An Introduction to Rockets
-or-
Never Leave Geeks Unsupervised

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What is a Rocket?

- A propulsion system that contains both oxidizer and fuel
- NOT a jet, which requires air for O2
A Brief History

• 400 BC – Steam Bird

• 100 BC – Hero Engine

• 100 AD – Gunpowder Invented in China
  – Celebrations
  – Religious Ceremonies
  – Bamboo Misfires?
A Brief History

• Chinese Invent Fire Arrows 13th c
  – First True Rockets

• 16th c Wan-Hu
  – 47 Rockets
A Brief History

• 13th – 16th c Improvements in Technology
  – English Improved Gunpowder
  – French Improved Guidance by Shooting Through a Tube “Bazooka Style”
  – Germans Invented “Step Rockets” (Staging)
A Brief History

• 1687 Newton Publishes Principia Mathematica

"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

"Force is equal to the change in momentum (mV) per change in time. For a constant mass, force equals mass times acceleration."

F = m a

"For every action, there is an equal and opposite re-action."
Newton’s Third Law

MOMENTUM is the key concept of rocketry
A Brief History

• 1903 Konstantine Tsiolkovsky Publishes the “Rocket Equation”
  – Proposes Liquid Fuel

\[ V = V_e \times \ln \left( \frac{M_i}{M_f} \right) \]
A Brief History

• Goddard Flies the First Liquid Fueled Rocket on 16 Mar 1926
  – Theorized Rockets Would Work in a Vacuum
  – NY Times: Goddard “…lacks the basic physics ladeled out in our high schools…”
A Brief History

• Germans at Peenemunde
  – Oberth and von Braun lead development of the V-2
  – Amazing achievement, but too late to change the tide of WWII
  – After WWII, USSR and USA took German Engineers and Hardware
Mission Requirements

• Launch On Need
  – No Time for Complex Pre-Launch Preps
  – Long Shelf Life

• Commercial / Government
  – Risk Tolerance
  – R&D Costs
Mission Requirements

• Payload Mass and Orbital Objectives
  – How much do you need, and where do you want it? Both drive energy requirements.
• Low Earth Orbit (LEO)
• Geostationary Transfer Orbit (GTO)
• Geostationary Orbit (GEO)
  – 35,785 kilometers (22,236 miles)
• Beyond Earth
  – Transfer orbits change based on velocity
Some Orbital Measurements

<table>
<thead>
<tr>
<th>Alt (mi)</th>
<th>Radius (mi)</th>
<th>Circum (mi)</th>
<th>Period (hr)</th>
<th>Speed (mi/hr)</th>
<th>Energy/KEVIN (Mj)</th>
<th>Energy (gal-gas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4,076</td>
<td>25,615</td>
<td>1.46</td>
<td>17,444</td>
<td>2,874</td>
<td>22.1</td>
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<tr>
<td>22,326</td>
<td>26,302</td>
<td>165,265</td>
<td>24.0</td>
<td>6,867</td>
<td>5,186</td>
<td>39.9</td>
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</table>
Self Eating Watermelon

• Approximately 91% of Liftoff Mass is Propellant
• Approximately 3% is Vehicle
• Approximately 6% is Payload
Orbital Inclinations
28.5 Equatorial Orbit
51.6 Orbit (ISS)
Polar Orbit
Geostationary Orbit
Comparisons of Mars and Earth orbits
\[ V = \text{Velocity} \]
\[ \dot{m} = \text{mass flow rate} \]
\[ p = \text{pressure} \]

\[ \text{Thrust} = F = \dot{m} V_e + (p_e - p_0) A_e \]
Liquid Rocket

\[ \text{Thrust} = F = m \ V_e + (p_e - p_0) \ A_e \]

- \( V = \text{Velocity} \)
- \( m = \text{mass flow rate} \)
- \( p = \text{pressure} \)
<table>
<thead>
<tr>
<th></th>
<th>Liquid</th>
<th>Solid</th>
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</thead>
<tbody>
<tr>
<td><strong>Complexity</strong></td>
<td>High Speeds and Pressures</td>
<td>Very Simple</td>
</tr>
<tr>
<td><strong>Controllability</strong></td>
<td>Throttle-able</td>
<td>Committed Once Lit</td>
</tr>
<tr>
<td><strong>Storability</strong></td>
<td>Depends on Propellants</td>
<td>Long Duration</td>
</tr>
<tr>
<td><strong>Handling</strong></td>
<td>Toxic/Haz</td>
<td>Stable</td>
</tr>
<tr>
<td><strong>Specific Impulse</strong></td>
<td>Varies</td>
<td>Moderate</td>
</tr>
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</table>
# Liquids

<table>
<thead>
<tr>
<th></th>
<th>Cryos</th>
<th>Hypers</th>
<th>Hydrocarbons</th>
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<tbody>
<tr>
<td><strong>Storability</strong></td>
<td>Cryo Temps</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Handling</strong></td>
<td>Hazardous</td>
<td>Toxic</td>
<td>Stable</td>
</tr>
<tr>
<td><strong>Specific Impulse</strong></td>
<td>440 – 460 s</td>
<td>260 – 290 s</td>
<td>265 - 300 s</td>
</tr>
</tbody>
</table>
Systems Integration

- **Nose Cone**
- **Payload System**
- **Guidance System**
- **Structure System**
- **Fuel**
- **Frame**
- **Oxidizer**
- **Pumps**
- **Nozzle**
- **Fin**
- **Propulsion System**
Integration (NFL!)

- Actuators – Hydraulic or Electrical
- Life Support – Contingency Support
- Active Thermal - Heating and Cooling
- Passive Thermal Protection and Control
- Telemetry – Bandwidth/Encryption
- Power – Batteries/Solar/Fuel Cell
- Political and Other Considerations
- Etc…
Guidance Systems

Atlas

Vernier Rocket

Space Shuttle

Gimbaled Nozzles
Vectored Thrust
Spin Stabilization
Aerodynamic Stability
(Fire Arrows)
Center of Gravity & Center of Pressure
“The Earth is the cradle of mankind, but one cannot live in the cradle forever.”
—Konstantine Tsiolkovsky