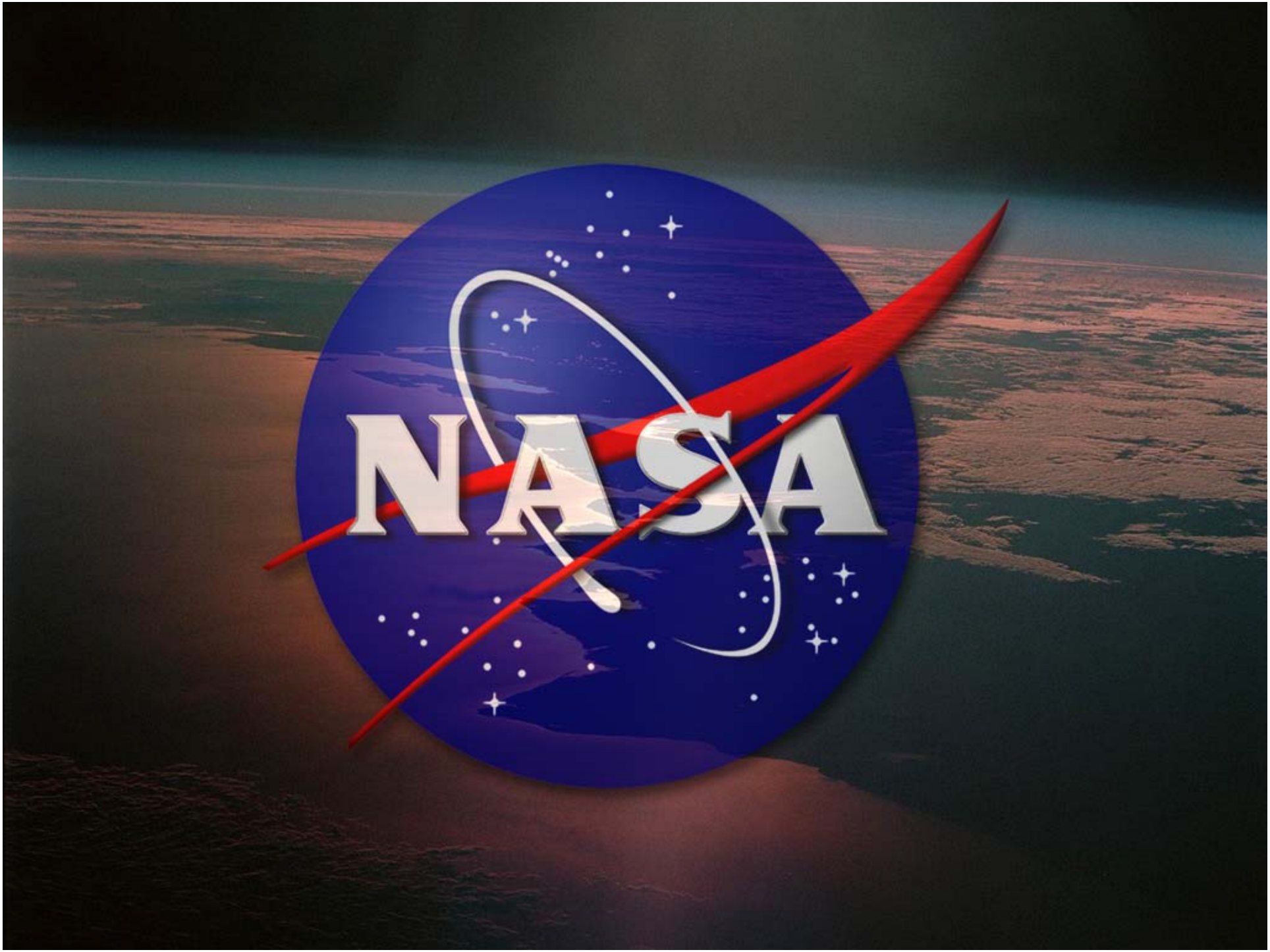

NASA

An Introduction to Rockets

-or-

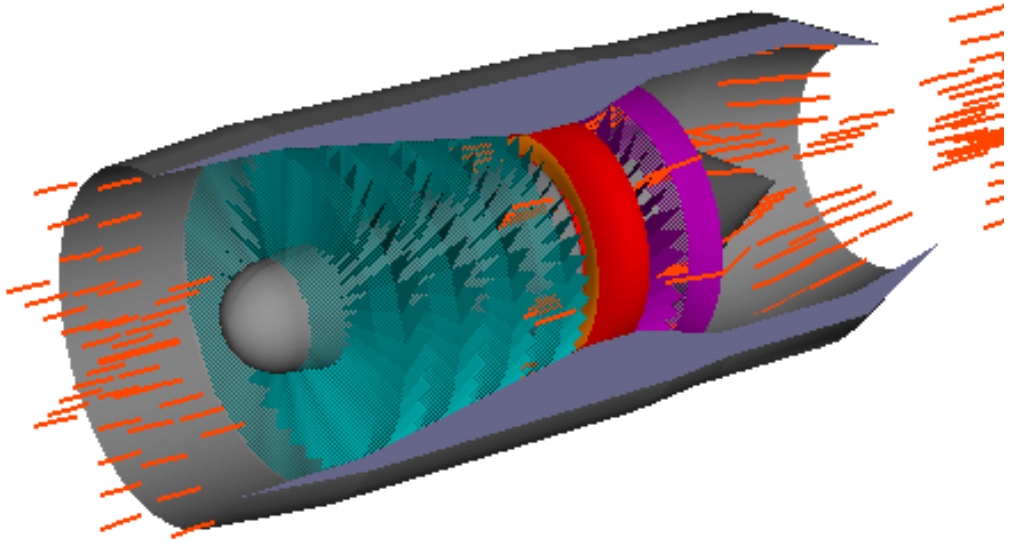
Never Leave Geeks Unsupervised

Kevin Mellett

27 Apr 2006

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

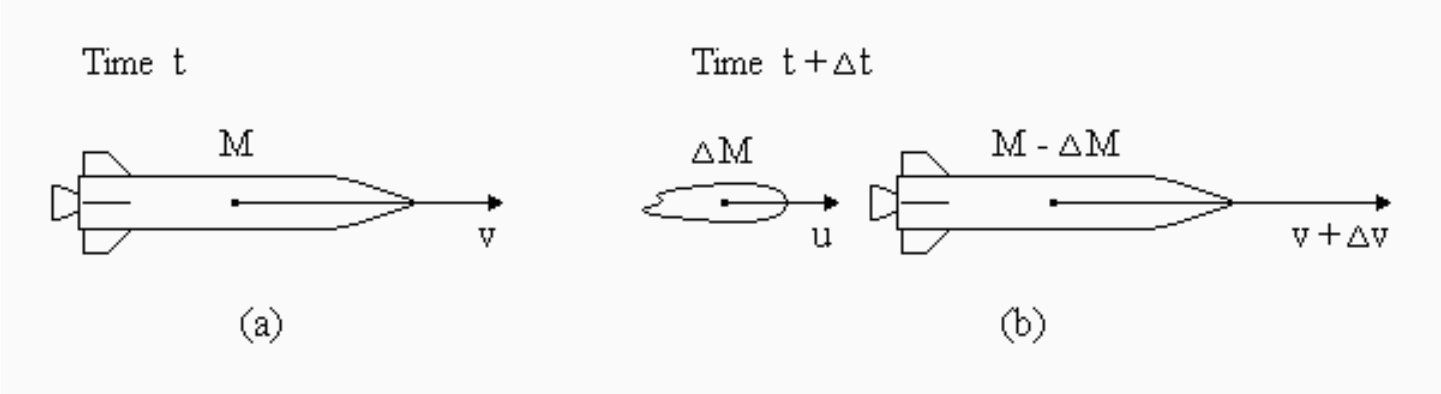
"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

"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

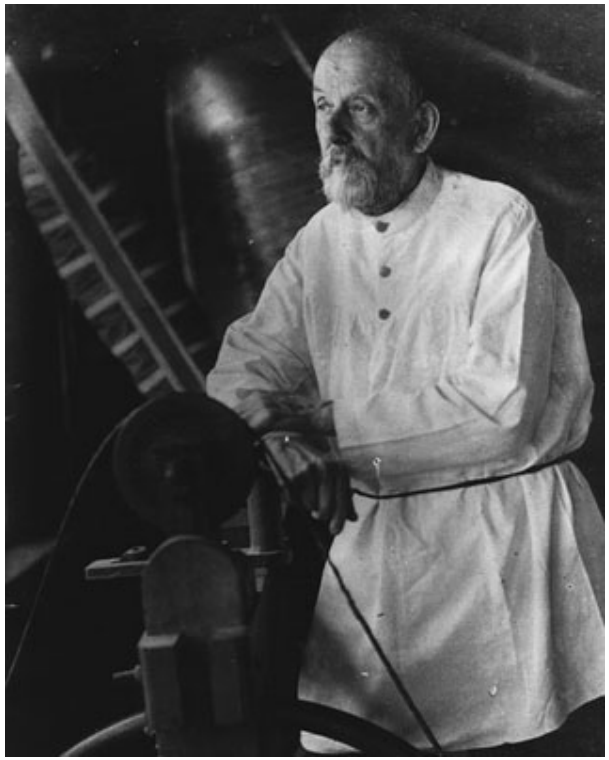


MOMENTUM is the key concept of rocketry

A Brief History

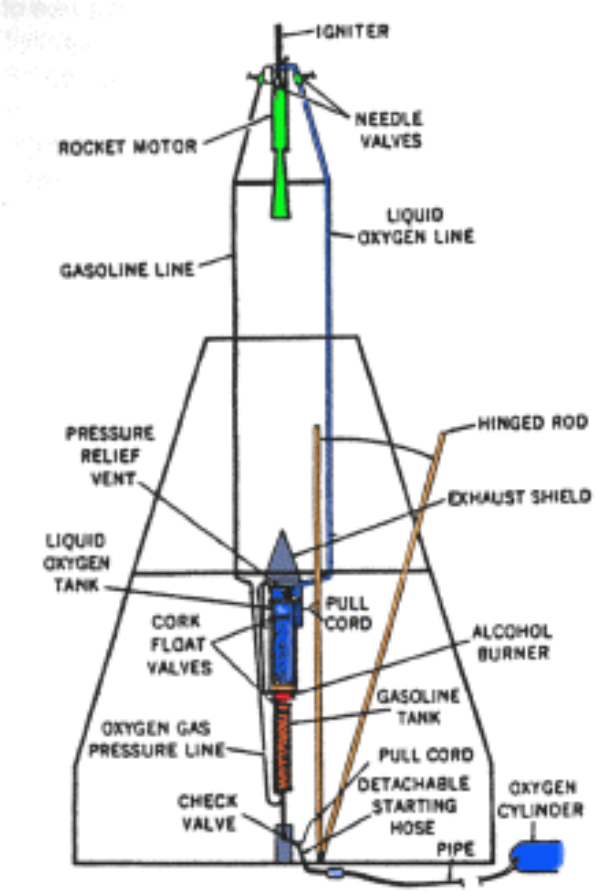
- 1903 KonstantineTsiolkovsky Publishes the “Rocket Equation”
  - Proposes Liquid Fuel

$$V = Ve * \ln\left(\frac{Mi}{Mf}\right)$$



A Brief History

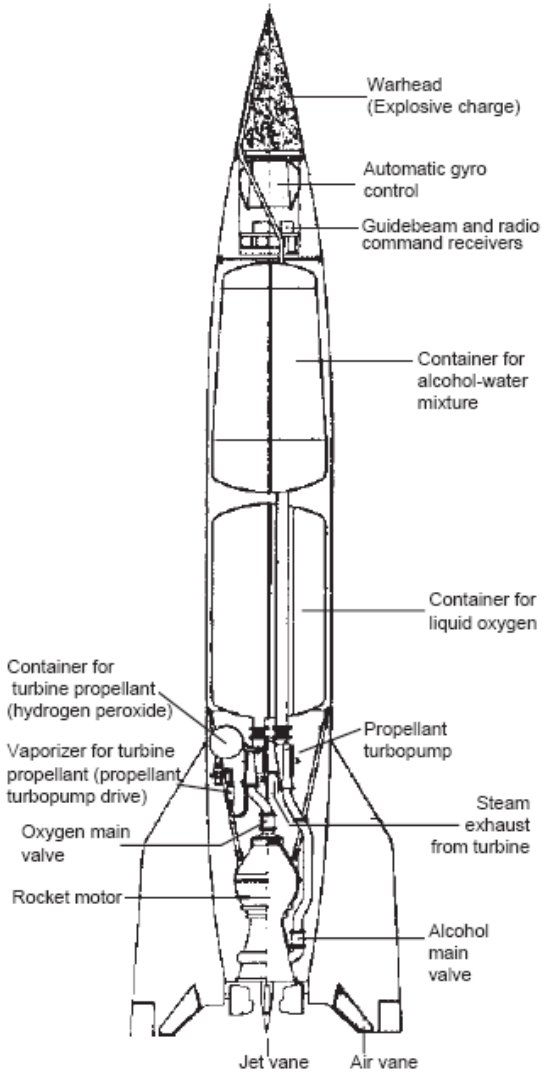
- Goddard Flies the First Liquid Fueled Rocket on 16 Mar 1926
  - Theorized Rockets Would Work in a Vacuum
  - NY Times: Goddard "…lacks the basic physics ladeled out in our high schools…"



Dr. Goddard's 1926 Rocket

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

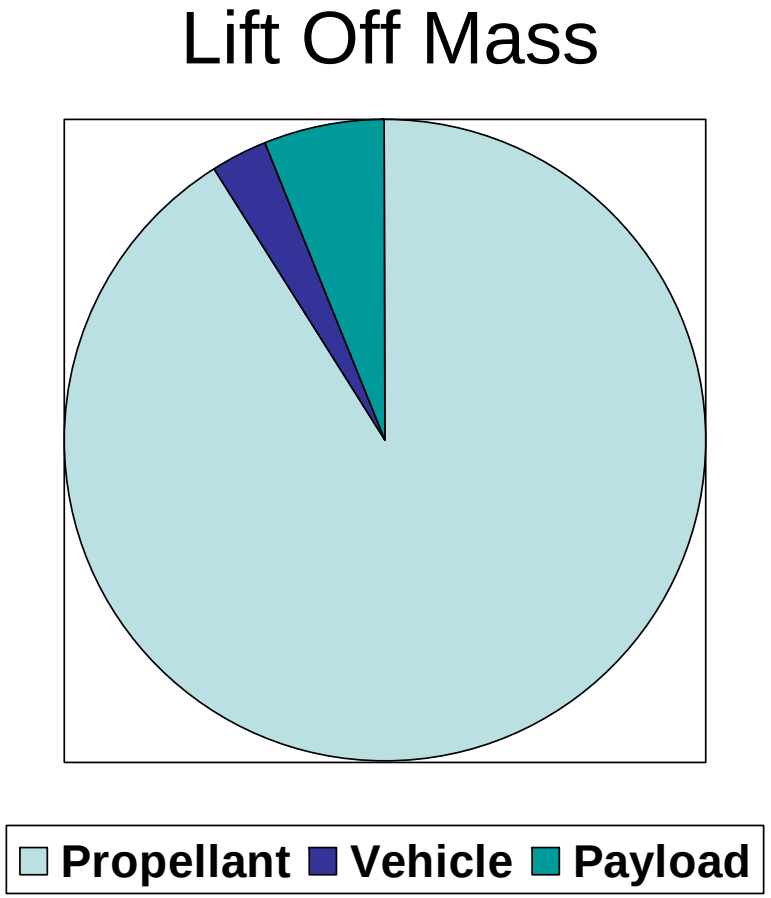
- Payload Mass and Orbital Objectives
  - How much do you need, and where do you want it? Both drive energy requirements.
- Low Earth Orbit (LEO)
- Geostationary Transfer Orbit (GTO)
- Geostationary Orbit (GEO)
  - 35,785 kilometers (22,236 miles)
- Beyond Earth
  - Transfer orbits change based on velocity

Some Orbital Measurements

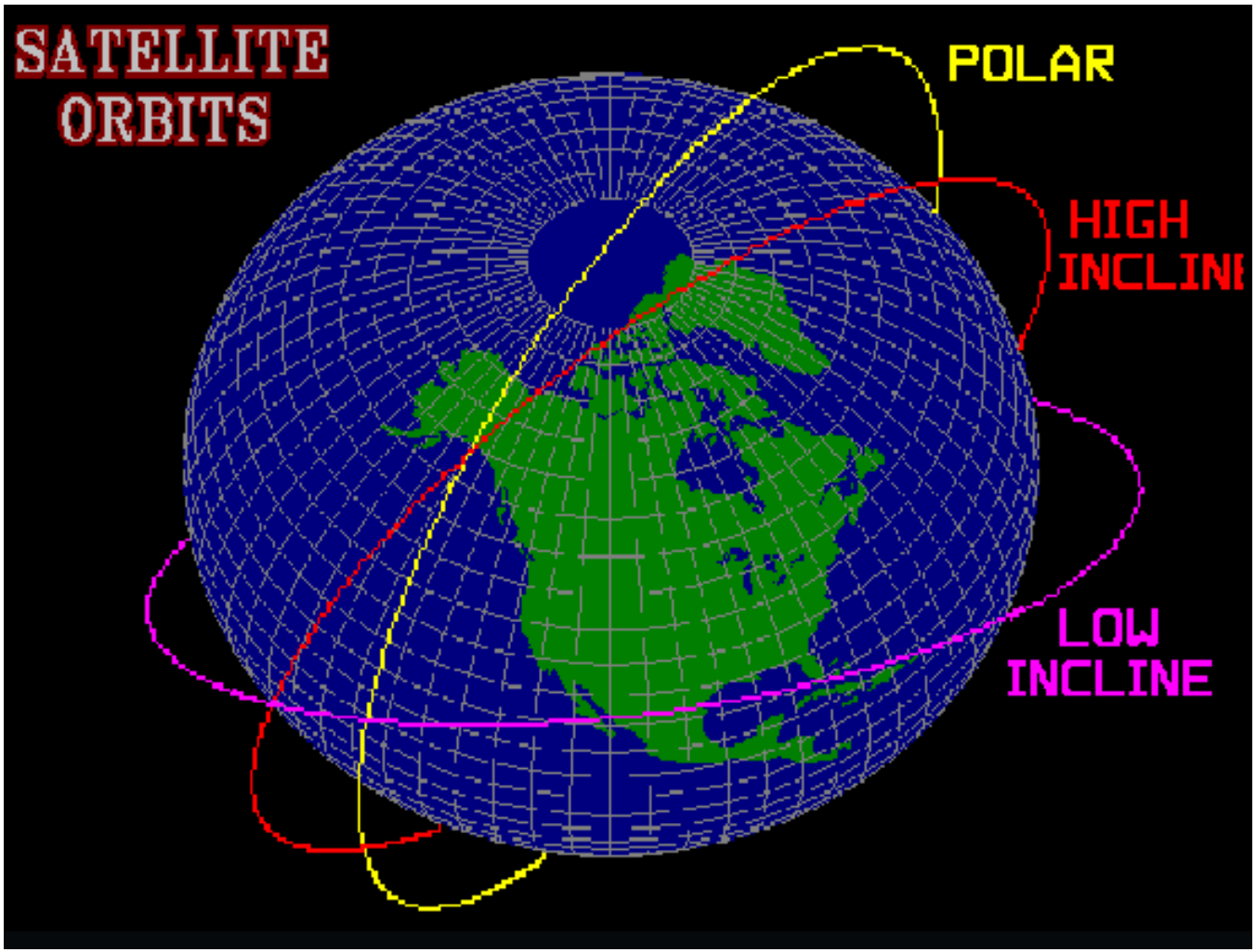
Alt (mi)	Radius (mi)	Circum (mi)	Period (hr)	Speed (mi/hr)	Energy/Kevin (Mj)	Energy (gal-gas)
100	4,076	25,615	1.46	17,444	2,874	22.1
22,326	26,302	165,265	24.0	6,867	5,186	39.9

Self Eating Watermelon

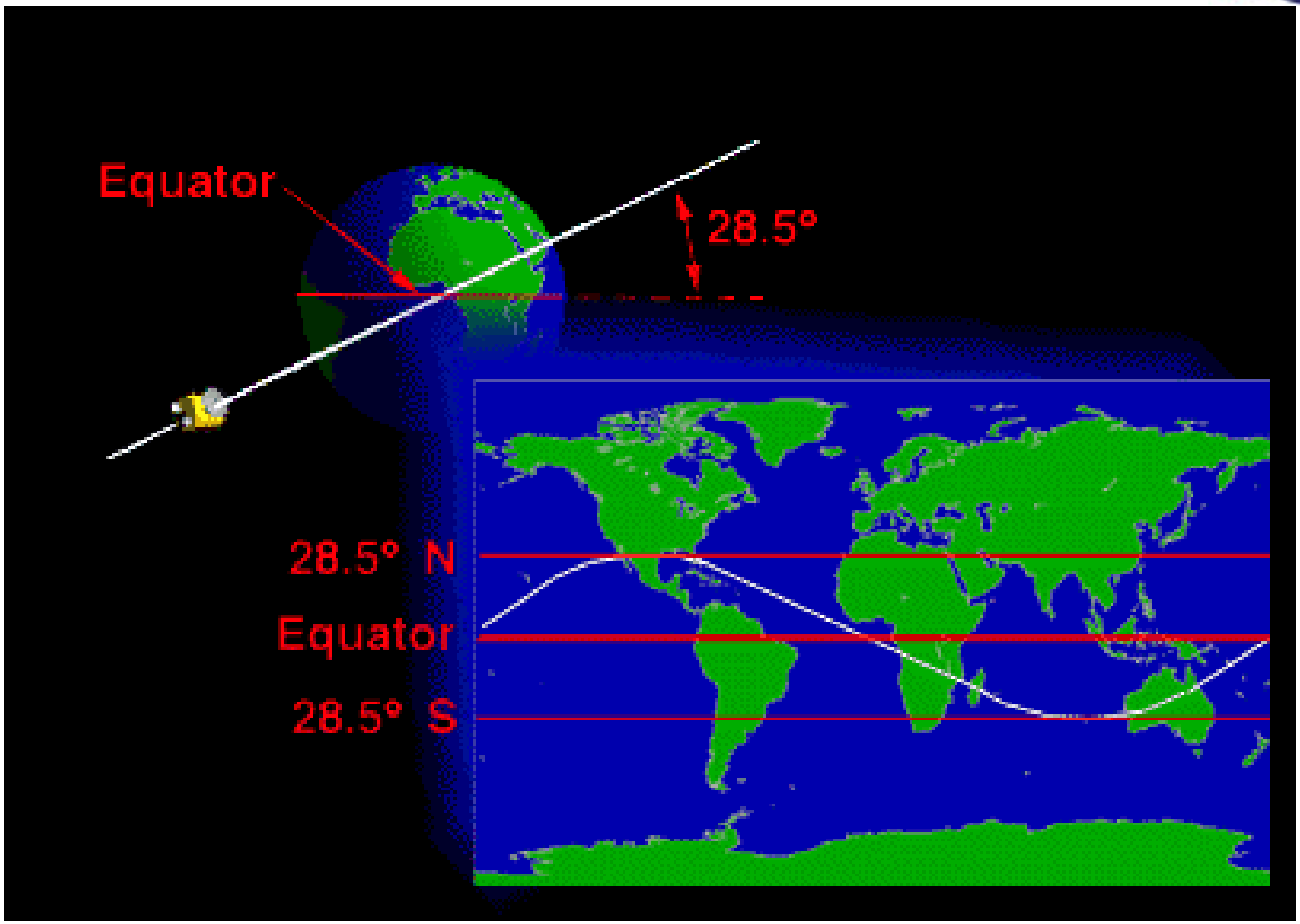
- Approximately **91%** of Liftoff Mass is Propellant
- Approximately 3% is Vehicle
- Approximately 6% is Payload



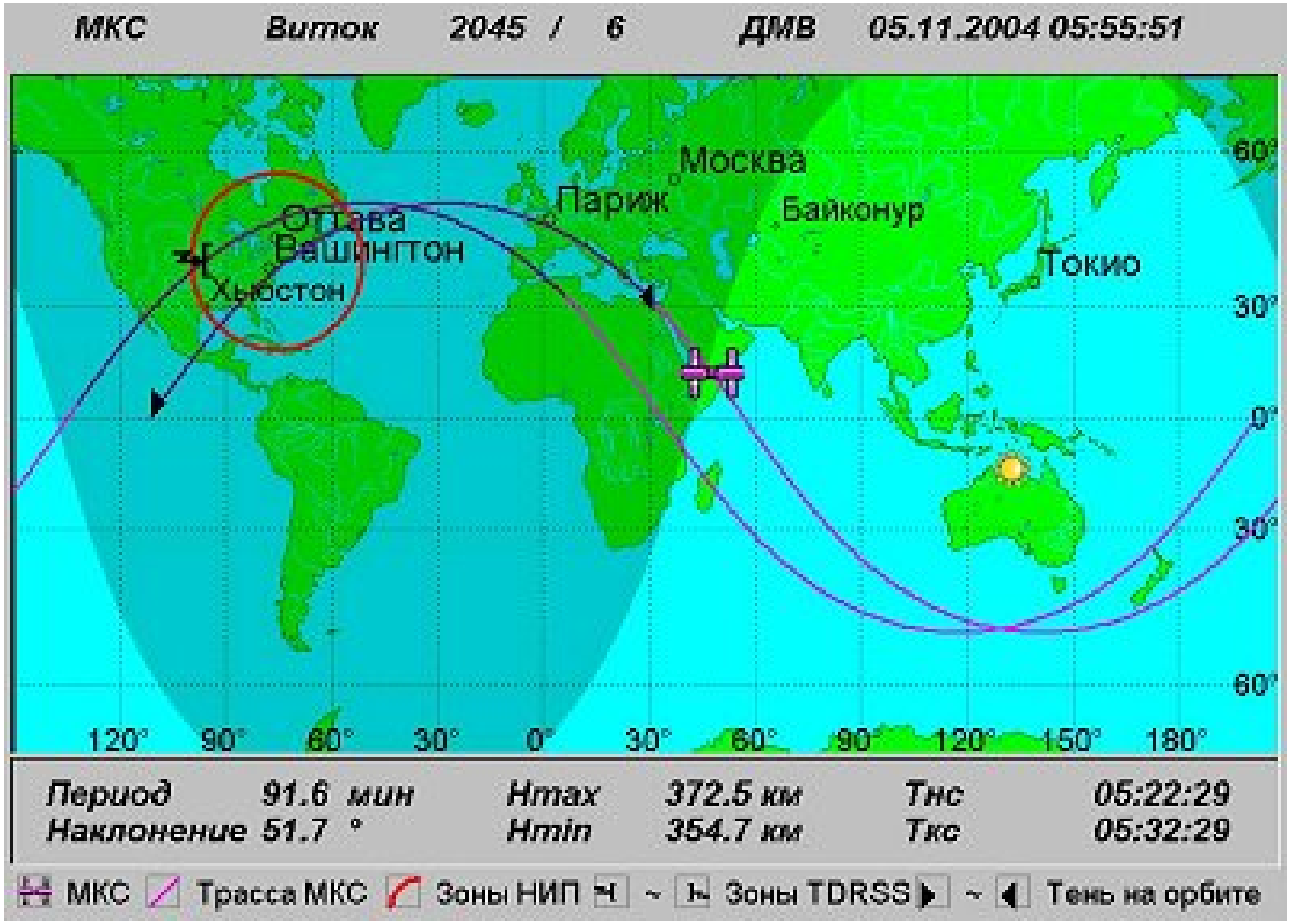
Orbital Inclinations



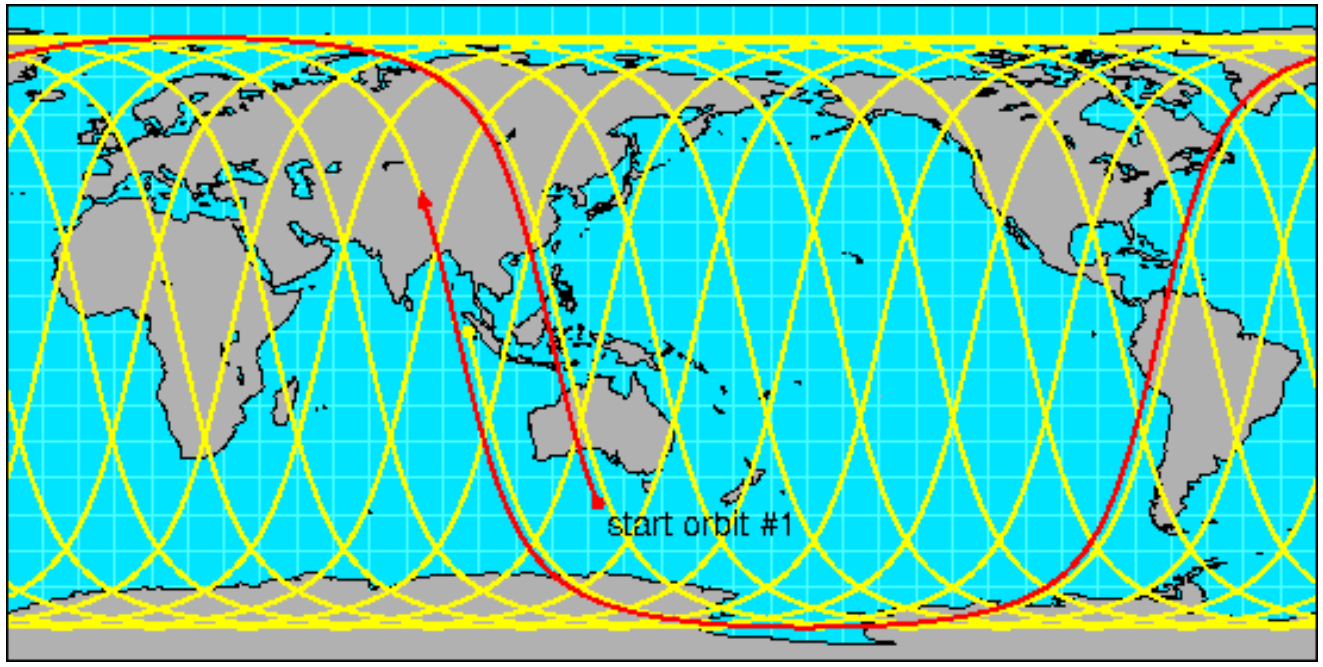
28.5 Equatorial Orbit



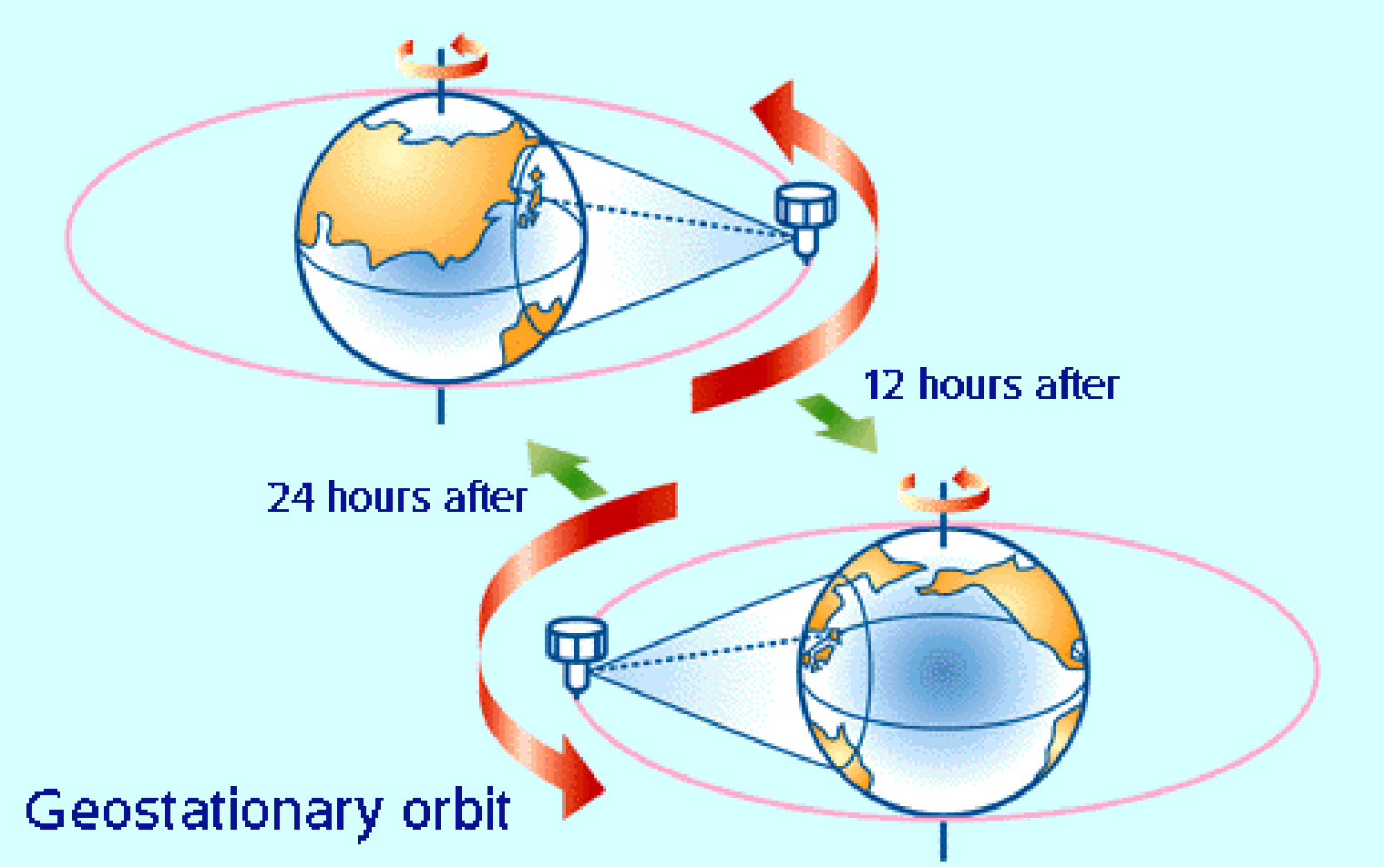
51.6 Orbit (ISS)

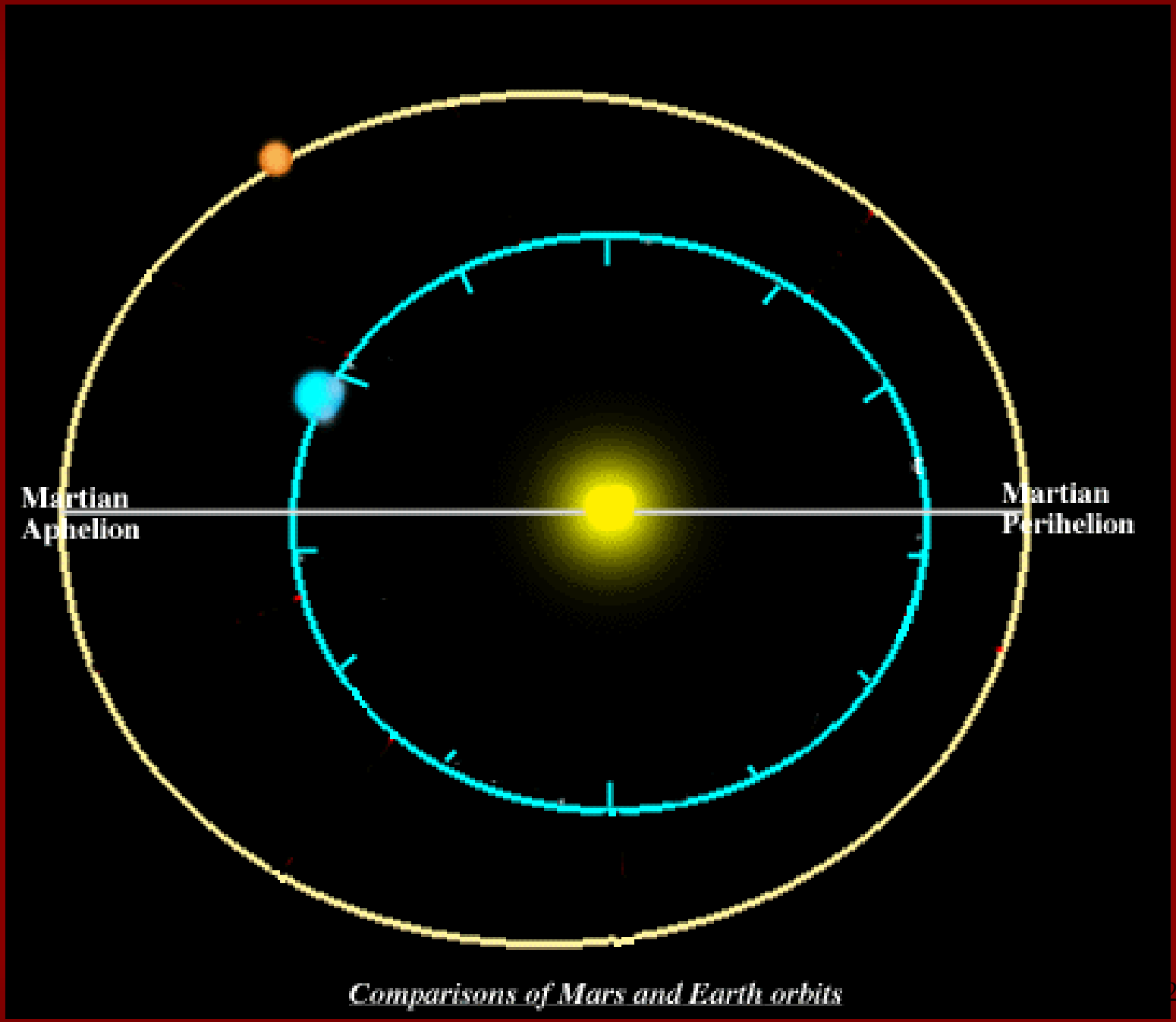


Polar Orbit

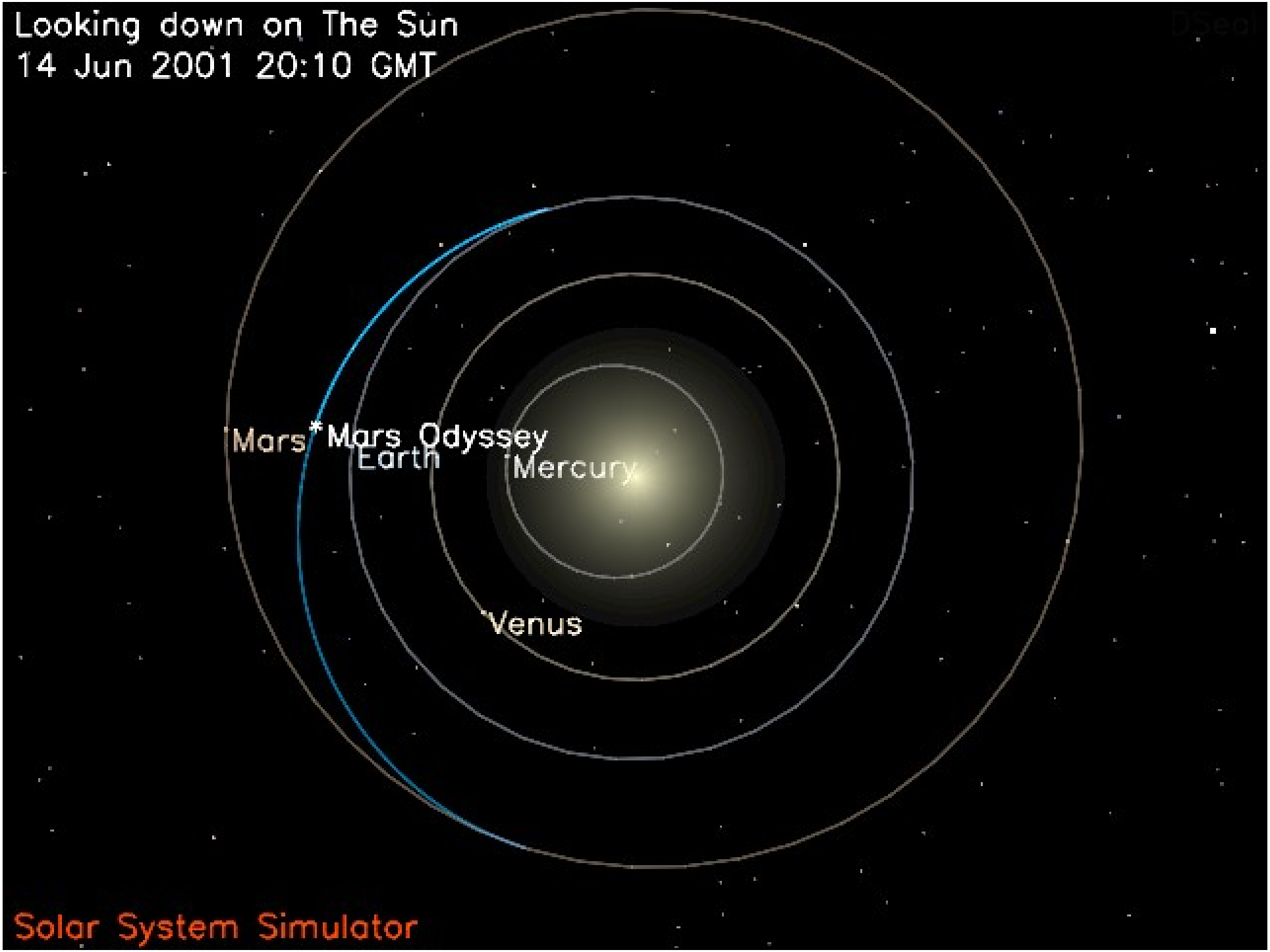


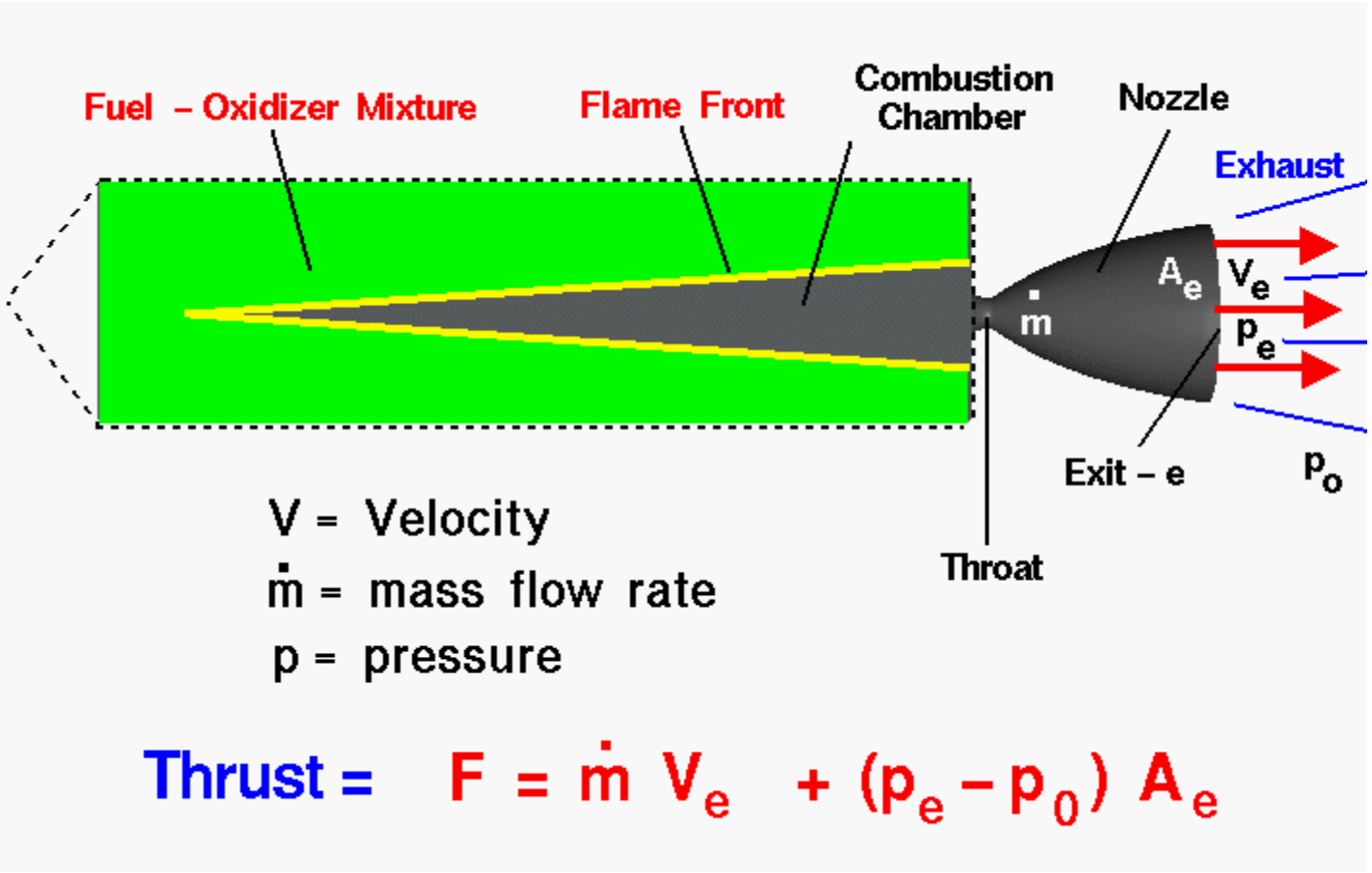
Geostationary Orbit



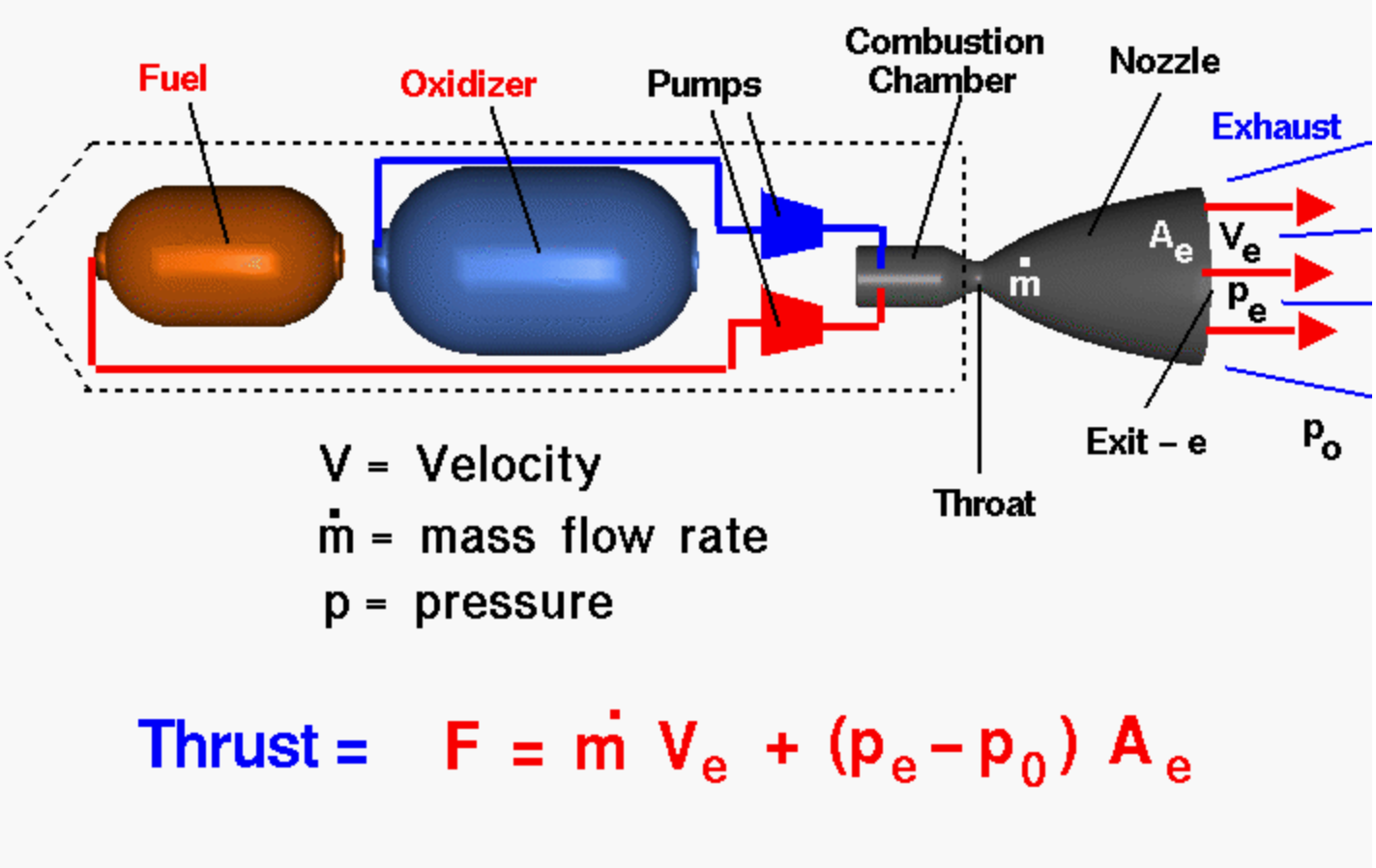


Comparisons of Mars and Earth orbits


Looking down on The Sun
14 Jun 2001 20:10 GMT
Mars
Mars Odyssey
Earth
Mercury
Venus
Solar System Simulator


Fuel – Oxidizer Mixture
Flame Front
Combustion Chamber
Nozzle
Exhaust
A_e
V_e
$\dot{m}$
p_e
Exit – e
p_o
Throat
V = Velocity
$\dot{m}$ = mass flow rate
p = pressure
Thrust = $F = \dot{m} V_e + (p_e - p_0) A_e$

Liquid Rocket



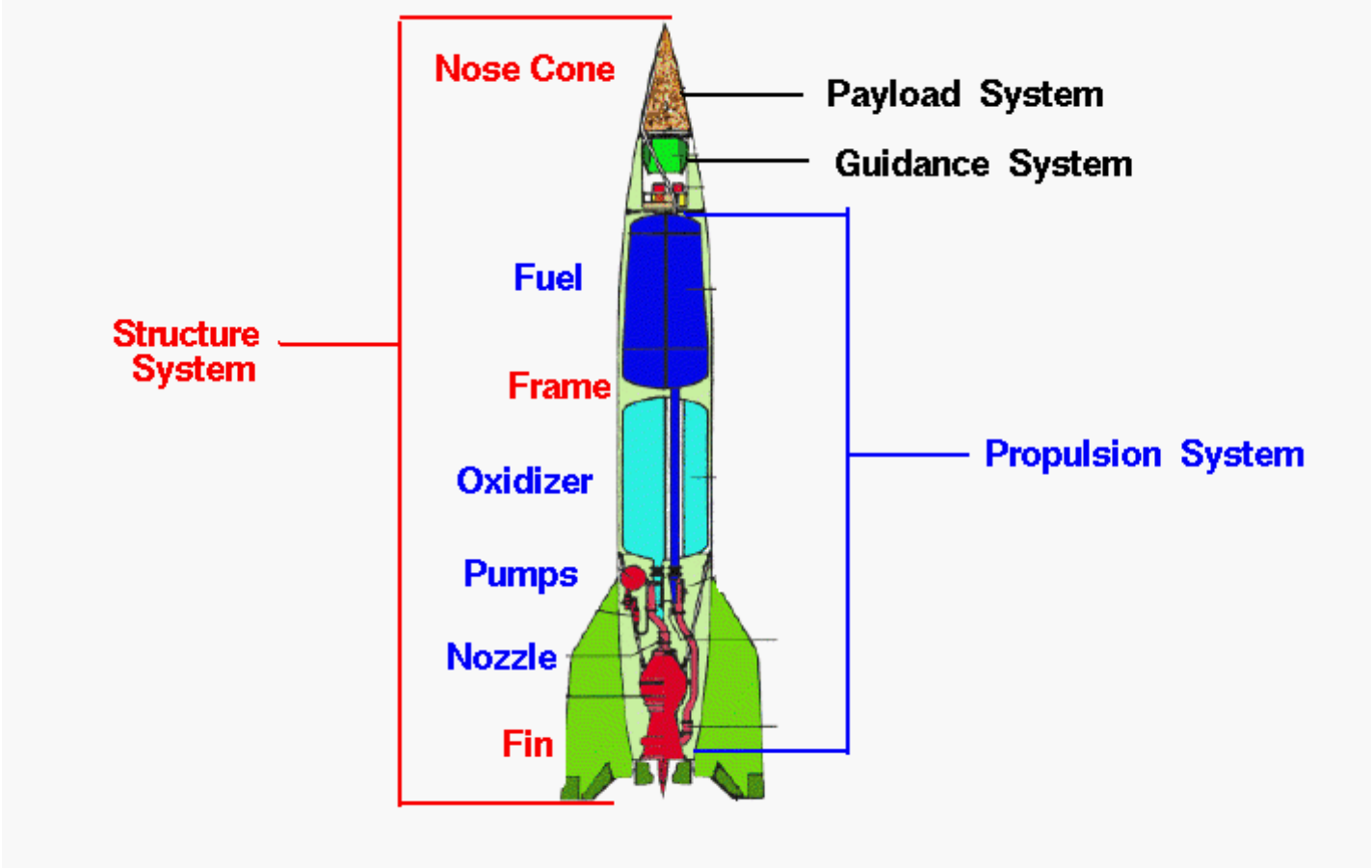
Liquids vs. Solids

	Liquid	Solid
Complexity	**High Speeds and Pressures**	**Very Simple**
Controllability	**Throttle-able**	**Committed Once Lit**
Storability	**Depends on Propellants**	**Long Duration**
Handling	**Toxic/Haz**	**Stable**
Specific Impulse	**Varies**	**Moderate**

Liquids

	Cryos	Hypers	Hydro-carbons
Storability	**Cryo Temps**	**Fair**	**Good**
Handling	**Hazardous**	**Toxic**	**Stable**
Specific Impulse	**440 – 460 s**	**260 – 290 s**	**265 - 300 s**

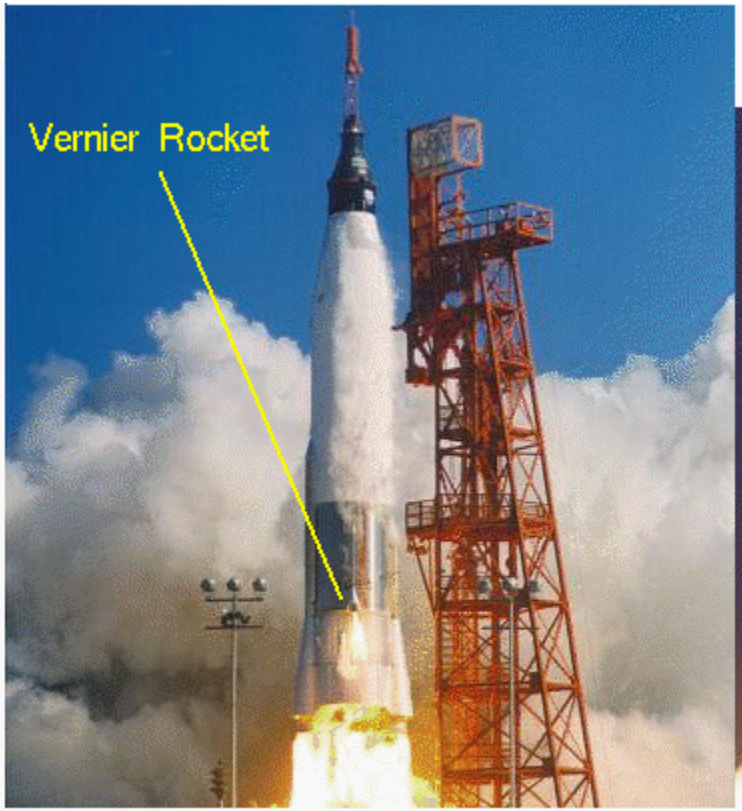
Systems Integration



Integration (NFL!)

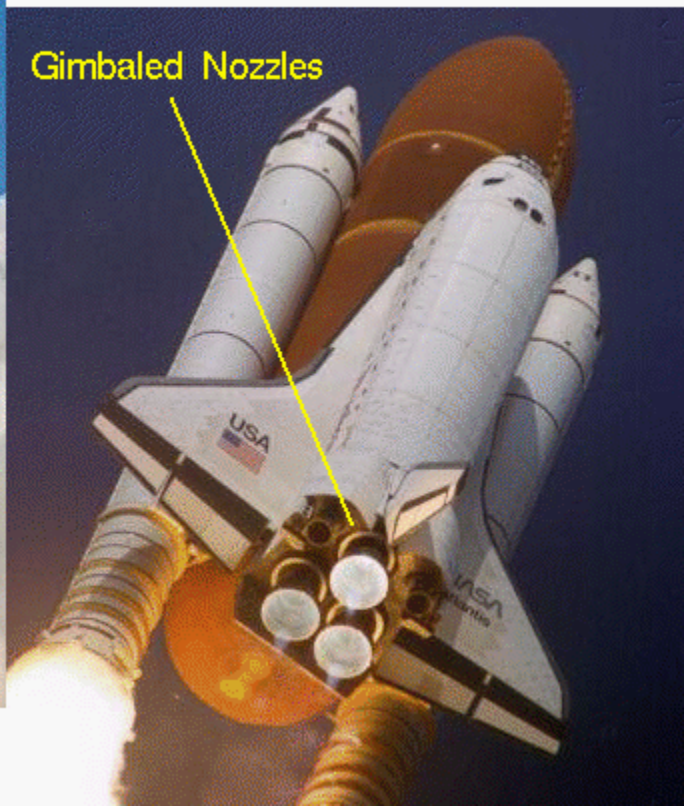
- Actuators – Hydraulic or Electrical
- Life Support – Contingency Support
- Active Thermal - Heating **and** Cooling
- Passive Thermal Protection and Control
- Telemetry – Bandwith/Encryption
- Power – Batteries/Solar/Fuel Cell
- Political and Other Considerations
- Etc…

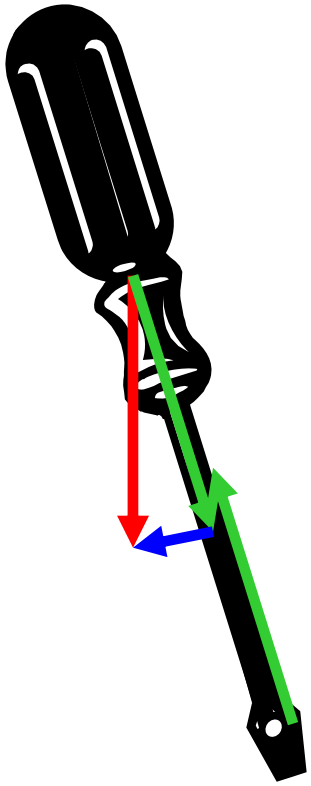
Guidance Systems

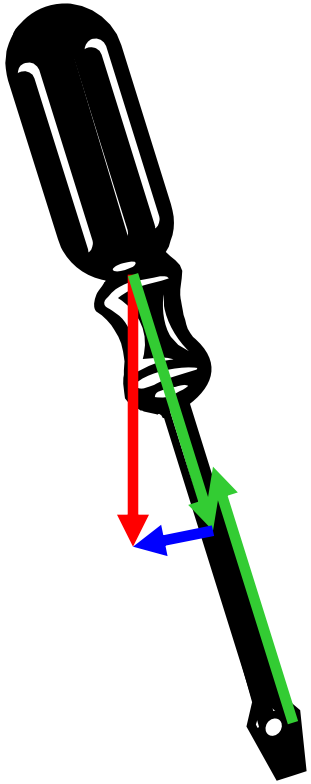


Atlas

Space Shuttle

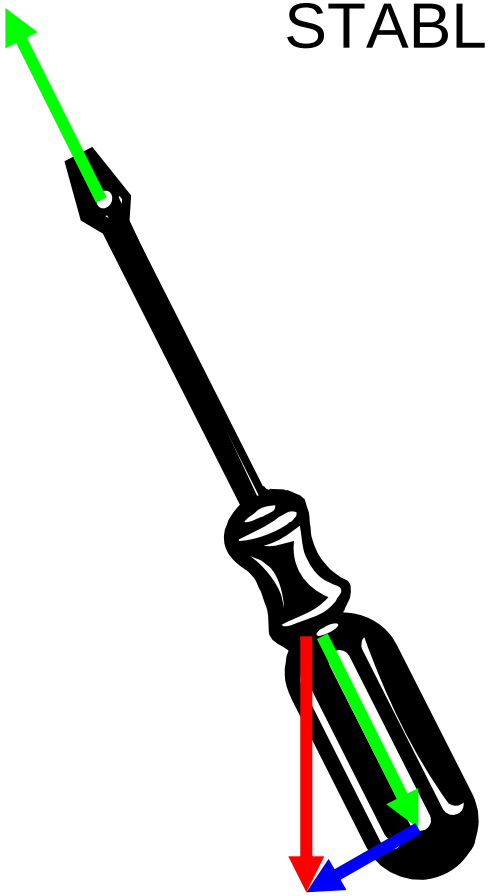




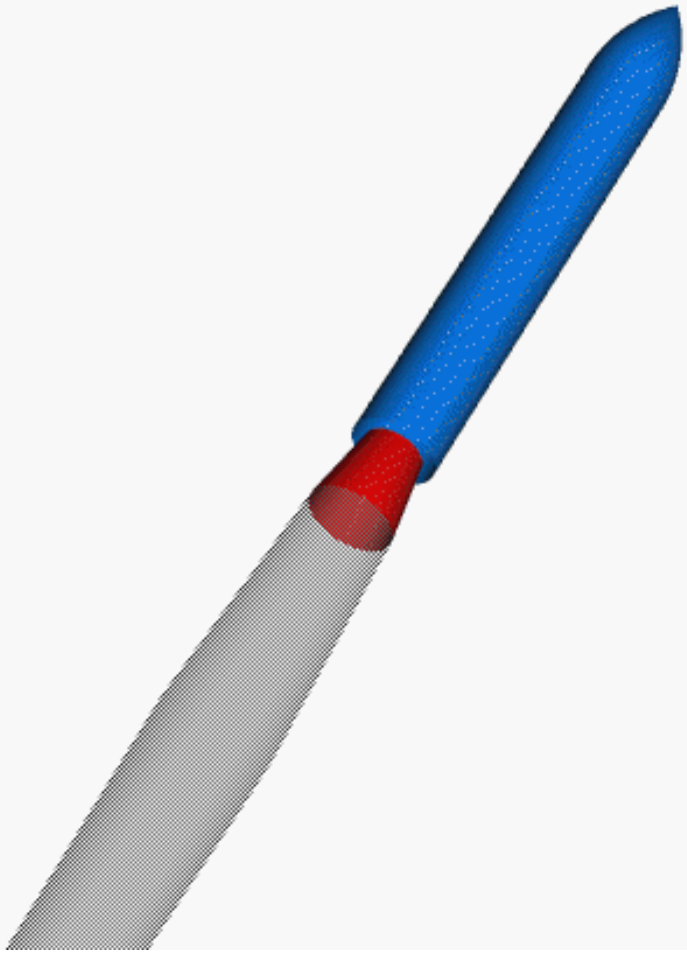


UNSTABLE

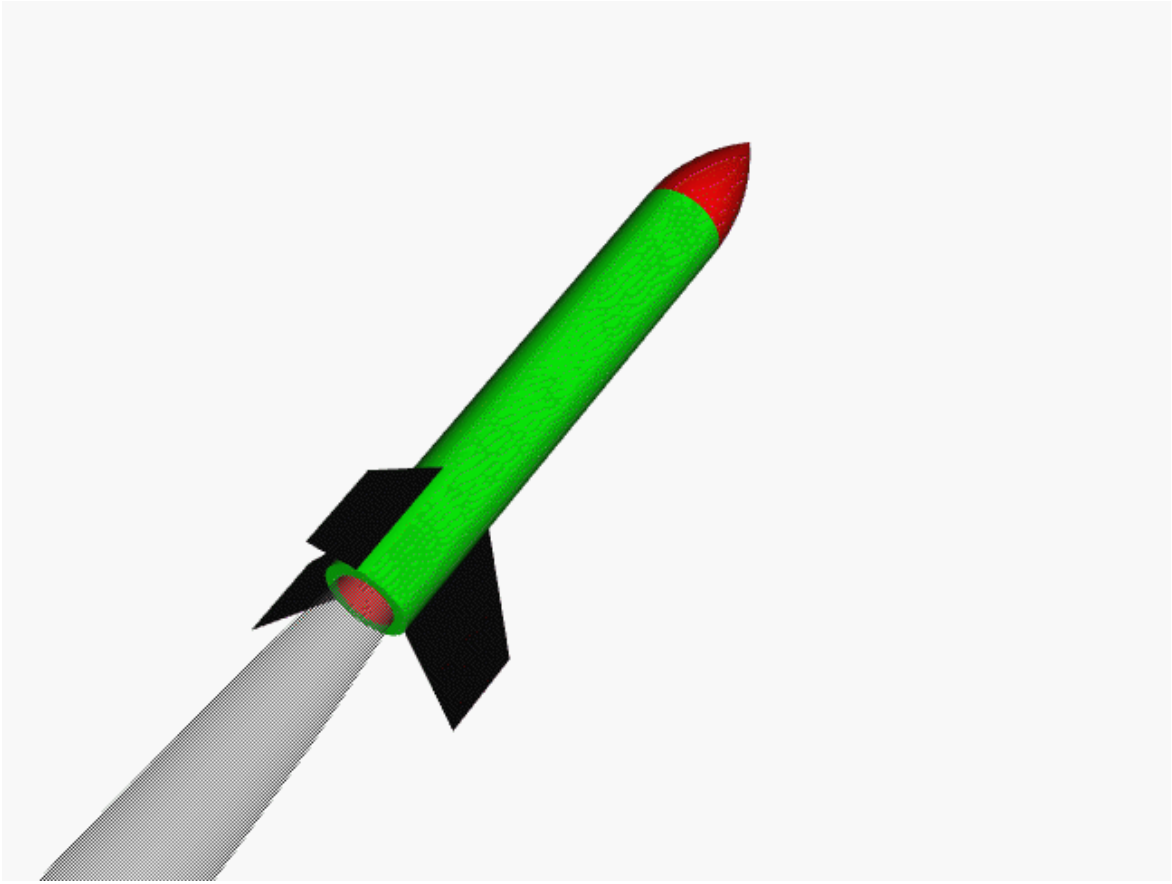
STABLE



Vectored Thrust

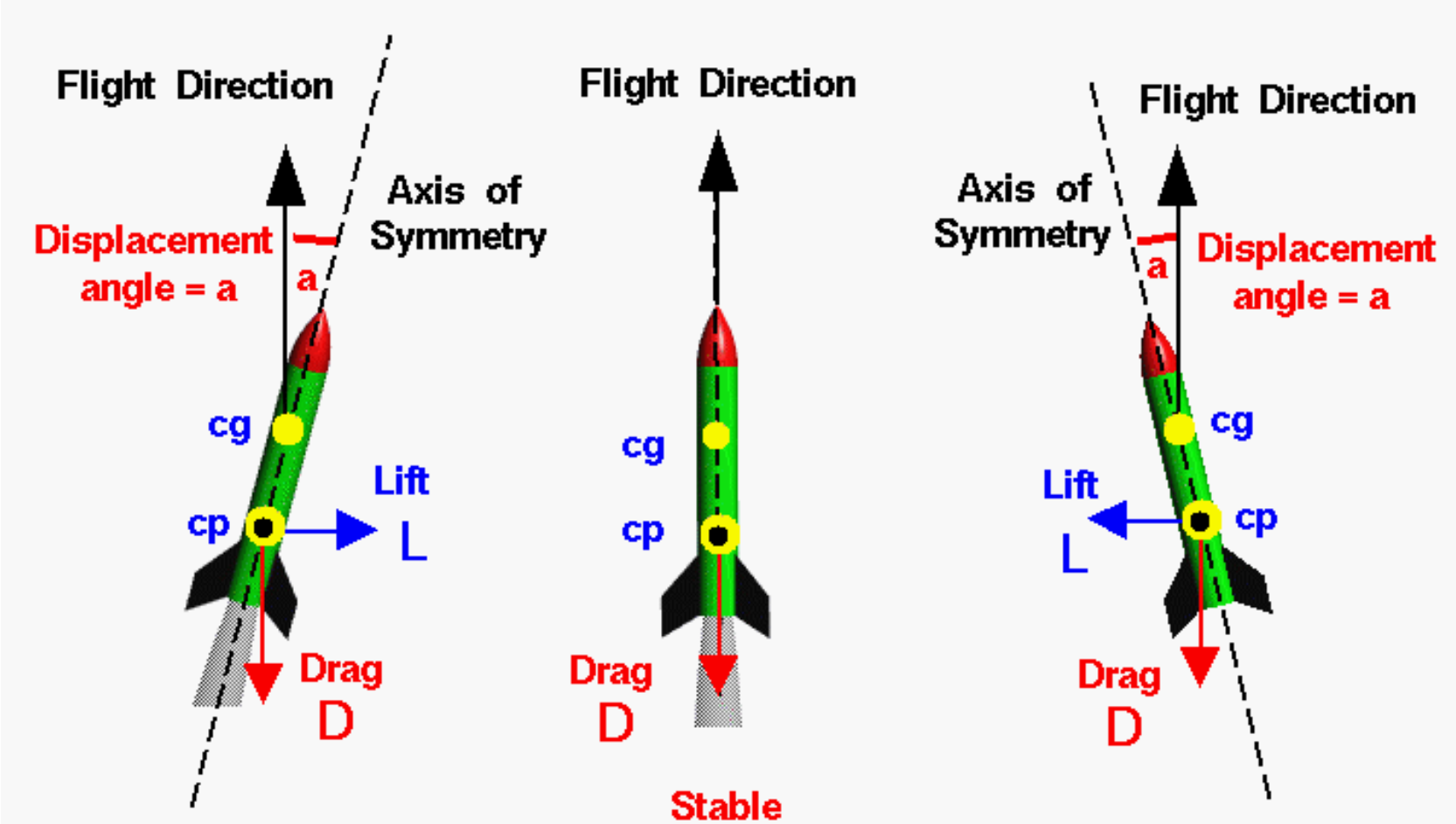


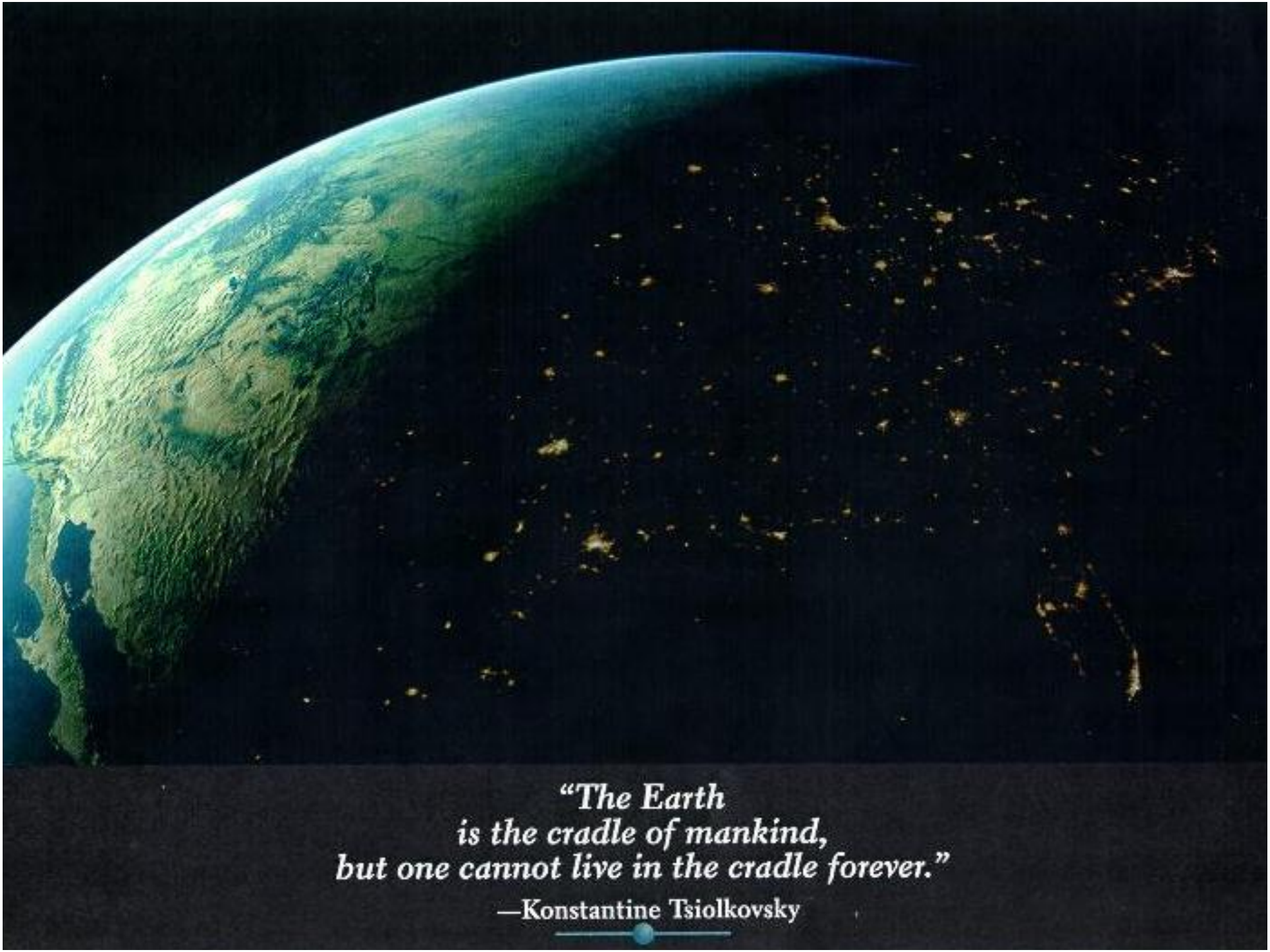
Spin Stabilization



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