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Summaries of Rick Fleeter’s Book: “The Logic of Microspace”

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Chapter 2 - Propulsion, Or How to Get There?

When sending something up into space two things that propulsion engineers focus on is overall payload weight, and the specific impulse (ISP) of the rocket. Because 99% of a rocket is usually fuel, only one percent on board actually is placed in orbit, and it typically costs between $1000 and $100,000 per Kg to launch something. Therefore space on board must be filled wisely. The specific impulse of a rocket is comparable to the “miles-per-gallon” efficiency of an automobile. This number tells rocket engineers how much propulsive force can come from the amount of propellant; the higher the number the better. With propellants, there are five categories, but really boil down to two important ones. The five categories are: inert gases, liquids, solids, electric, and hybrids. Liquids and solids, or combinations of the two are typically found in most rockets though. There has been a long ongoing debate among engineers about whether liquid or solid propellant is the best. Rockets requiring solid propellants have high ISP numbers, don’t need valves and pumps, don’t leak, and can be stored for decades before use. However liquids have higher ISP numbers and are in general smaller and lighter weight than most solid rockets. The debate still continues over which system is better, yet the in the foreseeable future there are propellants being produced with ISP numbers 10 or 100 times greater than those used in liquid and solid systems.

Chapters 3 – 5 Orbit mechanics

In Chapters 3-5, we learned about the different types of orbit patterns (LEO, GEO, and GTO) and how to get to and from different orbital heights. The different orbital heights determine how long a satellite can stay in such an orbit. A satellite 100 miles away from the surface of the earth usually stays up for about 2 weeks, whereas the shuttle is able to stay up for months while it is only 175 miles away from the earth’s surface. GEO (geosynchronous orbit) is usually used by TV, radio, telephone, and telemetry satellites, whereas LEO (low-earth orbit) is used by more “temporary” satellites. In order to get from these different orbits, a common maneuver used is called the Hohmann Transfer Orbit. This is where a rocket engine/motor is burned to either speed up or slow down the satellite. By speeding up, the apogee is increased, thus changing a circular orbit into an ellipse. When the desired orbital radius is achieved, the rockets are fired again in the opposite direction to establish a fixed orbital velocity and a fixed orbital radius.

Chapter 6:

This chapter mainly talks about some properties of magnets and their usage in a satellite. In the case of magnetism, particularly aboard satellites, there are really two uses: figuring out something about your position and/or attitude being more familiar one, and doing something about the attitude being the other one. The earth is not a perfect sphere so there is a kind of change in the gravitational force of the earth in different places; there is a change in the values of gravitation every year too. The main advantage of a flux gate magnetometer over a scout’s compass is that it gives the direction field in 3 dimensions.
The magnetometer is also calibrated to know how long it will take to flip the magnetization back and forth. A magnetometer normally uses 3 flux gates. The other basic use of magnets is to find the direction. This torque forces the magnetic needle to point north in a magnetic compass. To control this torque there are many ways and one of the main ways of doing this is by using ‘torque coils’. A coil with a slug of iron in it produces more magnet moment for a given amount of electric current than one without the slug. These iron core coils are standard for bigger LEO satellites, and are also found on small ones if space constraint doesn’t allow packaging the larger air core coils.

Chapter 7

This chapter explains the basics of radio, how to create radio frequencies and which frequencies are useful in certain areas. The most basic radio frequencies are created by having a wire move across a magnetic field to create an electric field. If we fluctuate the magnetic field or the current that causes the field to flow or move through the air at a frequency determined by the number of time you fluctuate the field. It then explains about low frequencies are used for underwater transmissions because they move well through water and that higher frequencies can be used for television and FM or AM radio transmissions. It then explains the ideas behind the piezoelectric crystal and how they create a frequency.

Chapter 8

This chapter expands on the ideas of chapter 7. It just delves into the frequency bands and the uses that they have. For instance satellites operate at about 500 MHz to about 15 GHz for high data rate transfers. Average wavelength and can be derived by dividing speed of electromagnetic waves by their frequencies, wavelength’s symbol is the greek letter lambda.

Chapter 9

This chapter explains the specific uses of radio's as they pertain to satellites themselves. The link is created by a transmitter and a receiver. And that the density of the radio waves diminish as it travels over 2000 km so that it you must have an excellent receiver to interpretate such a weak signal. And Phase Changing is an easy way for a receiver to be locked onto a frequency and to ignore all other electromagnetic waves.

Chapter 11:

This chapter mainly talks about controlling the attitude of a satellite. Gravity gradient uses the fact that the earth’s gravity gets weaker as your distance from the earth increases. Thus, a satellite with a weight stuck out on the end of a long boom sort of hangs on the end of the boom, like little iron filings all lining up in a magnetic field. The satellite doesn’t care if it is down and the weight is up, so a method to flip it over is needed. Gravity gradient satellites are popular because the stabilization is passive. No propulsion
or gyroscopic systems are needed to maintain the vertical orientation. Permanent magnet stabilized satellites have no stability around the field line and tend to roll about it, which precludes pointing at the earth. The most common way to deal with rotation is to design a three-axis stabilization system that uses reaction wheels. A small rotation forward is countered by the spinning an internal wheel in the same direction as the sensed upset rotation. The equal and opposite reaction of the rest of the body causes the satellite to slow its forward rotation proportionately to the amount the wheel spin speed is increased. When the spinning of the wheel becomes too large by the speed of the satellite rocket boosters are fired in the opposite direction to reduce the speed of the satellite and in turn reducing the spin of the wheel. A spinning body, suffering small torque impulses responds only by having its spin pointing, change by a small, fixed angle. The more angular momentum possessed by the body, the smaller its disturbance angle. One of the potential disadvantages of magnetic torquing is that the correct torque is not always available.

Chapter 12- Memory System’s of Spacecrafts

Memory systems are required on-board a spacecraft because there can be certain times when there is no power on-board, and data needs to be retained. If a satellite was in communication with the ground 100% of the time, then memory might not be necessary, but there are times each day that while a satellite is orbiting the earth it loses contact with the ground. Three major types of memory systems are: dynamic random access memory(DRAM); flash electrically programmable read only memory(flash EPROM); and static random access memory(SRAM). DRAM memory systems have the lowest cost per bit, and have a high density for storing information. The advantage of an EPROM system is that if electrical power is lost, the data can still be recovered because it is permanently stored, however it is very expensive. SRAM offers high data transfer rates and low power consumption. Two final areas of importance to mention are the effects of radiation on a memory system, and error detection. Memory systems must be properly shielded from high levels of radiation because over time the components inside will fail, leading to errors. Parity bits are used to detect errors and report where they are, however, they do not correct these errors. Multiple parity bits are found in systems to reduce the probability of an error not being detected.

Chapter 13 – The nuts and bolts of small satellites

As far as the hardware of the actual spacecraft is concerned, prices are always to be paid with respect to moving parts and materials. A certain component could cause an additional torque, cold welding, or even vaporization. When choosing materials, all thermodynamic properties – with respect to the sun and respect to its reaction to other materials – of each material must be taken into consideration. When considering design possibilities, the continual process of redesign can lead to a new, untested product which has not gone through all the testing that the original design had. So the book advises that, in general, designers would do better to consider ideas that worked for another mission; ideas that work well on earth, as well as in space; or ideas that are built from scratch and will hopefully beat the odds.
Deployment of an object all becomes a concern when designing a satellite. This is a particular interest to our semester’s emphasis on tethers. Deployment aids include pyrotechnic bolts, hot wax actuators, melting wires, and sublimations. Actual deployment mechanisms include hinges, carpenter tape, stacers, and Astomasts. All these work in the hope that the mechanisms affects on the satellites motion will be minimal.

Chapter 14- Batteries

Because most satellites use solar panels, there is a portion of each day that the satellite is out of direct sunlight, and is not able to receive power from this natural source. Batteries come to the rescue, and are able to support the satellite’s system in these periods of darkness. For example, most LEO satellites are eclipsed from the sun 40% of the time they are in orbit. There are however two main sources of generating power on board a satellite. As mentioned before, solar panels (photovoltaic arrays) are very common in converting the photons from the sun to electrical power. Batteries are the other source of power. Nickel cadmium (NiCad), nickel hydrogen (NiH2), and nickel metal hydride(NiMH) are the three most popular. Most satellites have a power requirement of going through 20,000 charge and discharge cycles. There is no over-the-counter NiCad battery that can meet that requirement, so special ones are fabricated, costing a couple thousand dollars apiece. Overall weight is another important factor to keep in mind when choosing a battery because launch costs are expensive.

Chapter 15

The ideas of clean rooms are explained in this chapter. A clean room is a necessity so that the satellite that you make is not affected by outside variables. You must protect the instruments for dust and dirt so that they do not malfunction, optical parts can be particularly effected by dust and dirt. Another big factor is Electro Static Discharge (ESD) this can fry panels and harm electronics. It is hard to contain because the only way to clean the satellite off is to rub it with a rag of blow off dust with air, both of which create ESD. So you must be careful when it comes to making you satellite.

Chapter 16:

This chapter mainly talks about the preferences that should be made when searching for a launch site for the rocket. It mainly says that a launch site closer to the equator is better for GEO satellite as this gives the rocket a 5% boost as the speed of the earth is high near the equator than at the poles as the radius of the earth is more at the equator than at the poles. The main preferences that should be looked into when making a choice for launch sites are,

\[ \text{On or near the equator} \]
Water or fully uninhabited desert ass around in an arc from west of due north all the way clockwise to the west of due south.

No large population center within 50 miles.

Politically stable and friendly – fitted out with infrastructure including daily jet service.

Good weather most of the time.

No major ecological, religious, commercial or territorial conflicts at the site or for hundreds of miles around the above mentioned arc.

Non-equatorial launch sites can be used for launching the LEO satellites.

Tether Applications:

A tether application for taking a satellite out of orbit, or out of a huge trajectory, is called aero braking which is similar to the Hohmann maneuver. The tethered version of aero braking involves a deployed tether with an airfoil attached to it. As the satellite approaches a planet the airfoil is dipped into the upper atmosphere of the planet and creates a drag force which slows the satellite down. In turn, the satellite is swung around the planet and into a large, elliptical orbit. As the satellite continues around this elliptical orbit, the tether sweeping through the atmosphere significantly reduces the orbital speed. This process is half of the Hohmann maneuver. Then, when the desired orbital radius is achieved, the tether could be released, thus putting the satellite into a stable orbit about the planet.

Power Generation From Tethers

Electrodynamic tethers may provide an economical means of electrical power in orbit. Essentially, the tether can be used to convert some of the spacecraft's orbital energy into electrical power. However, since converting the orbital energy into electrical power will lower the orbit of the spacecraft (there's no such thing as a free lunch), this technique is probably only useful for providing brief, high-power energy bursts to brief experiments. It can also generate electrical power for a satellite orbiting a planet with a magnetic field, or raise or lower the satellite's orbit - if the satellite has an electrically conducting tether. NASA tested a Tethered Satellite System on the Space Shuttle in 1995 and 1996. Although it broke on the second mission, the tether produced some surprises in how electrical currents are produced and conducted by extended objects in space. Marshall Space Flight Center is now developing a Propulsive Small Expendable Deployer System - ProSEDS - that will speed a rocket stage's return to Earth. The motion of the wire through the magnetic field provides the energy, and the electrons in the plasma provide the return path that completes the electrical circuit. Electrodynamic tethers can provide long-term propellantless propulsion capability for orbital maneuvering and stationkeeping of small satellites in low-Earth-orbit. The µPET™ Propulsion System is a small, low-power electrodynamic tether system designed to provide long-duration boost, deboost, inclination change, and stationkeeping propulsion for small satellites. Because the system uses electrodynamic interactions with the Earth's magnetic field to propel the spacecraft,
it does not require consumption of propellant, and thus can provide long-duration operation and large total delta-V capability with low mass requirements. In addition, the tether system can also serve as a gravity-gradient attitude control element, reducing the ACS requirements of the spacecraft.

http://www.tethers.com

Tether Satellite to generate artificial Gravity for long interplanetary travel:
A spacecraft connected to another body using a tether and rotated gives the centripetal force that acts as gravity. When the interplanetary travel is made possible the tether system is going to play a big role as our limbs will go numb when we are subjected to no gravity for a very long time. It takes about 6 months to go to mars. When the two objects are connected using a long tether a length about 2km and rotated at about 1rpm we can get 1g of acceleration. As the length of the tether starts to reduce to maintain this acceleration the system has to be rotated faster. This is the most promising method of producing artificial gravity to be present in interplanetary travel. There are many problems concerning this application of tether system and we are just getting to look at these problems in our class. The main problem concerning this problem at this moment is the deployment and the retrieval system of the tether.

This is what we have done so far in the class and in the last class we have come up with dates as to what should be done on what dates. The schedule is
Nov 7\textsuperscript{th} – Telecom with JSC participants
Nov 14\textsuperscript{th} – Develop project goals for fall and spring
Nov 21\textsuperscript{st} – Trial run for presentation
Nov 28\textsuperscript{th} – Dress rehearsal (final run through)
Dec 5\textsuperscript{th} – Recap and plan for spring

Nov 29\textsuperscript{th} – Final presentation