SPACE ENGINEERING 3 SUMMARY

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1- Space environment

Three characteristic of SPACE: weightless, Intensive radiation, near vacuum.

2-Gravity field earth

The harmonic expansion model for satellite position in spherical position 3.8: R is the distance, Delta is Latitude, lambda is longitude. Pnm(x) is associated Legendre function, J and Lambda are scaling and orientation parameters which are representative for the shape of the model.

Physical interpretation of elements of the geo potential model are Zonal harmonics, Sectorial and tesseral harmonics, the below numbers ,n is degree and m is order.

J2,0 represents the flattening of the earth. J0,0 is the main term 1. J1,0 . and J1,1 will disappear if the gravity field origin coincides with the mass center of the earth.
J2,1 is a measure for the orientation of the principal moments of inertia of the earth.

LAGEOS height is 5900 km and ENVISAT 800 km.

Equation 3.11 and 3.12 for east west and north south acceleration and derivation page 20.

Page 21, a + deviation Delta Lambda will yield a negative direction of drift in some points and a positive drift in the other points. A positive value for aew causes a slowing down of the motion of the satellite w.r.t the earth. The + value for aew causes an increment of the total amount of energy of the spacecraft ,hence an increment of semi major axis a ,,➔ decrease of mean motion which is responsible of slowing down of the spacecraft.

3-Atmosphere

Equation 4.5 till 4.9 shows that pressure decreases more rapidly with altitude when the molecular mass M is large.
Proxy: a parameter which is representative of the magnitude of another parameter.

Equation 4.3 space drag parameters.
DRAG COEFFICIENT: mean free path is the distance that a particle travels before colliding with another particle. According to these collisions the particles change direction and velocity which the geometry of the impacts and type of particles affect the type of reflection.
Density: atmospheric density depends on solar activity and geometry. An increase of the solar activity may increase density with a factor of 10.

Velocity: Cartesian reference frame, possible errors in V are introduced by the motion of the atmosphere.
Cross sectional area: variations in it such as angle of attack or slip angle should be taken into account.
Equation 4.15: total amount of energy.

Effects of atmospheric drag on satellite mission components:
Semi-major axis: semi major axis is a direct measure for total amount of energy ,and atmospheric drag continuously exerts a decelerating force on satellite in low to intermediate orbits.(equation 4.15)
Eccentricity: since the satellite experiences most of atmospheric drag in perigee, it loses energy and it doesn't have enough power to reach the same apogee height,so the orbit shrinks to a circle and eccentricity tends to zero.
Life time: equaton 4.20, H is the density scale height and Delta a 2pi is the decrease in semi major axis after one revolution. L is expressed in orbital revolution.

In situ technique: the concentration of the gas in the direct surrounding of the satellite in measured.

4-Foreign objects

Space debris: such as fuel droplets and silvers of paints.

Micrometeoroids: mass ranging less than one gram. The move around sun in orbits that cross that of the earth, they can collide with active spacecraft. Their concentration is dependent on solar activity. Although they are really small, they can be more harmful because of high velocity.

Three different techniques for satellite:
Avoidance: active avoidance in orbits using lots of fuel in urgent situations. Passive has no collision avoidance maneuver.
Protection: to minimize the consequences of the hits by foreign objects that will come unavoidably, the same as using multi layer and double wall instead of single wall.
Prevention: LEO satellite with a negative delta V falls back to the atmosphere more rapidly. This is not possible for geostationary satellite. So at the end of life they are boosted to an orbit which is about 200 km higher than the original geostationary altitude.

5-Radiation

Spectrum :distribution of the energy intensity as a function of the wavelength
2 types of radiation in space
Electromagnetic radiation, particle radiation.

Spectrum components (5)
Gamma and Rontgen radiation: known as X rays, short wave. Boundary between them is not identifiable.

Ultra Violet (UV): permanent damage in DNA, but is absorbed by Ozone.
Visible light: 0.4 to 0.7 micrometer.
Infrared: 0.7< infrared<1000 micro meter. Connects to red part of the visible light.
Radio waves: > 1 mm

Types of spectra
Line spectrum: for gasses consisting of atoms only.
Band spectrum: collection of lines,for gasses consisting of molecules
Continuous spectrum: for gasses and fluids under high P and T, and for solids.

Equation 6.1 is Planck equation which should be derivated to 6.4 Wien's law.

electro magnetic radiation types (3)
Direct solar radiation
Albedo radiation: reflected by the Earth or clouds.
Thermal radiation: emitted by the Earth.

Positive and negative radiation effects on satellites
+Attitude determination,energy supply
_Damage: serious fatigue load ,Orbit perturbation, communication disruption

Lagrange point L1 : a favorable point for sun observation is a location between sun and the earth where the attractions exerted by the sun and earth and centrifugal force are in balance.

6-Magnetic field earth

Magnetic field origin does not coincide with the Earth geometric centre. There is a offset of 400 km. polarity of the magnetic field is not constant. In Equation 7.1, M represents the moment of the magnetic field [guass-m^3].

Dynamo theory: geomagnetic field in induced by the electric current in the centre of the Earth.
Equation 7.5 to 7.13 (radial and tangential component of the magnetic field.)

Van Allen Belts: regions with high concentration of charged and high energy particles.

Three different motions of the charged particles

1. **Cyclotron motion**: circular motion around the geomagnetic field line

The force which the charged particles experience in the magnetic field is called the Lorentz force which is perpendicular to the motion direction. (equation 7.16,figure 7.9)
There are two components of Vn and Vt ,which Vt is unaffected throught the motion but Vn changes its direction.

2. **Bounce motion**: travelling back and forth between the North and South Pole.

The geomagnetic field lines of the Earth converge toward the geomagnetic poles and the total field strength is dependent on altitude and geomagnetic latitude. (figure 7.10)

Since the geomagnetic field converges ,two components can be derived form that Bt(linear field) and Bn which is perpendicular to Bt. Due to Bt there is a Fn, and due to Bn there is a Ft which slows down the particle movement toward the pole which is heading.

3. **East-west (drift) motion**: (figure 7.8) is caused by presence of an external force (maybe the gravitational force) perpendicular to the magnetic field lines.

South Atlantic anomaly: phenomenon of interaction between Van Allen belts and geomagnetic field.

Single Event Upsets: this type of interaction is directly related to Van Allen Belts

How to prevent SEU (5) : avoid, shielding, space qualified components, technique to detect, reset the onboard computers.

7-Magnetosphere

Solar wind: the sun is the source of a stream of highly energetic charged particles.
Solar wind is electrically neutral and very thin.

Characteristic elements of the Magnetosphere:
Bow shock and magnetosheath: the boundary between the region where the solar plasma flow in unperturbed and the region where it is perturbed. When the particles pass this boundary the velocity and density decreases by a factor of 4.
Magnetopause: the boundary between the region where interplanetary particles are moving on one side and earth particles are moving on the other side. Van Allen Belts are situated in magnetopause.
Cusps: two openings where charged particles can penetrate the surrounding of the Earth.
Plasma sheet: at large distance the field is deformed to a pattern of parallel field lines which have an opposite polarity,the boundary is called neutral sheet. The region on both sides of the neutral sheet is called plasma sheet.
Plasmasphere: only relatively close to the earth the geomagnetic field lines do rotate along with the earth, the inner area is known as Plasmasphere.

8-Vacuum

Vacuum consequence on spacecraft.
Sublimation: due to net difference in internal partial pressure.
Mechanical properties: due to disappearance of oxide layer that has formed on earth
Lubrication: lubricants importance
Energy transfer: such as heat transfer

9-ground systems and mission operations

Functions(6)
Spacecraft tracking and acquisition:
Telemetry: downlink ,from space to ground**,** to provide tools and information for health monitoring.
Commanding: uplink commanding is necessary to control the functions of satellite.
Data processing: to deliver all engineering and scientific data in the proper format.
Data archiving and distribution: making sure that the information arrive at the right place.
Planning and scheduling: reconstruction and prediction of orbit,ground station activities ,orbit maintenance.

Elements(4)
Ground station: provide the link with the space segment for telemetry ,teleCo, and tracking. (equation 10.1)
Mission control system:
Electrical ground support equipment:
Ground communication subnet:connects all operational activities.

Ground software
Pre-pass: covers tools for orbit prediction, scheduling of events, for command list generation.
Real time: when satellite is in contact with ground station
Post-pass: addresses issues like health insurance.

ROM contains the basic instruction and safeguard modes, built into the satellite before launch and cannot be overwritten. RAM contains more detailed instruction and can be overwritten

Optimum
When sum of Developments cost and Operation cost is minimum, NOT when they are equal.

Mission phases (total 8)
Prelaunch phase
Early orbit phase
Switch-on phase
Calibration phase
Post mission phase

10-Spacecraft navigation and guidance,GPS

Navigation: determines the position and velocity of S/C related to the sun, earth or another planet.
Guidance: steers S/C to follow the predefined flight trajectory using info obtained from navigation system.

Figure 11.1 is the chart for guidance and navigation.
Equation 13.19 to 13.26, learn how to derive.

Code phase observation: a copy of the signal code sequence in the receiver, this code is phase shifted step by step and must be correlated with the received coded signal, the phase shift is a measure of the signal travel time, if two codes don't have max correlation, next code will be considered.

Equation (15.1) to (15.12)

Orbit refinement: combining the range and range measurements from the ground stations and equation of motion for a S/C in orbit, the orbital elements can be recalculated with these measurements.

Kalman filter (equation 17.2)
Equation (18.1) and (18.2) and figure (18.1)

Final approach: (page 192,193,194 and equations)
Two impulse transfer along the z axis
Two impulse transfer along the x axis
Continuous burn transfer along the z axis.

11-ENVISAT

ENVISAT has a Circular orbit,planned life time is 5 years,the launch is in 2002 which is exactly after peak of solar maximum. The launcher was Arian5 due to political reasons.

Repeat orbits: in these orbits the orbital parameters are chosen such that the ground track of the satellite repeats itself after a certain period (equation 22.5) and ENVISAT has a 35 day repeat orbit and orbital altitude in 780-820 km.

Sun synchronous orbit: in this orbit the orbit orientation w.r.t the sun is constant over time.
Eclipse length calculation :(page 209)
Visibility from Earth: (page 210)
In equation 22.13 Cd*A/m is the ballistic parameter. And life time is expressed in revolution.

LEO satellites may find some form of shielding:
1- Charged cosmic particles approaching the Earth are deflected by Lorentz force.
2- Van Allen Belts
So ENVISAT should remain below Van Allen Belts.

ENVISAT instrumentation:
ASAR (the advanced synthetic aperture radar):
MERIS (the medium resolution imaging spectrometer): measures ALBEDO level.
AATSR (the advance along track scanning radiometer) :measure sea surface Temperature With a resolution of 1*1 km.

GOMOS(the global ozone monitoring by Occultation of stars) : limb-sounding device.
MIPAS
SCIAMACHY
LR (laser retroreflector) : consists of mirrors that reflect incoming pulses of light in the direction of incidence to measure the travel time.
MWR (microwave radiometer): measures the humidity in the column of air below the satellite.
DORIS: measures the Doppler shifts of radio signals emitted by network of ground stations.
RA2: measures the distance between satellite and earth directly below the satellite, accuracy 4.5 cm.

ENVISAT propulsion module: 4 propeller tanks, which hold 300 kg of hydrazine at BOL. The **solar array** is 14*5 m and consists of 14 deployable rigid panels and delivers 6.6 kW at EOL.

Energy supply options for each satellite
Photovoltaic: conversion of sunlight to electric energy
Nuclear: large amount of energy but risky
Batteries: clearly not a option for a 5 year mission
Dynamic: not yet operational, just on paper.

Thermal control : ENVISAT has Silicium solar cells with an efficiency of 18%. And it must remain within 20+-20 Temperature. Payload module and Service module (both multilayer) are weakly connected from a thermal point of view through the central carbon-fiber composite cone and a small number of trusses.

Attitude control options
Infrared sensor
Narrow field sun sensor
Inertial platform using 3 gyroscopes
Star trackers

ENVISAT uses the option of star tracker and gyroscopes.

Launcher requirements
Reliability and availability
Be able to take the satellite mass to orbit
Satisfy the budget constraints
Satisfy political constraints

The launcher selection was driven by a combination of technical aspect and politics ➔ Arian 5.

12-ULYSSES

the primary objective of Ulysses mission is to explore the inner Helioshpere over the full range of a solar latitudes. It has a strange trajectory over the poles of the sun.

Two launcher options
Titan-IV with an upper stage
Space shuttle transportation system also with an upper stage is the choice.

Three different options to reach the required satellite orbit
Direct insertion
Electrical propulsion
Swing by along another planet

Swing by planet option
Inner planets
Outer planets

Inner planets are not a realistic option because:
1- One would have to slow down Ulysses w.r.t inertial space which is in sharp contrast with the wish for as much energy as possible.
2- It would bring the mission in conflict with minimum solar passing distance.

3 sections of trajectory
Earth swing by planet
Swing by around planet
Swing by planet-sun

After considering different aspects shown in table 23.3 **Jupiter** is the best choice for swing by.

Energy supply options are the same as ENVISAT which nuclear option in particular, a Radio-isotope Thermoelectric Generator (RTG) has been chosen,

Thermal control options
The suitable choice is one without dependence on distance to the sun. the s/c body is wrapped in thermal blankets and one side always faces space as radiator.

Attitude control options
Active
Passive

Since Ulysses weighs quite heavily, the choice was made on taking as little mass as possible.
➔ Spinner configuration, with a rotation of 5 rpm, Stability, low mass and simplicity as advantages.