Top Ten Reasons for Going Into Space

Reason Number 10
Colonization - in another twenty years it is estimated the population of the earth will reach over 8 billion. We could use a place to live.

Reason Number 9
Place a spy satellite over the Miss Hawaiian Tropics contest.

Reason Number 8
International Diplomacy - we went to the moon to beat the Russians, now we're building the International Space Station as a way to work with the Russians. Go figure. In any event, prestige and international relations are among the most powerful reasons we've had for going into space.

Reason Number 7
Natural Resources - some day we may be able to mine the Moon for green cheese and the asteroids for minerals and ores.

Reason Number 6
Researching the universe - orbiting observatories like Hubble Space Telescope, Advanced X-Ray Astrophysics Facility (AXAF), and Cosmic Background Explorer (COBE) to study the stars, galaxies, and the structure of the universe.

Reason Number 5
Technology Spin-Offs from NASA-developed technology like small solid-state lasers which led to Compact Discs, cordless power tools, solar power cells, laptop computers AND TANG.

Reason Number 4
Researching the sun, moon, and planets - deep-space planetary probes and manned exploration to study the atmosphere, composition, and physics of other bodies in the solar system.

Reason Number 3
Get Marvin the Martian’s autograph

Reason Number 2
Many applications that can be accomplished only from orbit, for example - telephone & TV communications around the world, weather observation and prediction (notably hurricanes), land surveys, and navigation (notably the Global Positioning System, GPS).

Reason Number 1
BECAUSE IT’S THERE.

Model Rocket Safety Code

- **Materials.** I will use only lightweight, non-metal parts for the nose, body, and fins of my rocket.

- **Motors.** I will use only certified, commercially-made model rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

- **Ignition System.** I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

- **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

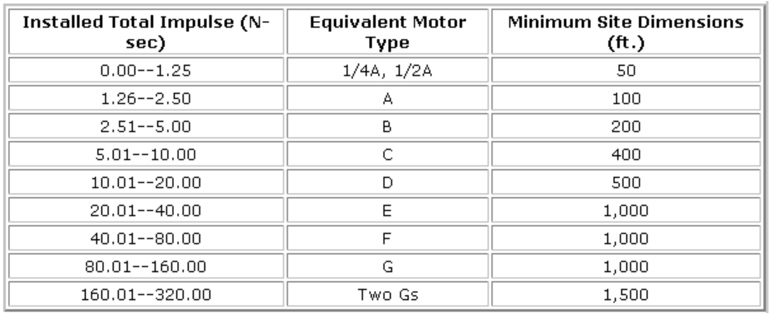
- **Launch Safety.** I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller, and 30 feet when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

- **Launcher.** I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of the rod when it is not in use.

- **Size.** My model rocket will not weigh more than 1,500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 pound-seconds) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than four ounces (113 grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

- **Flight Safety.** I will not launch my rocket at targets, into clouds, or near airplanes, and will not put any flammable or explosive payload in my rocket.

- **Launch Site.** I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.



Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Site Dimensions (ft.)
0.00--1.25	1/4A, 1/2A	50
1.26--2.50	A	100
2.51--5.00	B	200
5.01--10.00	C	400
10.01--20.00	D	500
20.01--40.00	E	1,000
40.01--80.00	F	1,000
80.01--160.00	G	1,000
160.01--320.00	Two Gs	1,500

- **Recovery System.** I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

- **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.

Newton's Laws of Motion

Newton's First Law

An object at rest will remain at rest

An object in motion will stay in motion - in a straight line, at the same speed

As long as no force is applied (more accurately, no unbalanced force).

Newton's Second Law

An object’s acceleration is proportional to the force applied to it.

The force to accelerate an object is proportional to the object’s mass.

In equation form, if we call the force "F", the object’s mass "m" and the acceleration "a", then Newton's Second Law is simply

F = m * a which is the most famous form of this fundamental principle of physics.

Newton's Third Law

"For every action, there is an equal and opposite reaction."

Rocket Propulsion

Propellant:

A rocket carries both the fuel and the oxygen to burn it. This is how a rocket, unlike any other engine, can operate in the vacuum of space. It is also why rocketry is the technology of space travel.

Oxidizer:

This is the oxygen or an oxygen equivalent that is used to burn the fuel. In reality, most rocket motors use some other substance to serve the function of oxygen in burning. One example - the black powder motors in model rockets use saltpeter (potassium nitrate) as the oxidizer to burn charcoal. Both of these are found in the black powder propellant, so you could fly your model rocket in space, if you really wanted to. The fuel will burn in a vacuum.

Thrust:

Thrust is the force, or "push" the rocket develops, measured in newtons or pounds (or tons for very big rockets).

Nozzle:

Nozzle increases the thrust of the rocket by increasing the speed of the exhaust.

Impulse:

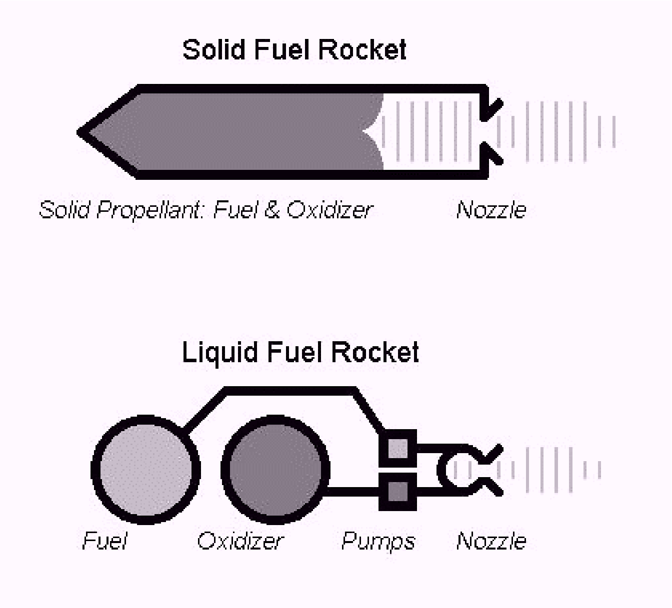
Impulse is the thrust multiplied by the burn time. This figure tells the "total push" the motor gives the rocket. For motors using the same propellant (e.g. black powder), a motor with twice the impulse will usually have twice the propellant, so it can burn twice as long for twice the total push.

Solid Fuel Rocket:

Solid Fuel Rocket:s use a solid mixture of fuel and oxidizer for a propellant. Since it has no moving parts, it is very reliable. However, once a solid rocket is ignited it cannot be shut down until all the propellant has been burned.

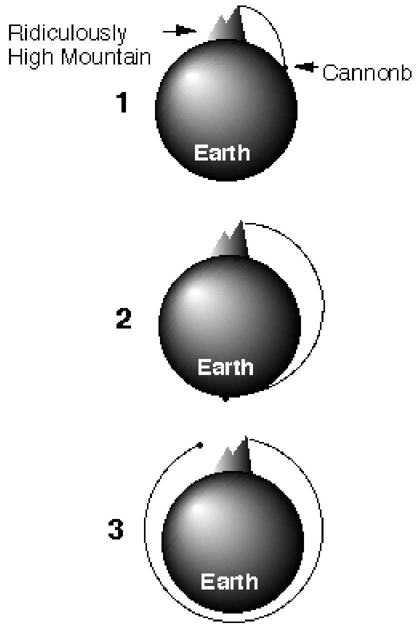
Liquid Fuel Rocket:

Liquid Fuel Rocket:s usesseparate liquid fuel and oxidizer, which are combined only at the moment of combustion. Pumps are required to get the fuel & oxidizer to the motor quickly enough to develop desired thrust. This makes liquid fuel rockets more complicated, however liquid fuel is up to twice as powerful as solid. Also, liquid fuel rockets can be turned off and then turned on again. On the space shuttle, they can be throttled for more or less thrust. So liquid fuel rockets are not only more powerful, they are more controllable.



How Orbits Work

What an Orbit Really Is...



The drawings at the right simplify the physics of orbiting Earth. We see Earth with a huge, tall mountain rising from it. The mountain, as Isaac Newton first envisioned, has a cannon at the top. When the cannon is fired, the cannonball follows its ballistic arc, falling as a result of Earth's gravity, and it hits Earth some distance away from the mountain. If we put more gunpowder in the cannon, the next time it's fired, the cannonball goes halfway around the planet before it hits the ground. With still more gunpowder, the cannonball goes so far that it never touches down at all. It falls completely around Earth. It has achieved orbit.

If you were riding along with the cannonball, you would feel as if you were falling. The condition is called free fall. You'd find yourself falling at the same rate as the cannonball, which would appear to be floating there (falling) beside you. You'd never hit the ground. Notice that the cannonball has not escaped Earth's gravity, which is very much present -- it is causing the mass to fall. It just happens to be balanced out by the speed provided by the cannon.

Getting Into Orbit

The cannonball provides us with a pretty good analogy. It makes it clear that to get a spacecraft into orbit you need to

- Raise It Up (the mountain) to a high enough altitude so that Earth's atmosphere isn't going to slow it down too much. In practical terms you don't generally want to be less than about 100 miles above the surface of the Earth. At that altitude, the atmosphere is so thin that it doesn't present much frictional drag to slow you down.

- Accelerate It until it is going so fast that as it falls, it just falls completely around the planet.

The required speed for a particular altitude A can be found from the formula:

$$v = \frac{1{,}113{,}263}{\sqrt{3{,}963 + A}}$$

where A is in miles and v comes out in miles per hour.

So for example the shuttle, orbiting at 200 miles up travels at

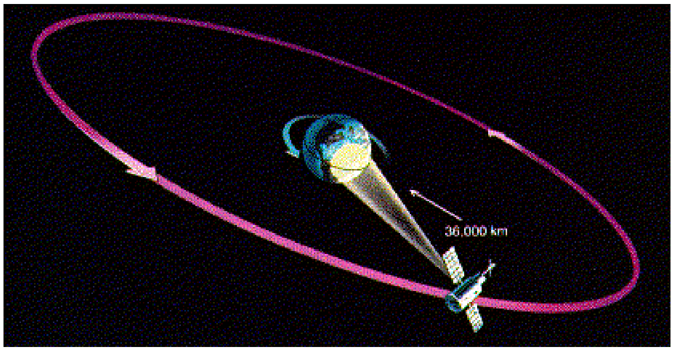
$$v = \frac{1{,}113{,}263}{\sqrt{3{,}963 + 200}} = 17{,}254 \text{ mph}$$

At that speed, it takes about 90 minutes to complete one orbit (an hour and a half to go all the way around the Earth!).

If we place a satellite ***way*** up - at an altitude of 22,284 miles, then to stay in orbit, the satellite should travel at

$$v = \frac{1{,}113{,}263}{\sqrt{3{,}963 + 22{,}284}} = 6{,}872 \text{ mph}$$

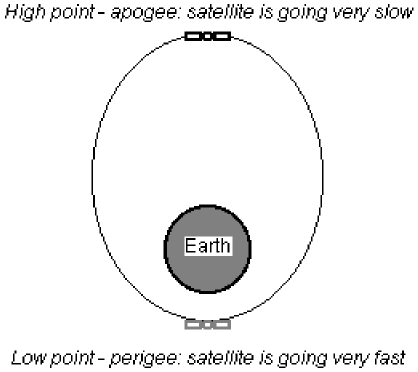
At that speed, you can show that it takes 24 hours to orbit the Earth. But since the Earth is rotating once every 24 hours, the satellite is going around the Earth at the same exact rate that the Earth is turning. The satellite stays above the same point on the Earth, or looking at it from the Earth's surface, the satellite stays in the same place in the sky. This is called a "geostationary" orbit, since the satellite seems to be stationary - it looks like it doesn't move! This is great if you have to point your satellite dish to pick up a signal from this satellite. Point it once and you're done.



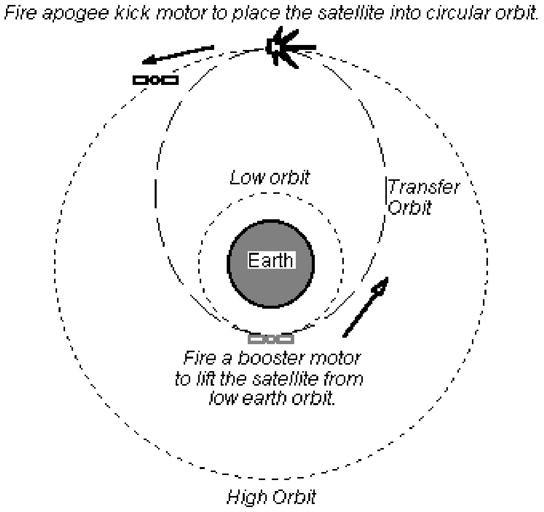
Apogee Kick

How does a satellite get from low earth orbit (where the shuttle lets go of it) to geosynchronous orbit?

- **Elliptical Orbits**: most orbits are not perfectly circular. All orbits are ellipses (flattened circles) with a high point (apogee) and a low point (perigee).
  - At apogee, when the satellite is farthest from the earth, it is going the slowest - it's ready to fall back toward the earth.
  - As the satellite falls it gains speed, and "overshoots" the earth, swinging quickly through perigee, then gaining altitude back toward apogee.
  - The satellite doesn't stay in orbit at the apogee distance because it isn't going fast enough when it reaches that point. It doesn't stay in orbit at the perigee distance because it's picked up so much speed by that point that it starts climbing again.
  -

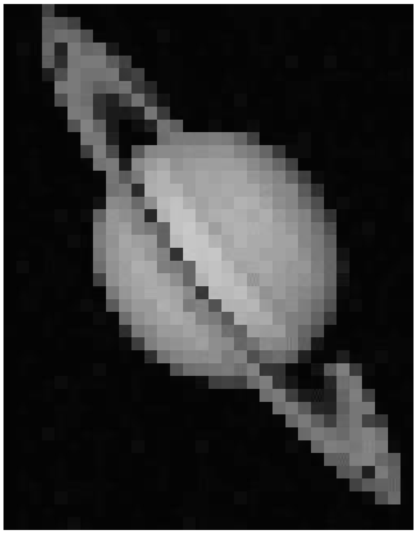


- **Transfer Orbit**:
  - If we speed the satellite up while it's in low circular earth orbit it will go into elliptical orbit, heading up to apogee.
  - If we do nothing else, it will stay in this elliptical orbit, going from apogee to perigee and back again.
  - BUT, if we fire a rocket motor when the satellite's at apogee, and speed it up to the required circular orbit speed, it will stay at that altitude in circular orbit. Firing a rocket motor at apogee is called "apogee kick", and the motor is called the "apogee kick motor".



Satellite Pictures

The satellite sees this picture, and divides it up into little squares...



...sort of like this (but this is exaggerated). For each square it assigns a number which corresponds to the brightness of each square in the image.

The satellite sends all the numbers by radio to scientists back on Earth.

The scientists use the numbers sent back by the satellite to determine the brightness of each square in the picture and put the picture together.

Spacecraft Systems

This section covers the basic systems required to build any spacecraft and will help you with two requirements: **requirement 5c**, design of a planetary probe, and **requirement 7**, design of a space station. On this web page you will find

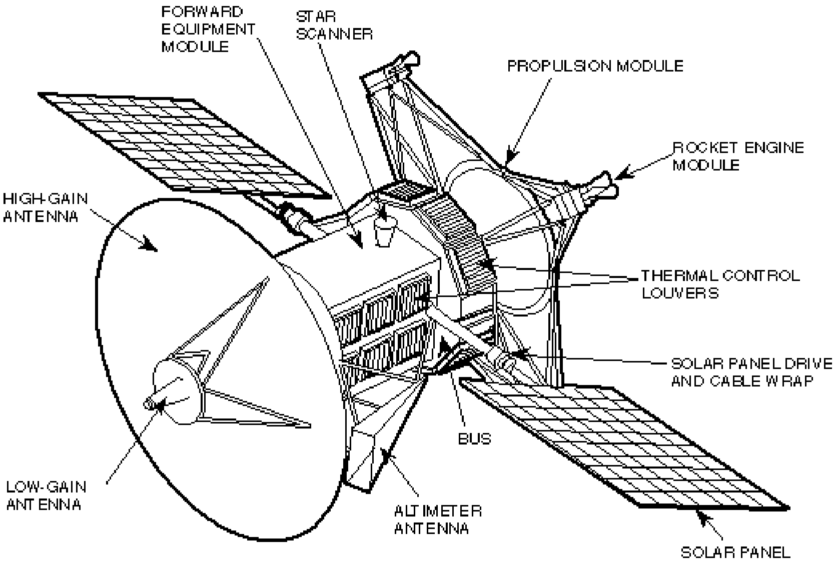
- a bunch of ideas for things to include and show on your design,
- how to get ideas from pictures of other spacecraft.

If you look at a picture or model of a spacecraft you can usually see how it works and what makes it go. Here's what to look for:

Summary of Spacecraft Systems

- Power Supply
- Communications
- Propulsion / Attitude Control
- Temperature Control
- Navigation/Guidance
- Science Instruments

Magellan Spacecraft Venus Orbiter Example



Spacecraft Systems

Power Systems

- Batteries: what they had on Sputnik, but they run down after a while. Rechargeable batteries are used as a backup for solar cells, for when the spacecraft passes through a planet's shadow or during maneuvers, when the panels aren't pointed toward the sun.
- Solar Cells: like on your calculator. These are the method of choice for most satellites and probes, because space is real sunny and they last forever. They look like big wings on the satellite, and can put out a few thousand watts. Not so

good for deep-space probes like those that go to Jupiter, which get too far from the sun to be any good.

- Fuel Cells: burn hydrogen & oxygen to produce electricity. Good for manned vehicles like Apollo or the Space Shuttle, where you have to carry a bunch of oxygen anyway. Not as good for unmanned probes, since like batteries they will run out .
- Radioisotope Thermoelectric Generators (RTG's): fancy name for itty-bitty nuclear reactors. Used on unmanned deep-space probes (which get far from the sun), since they don't need the sun to operate and the nuclear fuel lasts a long long time.

Picture of Pioneer Jupiter probe. Note the RTG's at the end of the boom arms and the large dish antenna for beaming a signal from Jupiter, 500 million miles away.

Communications

If a satellite or probe can't communicate back its findings then we might as well have launched a rock. The antennas are easy to spot:

- A large dish (the high-gain antenna) gives a stronger radio signal in one direction like cupping your hands around your mouth when you holler.
- A short aerial sticking out someplace (the low-gain antenna), which sends the signal in all directions. The signal is not as strong, but this antenna always works, even when it isn't pointed at the Earth.

Propulsion / Attitude Control

- This is the rocket system the spacecraft uses to move itself. You can often spot the nozzles, although sometimes (like on the shuttle) they may just be holes in the side of the fuselage.
- Propulsion: refers to rocket motors used to change the orbit or trajectory of the craft. Usually can be spotted as large nozzles that look like they could move the whole spacecraft.
- Attitude Control: a system of thrusters that controls which way the craft is pointing. Usually these are smaller nozzles or clusters of nozzles pointed in many different directions. Sometimes "reaction wheels" are used: heavy wheels that are turned with a motor. When the wheel is spun in one direction, the spacecraft, having nothing to hold on to, turns the other way.

Temperature Control

- Passive Cooling: as temperatures on the sun side of a spacecraft can reach 250 F and up, several methods will be used to help cool the spacecraft:
    - rolling it, so the hot side is turned away from the sun to cool off,
    - painting it with a heat reflector - white or gold - or covering it with a blanket or shade
    - louvers to control the amount of heat that gets radiated from inside the spacecraft.
- Active Heating: electric heaters or sometimes nuclear-powered heaters are used, especially for deep-space probes like Voyager and Pioneer.

This image of Mariner 10 to Mercury shows the little white parasol over the electronics to shade them from the Sun, 6 times as intense at Mercury as at Earth. The long boom arms hold the magnetometers.

Navigation & Guidance

- Star trackers and sun sensors are used by the spacecraft to see where it's pointing.
- Once the spacecraft has one point of reference, it only needs one more (sideways to the first point of reference) to know exactly which way it is facing. That's why both a star tracker AND a sun sensor are used.

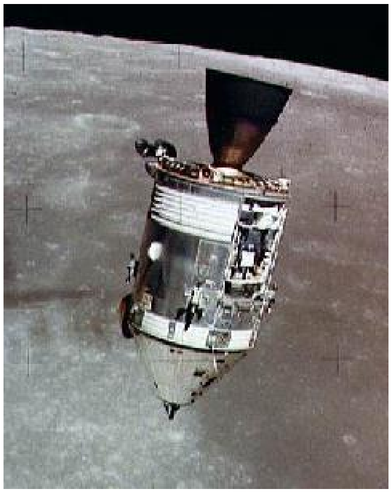
Science Instruments

Obviously the science instruments on board the spacecraft depend on its science mission.

- Direct sensing instruments: measure the spacecraft's own environment - particle detectors (for ions and electrons), dust detectors, magnetometers (measure the planet's magnetic fields) are typical.
- Remote sensing instruments: imaging instruments to take pictures of the planets, radio astronomy instruments look at radio waves coming from planets & stars, photometers and spectrometers analyze light to determine chemical make-up of atmospheres.
- Active sensing instruments: radar imagers (synthetic aperture radar or SAR) image the surface of heavily clouded planets such as Venus. Radar altimeters measure the height of the terrain allowing us to map Mars and Venus.

Manned Spacecraft Systems

For manned spaceflight like Gemini, Apollo and the Space Shuttle, additional systems will be found on the spacecraft - to keep the astronauts alive and to bring them home in one piece.



Life Support

What are all the jobs that need to be done for life support? These tasks will be particularly important for your Space Station design.

- Astronauts Have to Breathe: atmosphere control includes a supply of oxygen and removing carbon dioxide, both equally important (remember Apollo 13?). Also the pressure has to be maintained: if the hatch is opened, either everyone better be wearing a suit or there needs to be an airlock.

- Temperature and humidity control: people won't survive the temperatures that electronics and mechanics will. With astronauts aboard, the temperature must be controlled much more tightly. The Shuttle and the Space Station have water cooling and radiators for controlling temperature.
- Food and Water: food is usually carried along, water supplied by the fuel cells, reacting hydrogen and oxygen and producing water in the process. On an extended mission like the Mars expedition, water will need to be recycled and the food grown along the way in a greenhouse.

- Waste management: a dirty job but somebody has to do it - elimination or recycling of solid, liquid and gaseous waste.
- Radiation Protection: without an atmosphere the astronauts are exposed to cosmic and solar radiation, particularly solar flares. Some shielding to reduce the effects is needed.

Re-entry and Spacecraft Recovery

Consists of two parts, mainly -

- Heat shielding - to protect the astronauts and the vehicle from the extreme heat of re-entry into the atmosphere.
- Recovery system - parachutes, like on your model rocket, or in the case of the Shuttle an aerodynamic body that allows for a soft landing.