Fi Future:

- Anti-matter
Sci-Fi Future:
Sci-Fi Future:

- Boussard Ramjet Fusion Propulsion
Sci-Fi Future:

- Electrodynamic Tether
Sci-Fi Future:

- Jovian Electrodynamic Tether
Sci-Fi Future:

- Beamed Energy Propulsion
Sci-Fi Future:

- Plasma Rocket
Sci-Fi Future:

Space Elevator
- Konstantin Tsiolkovsky (Eiffel Tower)
- Arthur C. Clark (The Fountains of Paradise)

- 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:

Space Elevator
Getting to the moon

A. Reach Earth’s Orbit
   - Travel by current rocket technology at $5K - $20K per pound

B. Reach “Liftport”
   - Move cargo by rocket at modest cost

C. Reach the Moon
   - Cheap & reliable long-haul to and from the moon with a solar powered elevator; built with a ribbon anchored in earth’s gravity well.

*Lunar elevator provides cheap and reliable access to the moon.* This is because it eliminates the vast rocket fuel costs involved in braking on the way to the moon, and lifting off on the way back.
Sci-Fi Future:

$10 Billion