Introduction to Engineering Design II

Goals

- See an example of complex system design, using satellites

What are Satellites?

- Satellites are man-made objects in space that we use for many different things!
- Television, internet, phones
- Astronomy, research
- Earth observing

What are the physics behind satellites?

- Is there gravity in space?
- Do satellites have rockets on them?
- How do satellites stay in orbit

Key Equations

- Force of gravity:

$$F_g = \frac{Gm_1m_2}{r^2}$$

- Centripetal Force

$$F_c = \frac{mv^2}{r}$$

What is orbit?

- Orbit is when a satellite circles the Earth
- Satellites "stay" in orbit due to gravity
- Gravity acts as a centripetal force

- Let's derive how orbits work!

Derive

$$F_g = F_c$$

$$\frac{Gm_1m_2}{r^2} = \frac{mv^2}{r}$$

$$\frac{Gm_Em_S}{r^2} = \frac{m_Sv^2}{r}$$

$$\frac{Gm_E}{r} = v^2$$

How fast do satellites need to go to stay in orbit?

$$\frac{Gm_E}{r} = v^2$$

$G = 6.67408 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$

$M_E = 5.972 \times 10\text{^}24$ kg

$r = r_E + r_O$ = 6,371 km + 429 km = 6,800 km

What is v?

How fast do our satellites need to go?

- At a height of 429 km above the Earth, our satellites need to go ~27,550 km/hr!
- What happens to that speed if we increase the mass of the satellite?
- What happens to that speed if we increase the height of the orbit? What about decrease?

1. Problem Statement: Designing a satellite

I want to create a system that can take pictures of Kazakhstan from space

2. Define System Objectives

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Take a picture of all of Kazakhstan from space everyday for a year and send them back to Earth so we can look at them!

3. Define System Requirements

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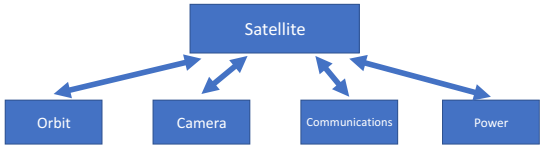
1. The system shall orbit the Earth at a height of at least 500km
2. The system shall take pictures of Kazakhstan at least once a day
3. The system shall remain in space for at least one year
4. The system shall be able to send its pictures back to Earth every day

4. Define Subsystem Objectives

Satellite

4. Define Subsystem Objectives



5. Define Subsystem Requirements

1 Orbit **2 Camera** **3 Communications** **4 Power**

5. Define Subsystem Requirements

1 Orbit

1. 500 km orbit
2. orbit lasts for 1 year
3. orbit goes over Kazakhstan every day

2 Camera

1. Picture everyday
2. Camera lasts 1 year
3. Camera can see all of Kazakhstan
4. Camera can turn towards Kazakhstan

3 Communications

1. Send picture back to Earth every day

4 Power

1. Satellite can power itself
2. Power on communications and Camera

6. Repeat and Refine