

# **Space Weather effects to Satellite Communications**

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## **1. Introduction**

We would understand that "SPACE" is the large empty of atmosphere, has the border from the beyond of the earth's atmosphere and expand to the universe. In fact, space is all time changeable with high power particles, radiations, electro-magnetic, small and large objects compare to our seen on our planet. The distance between these objects are different, would be from zero to the speed of light (300,000 km/s) or more. The temperature on the object toward solar side would be high, but the opposite side would be low even both side are very near each other. In addition, there are a lot of particles toward to the skin of objects and some particles would pass the objects. The electromagnetic in some space region would be high density, space weather is all time changeable. These activities are affected to the movement of spacecrafts and satellites.

### **1.1 Space starts from where?**

Presently we could not define yet the border of earth atmosphere and space. The international law basic on various international agreements has defined the lowest space over earth atmosphere that space would be start from the perigee orbital slot of the space object. However until now we have not yet defined the above permanent mentioned position. The international law has defined that the aircrafts and rockets fly over the sky of which country would be the right of that country without thinking the level from the earth surface.

### **1.2 Minimum level of Satellite**

The earth atmosphere would not end immediately or the space would not start immediately in every position from the earth surface. The earth atmosphere would be continued over 1,500 km from the earth surface. In practical, the lowest level of satellites in circular orbits would have the level about 150 km from the earth surface. If they don't have the propulsion, they could remain in their orbital slots about 1 to 2 days, loss the speed and eventually fall down to the surface of the earth. Therefore we could define as the space would start 150 km from the earth surface.

## 2. The Earth's atmosphere

Due to the maximum high level of atmosphere from the earth surface would define the satellites moving around the earth planet, the spectrum of radio frequency which transmit and receive by satellites would be absorb, expand and change the direction in the earth atmosphere.

We divide the earth atmosphere into many layers with different characteristic (figure 1) but their borders are not clear, some layers are duplicate or split into many sub-layers. The borders of the earth atmosphere have defined in many types due to the research by various scientific in many standard applications such as pressure or temperature.

Only the level from the earth surface could not defined the end of this layer and start other layer due to these layers are changeable all time depend on the period of the day, the seasons of the year, the activities of the sun and many more factors.

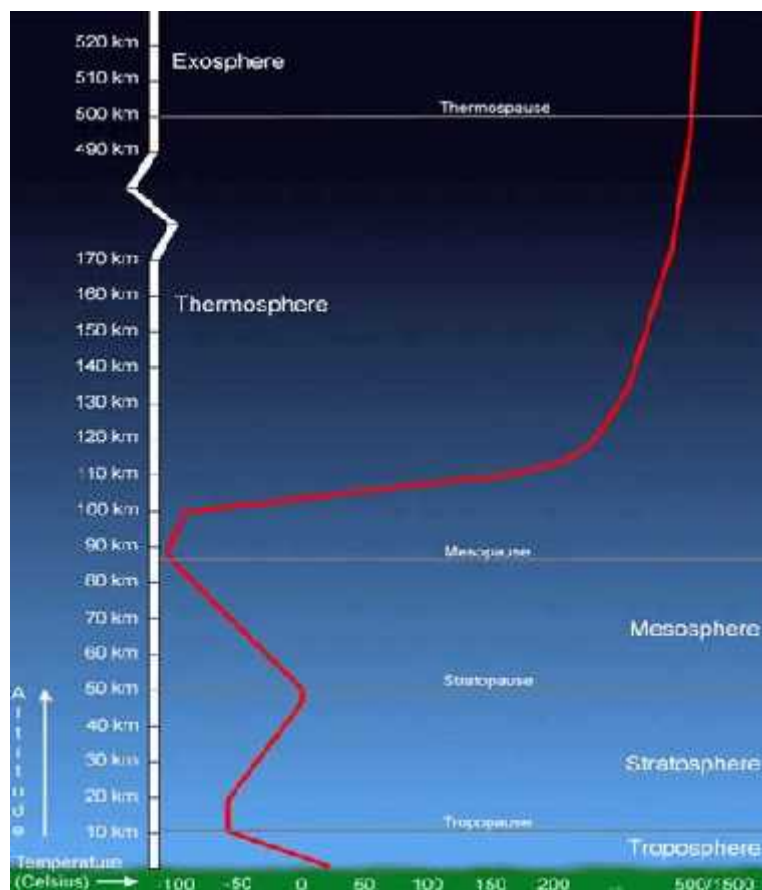


Figure 1. The level and temperature of the earth atmosphere



**Figure 2. The thin atmosphere over the earth surface**

## **2.1 Troposphere**

Troposphere has the border from the earth surface to Tropopause which is the top of Troposphere. Almost of the cloud and weather are in this layer, compose by 99% of all water vapor and 90% of all gases in the earth atmosphere.

This means more and more high level, the quantity of water vapor and gases are lower and lower which half of the earth atmosphere is lower than 5 km. Therefore if not familiar with this situation could not live comfortable and need more oxygen to breath.

In general the temperature would decrease  $10^{\circ}\text{C}$  when the level from the earth surface increase every 1 km until tropopause. The gases would be expanded when the temperature increase in Troposphere, the temperature nearby the earth surface is higher than the next respective layer due to the gravitational field.

Therefore the weather in Troposphere is all time changeable and this unstable situation

## **2.2 Stratosphere**

Stratosphere is over Troposphere, has the border from Tropopause in which the level is from 48 to 53 km from the earth surface. The temperature in this region increase a little bit depend to the level (Fig.1) most of atmosphere will move in horizontal. The maximum temperature is about  $0^{\circ}\text{C}$  at Tropopause and 99% of the atmosphere will be in Stratosphere and Troposphere.

The atmosphere is this layer at the level of 15 km will not have the water vapor and cloud at all. The breath assist would not help the human due to the natural human pressure is the same on the surface of the earth. Therefore, at this level the blood could

not absorb the Oxygen ( $O_2$ ). In addition, there will have water vapor and Nitrogen in human body from the mouth and eyes first. Then will occurs in the black and red veins which will be great suffer. So, the human body needs to have the pressure control room or human suit and hat to protect the pressure at the higher than this level.

Ozone ( $O_3$ ) as we are well aware that would absorb Ultra Violet (UV) from the Sun light which would be dangerous for human kind and livelihood is in this Stratosphere layer at the level from 20 to 34 km from the earth surface.

### **2.3 Mesosphere**

Mesosphere has the border from Tropopause to Mesopause at the level from 50 km to 80-90 km from the earth surface. The temperature will vary depend with the level (Figure 1) and at Mesopause will have minimum temperature about  $90^{\circ}\text{C}$ .

At the level higher than 50 km the atmosphere will lighter and lighter, the turbo engine cannot work, the spacecraft or rocket at this level need to have Propellant and Oxygen tanks connect to turbo engine in order to burn and propulsion.

### **2.4 Thermosphere**

Thermosphere start from 90 km until 320-600 km, the temperature will increase as of level of the high in which start from  $-90^{\circ}\text{C}$  until to the region maximum temperature of  $1475^{\circ}\text{C}$  in day time and  $225^{\circ}\text{C}$  in night time (Figure 1).

At the level higher than 100 km, the wings of aircraft cannot support the moving of flight due to the lightest of atmosphere. At this level will not hear any sound outside of the spacecraft due to the lightest of atmosphere cannot conduct the spectrum of sound.

If we look more high level from 160 km, the sky will be dark between the stars even if it is day time due to not enough atmosphere to reflect the sun light blue color as we see on the earth surface.

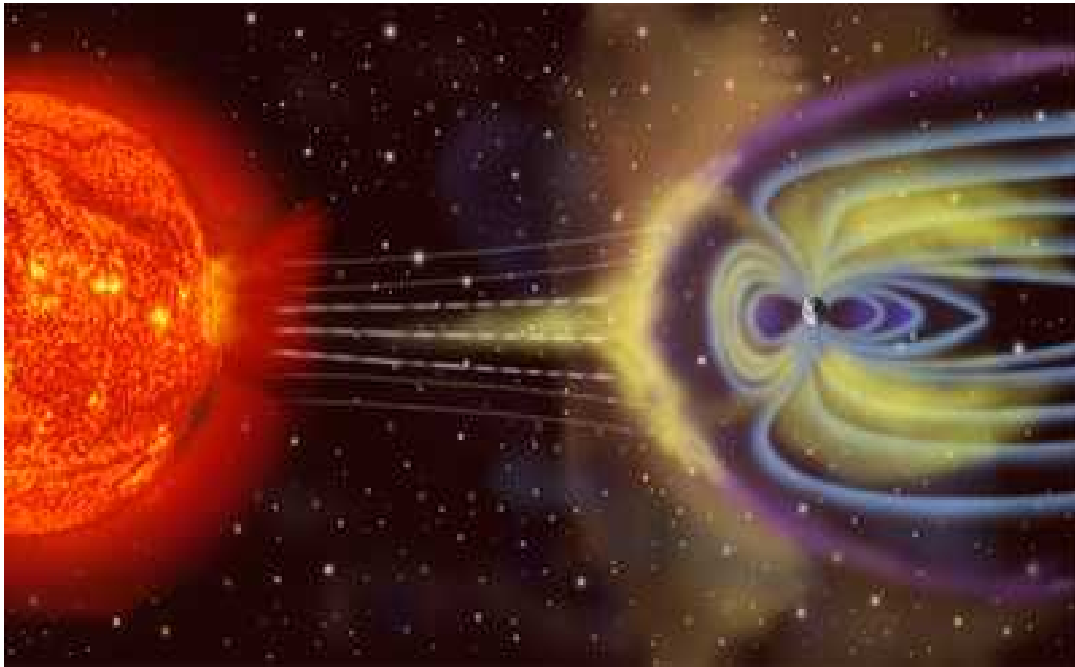
### **2.5 Exosphere**

Exosphere start from the end of Thermosphere and expand until the space, in this region the density of atoms and molecules of gases is very low, the single atom will take at least 20 minutes to hit another atom. After hit, the atom will have the higher power enough to win the earth's gravity and disappear into the space. This lowest density has evaluated that the number of particles in the atmosphere over 1,600 km is equal to the number of particles  $1\text{ cm}^3$  over the sea. However the satellites orbit around the earth about 1,000 km will be slower due to the resistance of atoms and molecules in the atmosphere.

### 3. Resistance Force from Atmosphere

The satellites in the earth orbit will face with the resistance from the atmosphere of the earth. These resistances would depend to the density of the atmosphere, form, quantity, the material to produce satellites and other components.

These resistances will affect the satellites to moving lower and lower. In conclusion the resistance from the atmosphere lower than 1,000 km is somewhat very high.



**Figure 3. Magnetic field of the earth from space view (Solar wind)**

#### 3.1 Scandal and Heat protection

The move of satellites pass the atmosphere will affect with atmospheric molecules can issue the high temperature, this would not affect inside of satellites or space crafts if covered by the heat protection and this high temperature will disseminate to all the space crafts if there have not enough thermal control when the space crafts passed the earth atmosphere. These space crafts would be burned if passed the earth atmosphere. In order to award the satellites not to be burned from the hit of the earth atmosphere, we would move carefully the satellites in the high level of the earth atmosphere.

#### 3.2 The solar effect

In the event of most radiation and power transmission of the Sun will make the outer layer hotter and expand in to the space affected to the higher protection of the air at the higher level.

### 3.3 Appropriate Orbital Slot

The satellites at the level of higher than 100 km will face with the very high resistance force of the air which is not suitable in practice. Therefore in general the satellites will have the orbital slots more than 600 km which will have lower air resistance.

### 3.4 Ionosphere

As we are aware that we have divided the earth atmosphere into various format by physical characteristic including Ionosphere has more format of layer in which divided by the density of gas molecule instead of the temperature change (figure 4). Ionosphere starts from Mesopause 50-80 km from the earth surface and extend far until 400 km. Atoms and molecules of gases in this atmospheric layer are shooting by electromagnetic spectrum in the form of X-ray and Ultra Violet (UV) from the Sun and Galaxy Cosmic Ray. The high power from far space made the upper atmosphere ionize into electrostatic or free electron and these particles are the main factors in Ionosphere.

The quantity of rays made ionize in the earth atmosphere are big different between day time and night time due to solar activities such as sun spots, solar flares and other change on the surface of the sun make various rays and high power particles. When these particles in Ionosphere face with the high intense electromagnetic in north pole and south pole made various light color on the sky namely Aurora Borealis on the north pole and Aurora Australis on the south pole.

Due to Ionosphere layer compose mainly by electro particles which could absorb and bench the field of electro-magnetic especially the Radio Frequency. Therefore Ionosphere would be effects to the design of space crafts and the communications between the satellites and the earth stations. In addition Ionosphere could reflect in some bandwidth of radio frequency.

Ionosphere composes by 4 regions: D, E, F<sub>1</sub> and F<sub>2</sub> (Figure 4)



ionosphere  
**Figure 4. Ionosphere layers**

Due to the evolution of the density of electrons change compare with the level of high, the scientists divided the Ionosphere into many sub-layers such as D layer (50-95 km), E layer (95-160 km) and F layer which have  $F_1$  (160-250 km) and  $F_2$  (250-1,000 km). D layer compose by free electrons enough to transit of radio frequency in the band of Amplitude Modulation (AM). In day time, this band of radio frequency will be somewhat absorb due to there are a lot density of particles from solar photo ionization. Therefore D layer is quickly change by solar activities even day time and night time.

E layer has usually density of electrons change like D layer but the number of particles is smaller in night time. F layer is the area directly effect by solar activities,  $F_1$  layer will appears only in day time and will have more density of charged particles after big solar eruption (every 11 years cycle),  $F_2$  layer has maximum density of electrons in both day time and night time and therefore  $F_2$  layer can reflect and absorb steadily some bands of Radio Frequency. The signal of satellite television such as Direct To Home (DTH) will decrease the power by the resistance of the earth atmosphere as mention below:

In day time, the Radio Frequency in band AM (530 – 1,650 MHz) will be absorb in D layer. But in night time, D layer will disappear very fast, therefore AM Radio Frequency will pass D layer and reflect to the earth by charged particles in E layer which is the reason to identify why AM Radio Frequency can transmit signal more far in night time. The signal of Radio Broadcasting in Short Wave (SW) range bandwidth of 6-30 MHz will reflect in E layer and F layer down the earth surface and can reflect many round between the Ionosphere and the earth surface.

Due to the signal of Radio Frequency lower than 30 MHz reflect in E and Flayer, this Radio Frequency Band is not appropriate for Satellite Communications. Background Noise in which originate from the Earth Atmosphere, the Sun and Cosmic Rays affect to the Communications via Satellites by the Radio Frequency lower than 300 MHz. But the Frequency more than 300 MHz, the molecule of water ( $H_2O$ ) and Carbon Dioxide ( $CO_2$ ) will absorb heavily the electromagnetic spectrum and become heater but in some range of frequency between 300 MHz and 300 GHz which absorbed by various molecules of Atmosphere will be used in Satellite Communications could be more consider carefully.

The Radio Frequency in the range of 300 MHz and 300 GHz major part can pass the Earth Atmosphere, therefore this range is being use in the Communications between the Satellites and the Earth Stations. However, this mentioned frequency disturbed and refracted in  $F_2$  layer, this refraction made the signal go out from its original direction due to the density of air and far more than the direct communication between the transmitter and receiver, the receiving signal is more delayed and affect to the system such as Global Navigation Satellite System (GNSS) for example the Global Position System (GPS) of the United States of America.

#### **4. Solar activities**

The Sun reject high power of particles and radiate steadily the electro-magnetic in the form of light and spectrum of frequency. These particles and spectrum are namely Solar Wind. In addition there are the big storm of the Sun namely Solar Flares. The Sun



reject high power of particles and radiate magneto-electric in the form of light and frequency spectrum steadily. These steadily of particles and spectrum frequency are namely Solar Wind.

In addition there are the huge burn of the Sun namely Solar Flares which originate from the huge eruption, mainly Electrons and Protons in parallel with the radiation of huge power of magneto-electric spectrum. The huge eruption on the Sun is divided into many cycles, the Sun rotates around itself about 28 days per one cycle. We can observe many specifications from the Earth surface such as Sun Spots. These Sun Spots will have the evolution of 11 years cycle which relate to the huge burn of the Sun such there are more Sun Spots, there will have more huge eruption and the magnetic pole of the Sun will change every 22 years which originate this huge eruption.

#### **4.1 Electromagnetic Radiation**

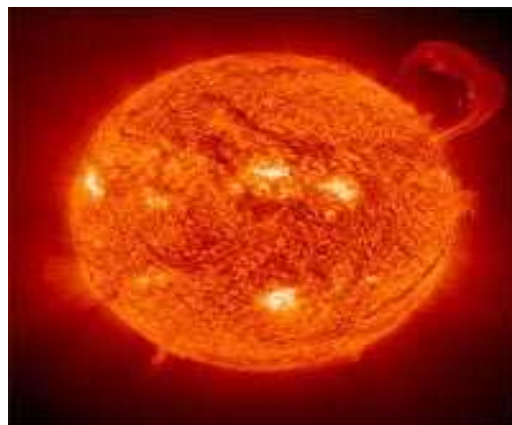
The electromagnetic wave which disseminate from the Sun will have the spectrum from Radio Frequency until X-rays. The power effect into the earth atmosphere namely Solar Constant. The spectrum which disseminate from the Sun compose by dangerous spectrum and could change the skin of various objects. The maximum dissemination originate from Solar Flares which disturb heavily to the Broadcasting Communications.

#### **4.2 Solar Wind**

Due to appear Corona over the Sun, protons and electrons will have enough velocity to lift off the Sun. This effect push the charged particles to every direction around the Sun namely Solar Wind. When the Solar Wind reach to the orbit around the Earth will have the velocity about 300-700 km/s by the density of 1-10 particles/cm<sup>3</sup>. Both the velocity and the density are depend on the Spot over the Sun.

The Solar Wind will affect to the satellites orbiting around the Earth, especially the satellites which have more ratio of surface and mass such as the satellites have big Solar Cell. When the Solar Wind reach, the satellite will have the orbit lower and lower, facing with the huge resistance from the air in day time but in night time the satellite is behind the earth planet and safe from Solar Wind.

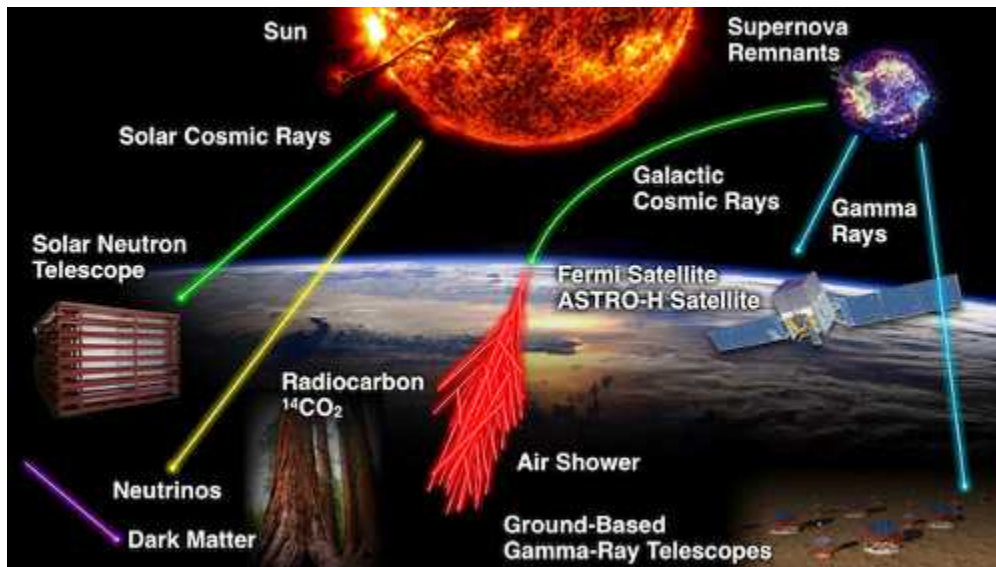
#### **4.3 Solar Flare**



**Figure 5. Solar Flare**

Electron particles with high velocity which expanded from Solar Flare could be easily destroy the space crafts and satellites. The Solar Flare could expand as far as its power end from a few minutes to many hours. The frequent of Solar Flare will depend to the number of Sun Spot, the Earth Planet will affect from many minutes of light. After that it will suddenly disturb the Ionosphere (SID) and affect in Radio Communications especially in Short Wave (SW) Frequency Range 3-30 MHz which reflect steadily in the Ionosphere from 15 minutes to 1 hour in the period of Solar Flare and disturb largely in Radio Communications.

#### 4.4 Cosmic Rays



Cosmic Rays around the Earth Planet originate from 2 main sources such as from the Sun namely Solar Cosmic Ray and other stars in the Universe namely Galaxy Cosmic Ray. These Rays are from the expansion of high velocity of protons and electrons particles. Cosmic Galaxy Rays have a lot of energy but lower dangerous due to a few of its Rays can enter to the Earth atmosphere except in the event of Solar Flares which produce many thousand times in a very short period.

The activities of human space in these mentioned period could be use the protection for heavy spacecraft which is not suitable in recent applications due to the increase of satellites launching expenses. Therefore we have to choose another options such as decrease the action plan and accompany the astronauts return back to the earth surface before these events. The particles from Cosmic Rays could be destroy the space crafts and satellites.

The method of protection cannot be made in practice due to high power of particles. In order to solve these problems we select the suitable equipment and when the working equipment damage, the standby equipment could replace automatically, error detection, correction and reset. The Cosmic Rays affects mostly the satellites Polar Orbit and Geo-synchronous Earth Orbit (GEO) due to these orbits are outside or nearby the Earth magnetic field.

## 4.5 Thermal power

The Sun radiates a huge amount of power, the satellites which orbit around the Earth planet will not be protected by the Earth atmosphere. Every part of the satellite which receives directly the Sun light will have very high temperature and will absorb this temperature. The Sun light which reflects from the Earth surface is also an important thermal power to the satellite when it is located in the shadow of the Earth planet in Low Earth Orbit (LEO).

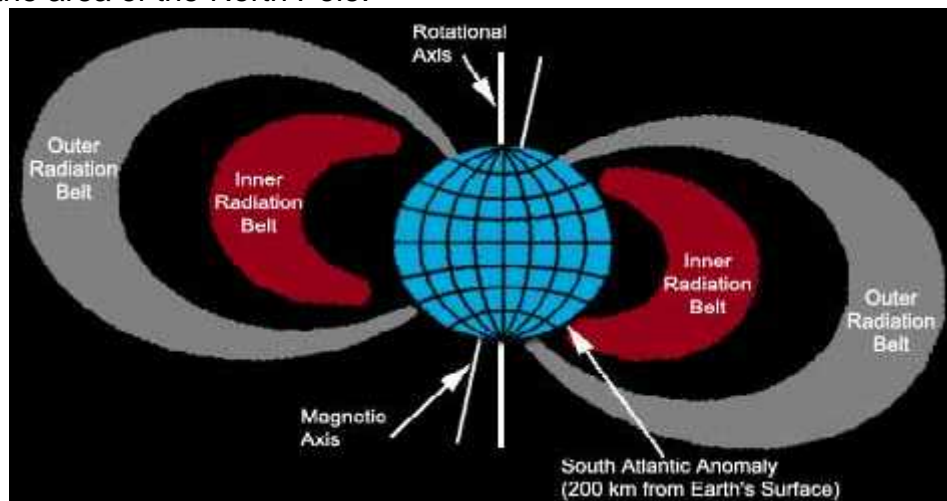
The temperature from satellite could be spread out to the cool of space, having the effect that the temperature at the skin of satellite decreases more than  $-100^{\circ}\text{C}$ . In addition, the thermal power is more increased by the internal work of satellite such as battery, computer and others. This thermal power will be gotten rid of, if not it will destroy the equipment inside the satellite. Thermal control is the most important, therefore when designing the satellite we have to consider in 2 systems such as Passive System and Active System.

In the Passive System it is easy to make satellite turn around itself in order to receive overall the Sun light by using the high grade reflecting material fixed to the surface of satellite to protect the thermal power absorbed into the satellite.

In the Active System include the heater and the cooler, the thermal control inside the satellite is very complicated due to some equipment inside the satellite need to have the temperature near  $0^{\circ}\text{C}$ , while the Unified Propulsion System (UPS) need to keep the temperature about  $30\text{-}40^{\circ}\text{C}$ .

## 5. Magnetic Field of the Earth

Our Earth planet has a magnetic field around itself spread out from the north magnetic pole, pass the space around the Earth planet and return to the south magnetic pole, in fact the north magnetic pole is in the area of the South Pole, while the south magnetic pole is in the area of the North Pole.



Various planets in the Solar System have different magnetic poles, but the actual accepted theory is the magnetic field around the Earth planet comes from the moving of metal liquid in the core of Earth planet.

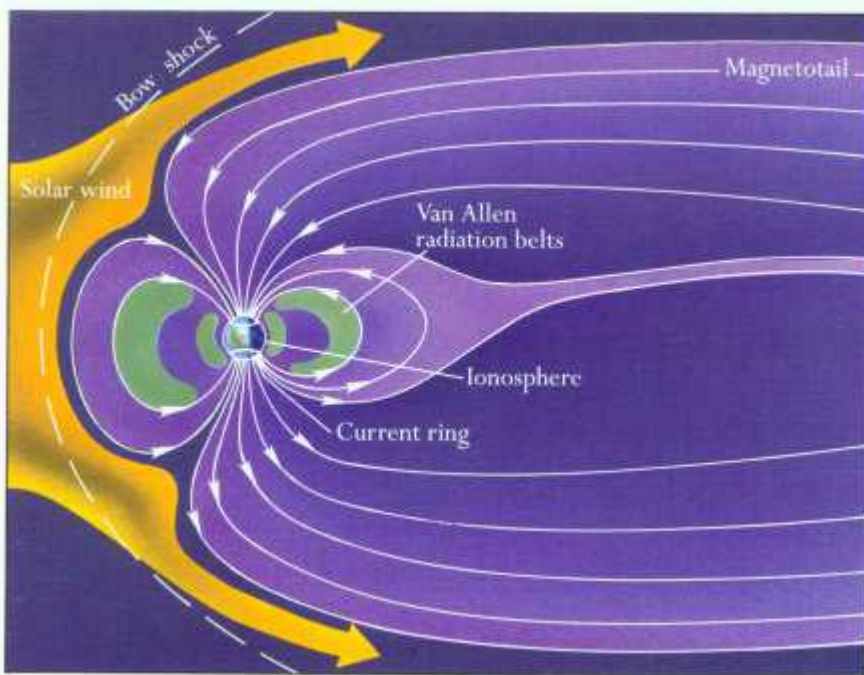
## 5.1 Magnetosphere of the Earth

The magnetic field which expand around the Earth planet is namely Magnetosphere, while the Solar Wind move from the Sun to the Earth planet will face with the Earth Atmosphere in the side received the Sun light. The Solar wind will affect and push the magnetic to the Earth surface and increase the magnetic density in this region. In opposite, the Solar Wind will push the Earth magnetic field to enlarge the Earth's Magnetosphere look like the form of water tall (as shown in 5.3).

## 5.2 Magnetopause

The border of magnetosphere namely magnetopause is the area in which Solar Wind is balance with the pressure of Earth magnetic. The Magnetopause is defined as the side in to the Sun has the distance about 10 times rayon of the Earth, but in fact this position would change from 7 to 14 times due to the evolution of the Solar Wind.

## 5.3 Magneto Tail



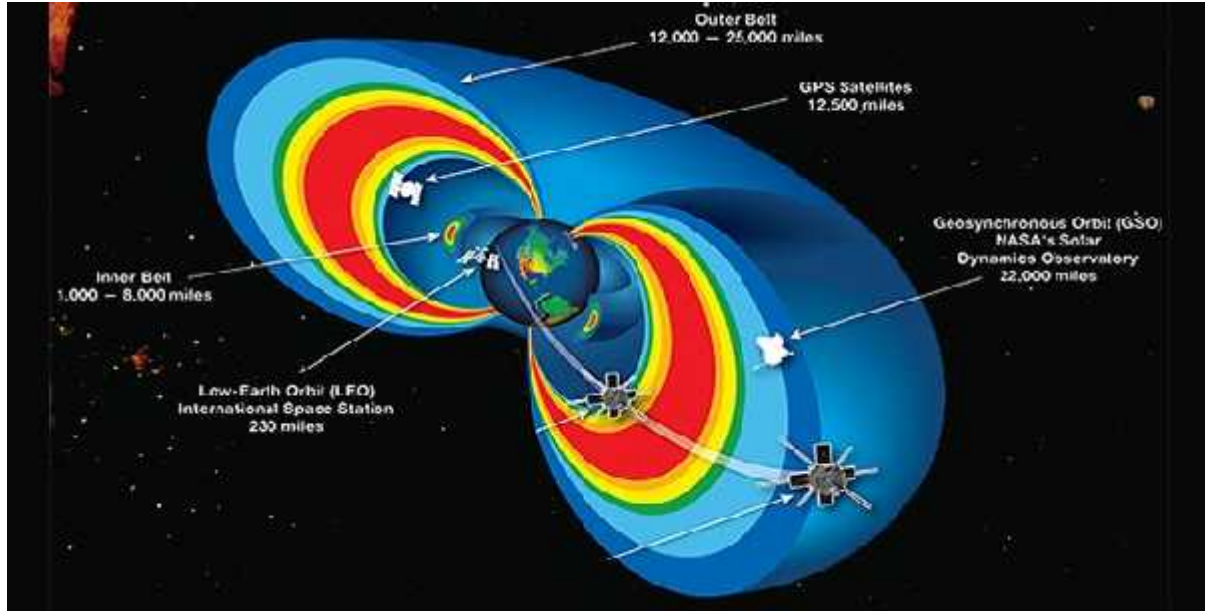
In the other side of the Earth planet which is opposite of the Sun, the Solar Wind make the magnetic of the Earth in the form of tail namely "Magneto Tail" which would have the distance far more than 1,000 times of the Earth's rayon. In the Magneto Tail is the area of high power density of charged particles and have the border about 300 times of the Earth planet's rayon.

## 5.4 Shock Wave

When the Solar Wind face with the magnetic of the Earth planet, the Solar Wind will shock and change the direction. The form of this Shock Wave look like the water wave when the head of boat moving over the water surface. The direction of Shock Wave will

not in the original area, in fact it bends the front of the magnetic field of front Earth and push to the distance of more than 10 to 15 times of the rayon of the Earth planet as show in 5.3.

### 5.5 Van Allen Radiation Belts



In 1958 the scientist namely James Van Allen has explored that the Magnetosphere has composed by a lot of the charged particles inside of the Earth's magnetic field and namely "Van Allen Radiation Belt". He refers to the data from satellite Explorer I which has been launched into the orbital slot by the United States Army and draw the map of particles which remain inside the magnetic field of the Earth planet.

This received data indicates the Magnetosphere has the special form and the Belt of high power particles remained has the form like Donut which divided into 2 Belts as Inner Radiation Belt and Outer Radiation Belt (as show in figure 6).

The Inner Radiation Belt start from 400-10,000 km from the Earth surface, inside there are a lot number of protons and maximum density at the level of 3,500 km which has the border from the latitude 40°North to 40°South and the Outer Radiation Belt start from 10,000 to 60,000 km from the Earth surface, the maximum density of electrons at the level of 16,000 km. When the charged particles faced with the magnetic of the Earth plane, they will remain in that field and reflect inside of the magnetic between the North Pole and the South Pole of the Earth planet.

### 5.6 Spacecraft orbit in the Van Allen Belts

From the launch of spacecraft or satellite into the Low Earth Orbit (LEO) at the level of 200-600 km from the Earth surface, we are aware that the radiation from the space is not much dangerous in the quantity due to the protection of the particles from the Van Allen Belts. However the satellites in the Geostationary Earth Orbit (GEO) at the level of

about 36,000 km from the Earth surface are nearby the center of Outer Van Allen Belt which have a lot of charged particles. Therefore the human inside of the spacecraft in this region will have the good protection and position the orbital slot to receive the minimum quantity of radiation.

### 5.7 Electromagnetic Force

When the satellite in the orbital slot passed by the Earth magnetic field, the satellite will look like the magnetic tank due to the electric and electronic equipment inside and outside of the satellite produce itself electromagnetic. In addition when the satellite passed the charged particles of the Earth atmosphere, the negative electrical charge will appear on the surface of satellite affect directly when the satellite pass the magnetic field of the Earth planet. From this reason the satellite has the magnetic resistance force and affect in the orbital slot.

### 5.8 Aurora



The Aurora is the color field characteristic in the sky of the night on polar region appears on the north and south of polar region due to the magnetic field bench to the Earth planet at the level of 100 to 300 km from the Earth surface.

The north and south polar Aurora appear from the solar wind conflict with the earth magnetic field. The solar wind compose by the charged particles moving with high speed to interfere the Earth magnetic field and these charged particles face with the gas molecules above the north and south poles of the Earth. The Aurora on the north pole region is namely "Aurora Borealis" and the Aurora on the south pole region is namely "Aurora Australis"

## 5.9 Geographic Anomalies

The center of the Earth magnetic field move from the center point about 430 km to the west direction of Pacific Ocean made 2 regions of the Earth surface have higher or lower than the expectation as mention below:

- The anomaly in the South Atlantic Ocean is the region low density and low level of the Earth magnetic field. The charged Aurora face with the high density of the Earth atmospheric particles look like the same of the Aurora on the North and South regions of the Earth planet and interfere with the high radio frequency.
- The anomaly in the South East Asia is the highest density irregular of the Earth magnetic field. The charged particles in  $F_2$  region of the Earth atmosphere affect to the radio communication when the satellites pass in this region.

In order to decrease these anomalies we have to select none or lowest affect radio frequency in this region.

## 6. Space Weather effects to Satellites

The space weather is the main important factor to the work of satellites around the Earth planet as mention below:

### 6.1 Atmospheric affects

- The resistance force of the atmosphere made the satellites have the orbit lower and lower, decrease the period in its skills in the space. As mentioned above, the Earth atmosphere will not suddenly end at the level of 1,000 km which have the resistance force to the satellites.
- The atoms of Oxygen ( $O_2$ ) would split the surface of the satellite, the atmosphere over the sea compose by 21% of Oxygen ( $O_2$ ), 78% of Nitrogen and 1% of other gases. Normally the atoms of Oxygen are pair in molecule  $O_2$  as we are aware. Under the pressure of some status, the molecule of Oxygen will split into 2 atoms and these split atoms will looking for its partner in order to become the new molecule of Oxygen again. In the high level of the Earth atmosphere, the molecules of Oxygen are very few and very far from each other. Therefore the rays and charged particles compress the molecule of Oxygen and split it into 2 single atoms of Oxygen which will not be able to combine with another atom.
- As we are well aware that if we lay the metal in the air about a few days, we will see the oxidized on the surface of the metal. This chemical process is called the Oxidation which occurred by the molecules of oxygen combine with the metal and become metal oxide such as  $FeO_2$ . The problem from  $O_2$  oxidation is less than the problem from O which could be destroy the surface of the metal. Therefore the space craft and the satellite face with the atom of oxygen will have

the oxidation which will immunize the equipment, change the characteristic of thermal control or destroy the measurement equipment.

- However the atoms of Oxygen float in the high level of the Earth atmosphere will combine with the remaining molecules of Oxygen become the special molecules as we call Ozone ( $O_3$ ) which can be the fence to protect the dangerous rays would destroy the life on our Earth planet, especially the rays of Ultra Violet (UV) would cause the inflammatory skin or cancer.

## 6.2 Space affect

When the space craft or satellite escape from the atmosphere or the low density area would affect by the space weather as mention below:

- **Outgassing**

The gases release from the objects of space crafts and satellites would cover various measurement equipment under the pressure of atmosphere over the sea has the force more than  $100,000 \text{ N/m}^2$ . The Soda water in cans has the pressure higher than atmospheric pressure, the Carbon Dioxide ( $CO_2$ ) could combine with the liquid in cans. When we open the cans, the gas leave from the liquid and float to the air, the pressure will decrease until the same level as outside the cans.

The satellites and space craft will have the same problems, the material which use to produce the satellite will have the gas content inside the object. Under the air pressure, when the pressure release to the space, the gas will start to release from the object which namely "outgassing". This event is not much damage but in some case the outgassing would cover the skin of important equipment such as the measurement, light path or lens of camera.

Therefore we have to select carefully the material to manufacture the satellite and space craft. After complete the integration we put it into the Vacuum Chamber and test with various level of temperature the same as in the space environment.

- **Cold welding**

The cold welding is the combination of the nearby metal into the unique object. The cold welding occurs when at least two or more objects are moving nearby each other in the space. At small distance in space, various objects could move freely after leave the Earth surface in the orbital slot.

The vacuum in space could decrease the distance between the objects and eventually weld into one object. When this event occurs, the controller on the Earth surface will make every attempt to split the above mentioned object such as control that side of satellite to the Sun and the opposite side to the shadow in order to have the different temperature and eventually could separate each other.



- **Heat transfer**

The heat transfer has 3 types such as: Conduction, Convection and Radiation, but in space we could release the thermal from satellite by only the Radiation. Therefore we need the material to produce the satellite with high Emissivity.

### **6.3 Space Spam and Meteorites effect**

The space is not empty but there are a lot of waste such as meteorite or comets, the old satellites and space crafts. The comets which we have seen the bright in the sky are the natural objects and the meteors from the comets are more than 20,000 tons each year, there are a lot opportunity the satellites and space crafts would hit with these objects.

However since the start of space exploration, the waste from satellites and space crafts are increasing every year. All operation in space even the hand glove and keys of space human are remaining float in space. The nearby environment of the Earth are accumulating of waste about 2,000 tons which are more risk for the satellites and space crafts to hit with these waste when they are in Low Earth Orbit (LEO) with lower than 2,000 km from the Earth surface.

The inspection of space objects is the task of NORAD (North America Aerospace Defense Command) of the United States of America which follow up steadily the objects in space. NORAD has found there are the objects bigger than the ball and more than 7,000 objects orbit around the Earth planet, there are the small objects the same size of golf ball about 40,000 number.

In addition there are the very small objects more than billion number discard in satellite orbit which originate from the small piece of metal, small piece of color paint and others.

The waste in Low Earth Orbit (LEO) will have the velocity more than the waste in Geostationary Earth Orbit (GEO). The hit between two objects has the effect could be consider from the velocity and the mass of two objects.

\The small piece of metal or the small piece of color paint would have the velocity more than 7 km per second, when it hit with the satellite, the satellite will damage more than shut by the gun.

For example in 1983, the Space Shuttle bring the effect from the hit with this type of waste during the operation in space and return to the Earth surface. The small piece of color paint only 0.2 mm hit with the Challenger space craft can make the hole in the window of space craft size 4 mm, the expense to repair this window is more than 50,000 US Dollars.

From many billions of small waste objects to many thousands of large waste objects would hit the satellites, therefore we estimate that the satellites and space crafts which have the surface area of 50 to 200 m<sup>2</sup> orbit at the level of 300 km from the Earth surface (Space Shuttle level) would hit the large objects bigger than the ball less than one out of

a hundred thousand case and the opportunity to hit with small objects size 1 mm about one out of thousand case within one year in the orbit.

Now we initiate to consider the method to get rid of these waste according to the concept of Sir Arthur C. Clark who initiate the applications of satellites and its orbits around the Earth planet for the benefit of humankind in the past 50 years ago that we will have a lot of waste in the sky.

Now we could define the special orbit namely the graveyard orbit to keep the retire satellites by design the satellites to keep enough energy for propulsion itself into the orbit higher than Geostationary Earth Orbit (GEO) about 200 km.

When the satellites expired, these satellites would destroy by the meteorites or charged particles. Another method to get rid of the expired satellites is to tie the satellites with stamping equipment and pull the satellites lower and lower in order to burn the satellites in the high level of Earth atmosphere.

#### **6.4 Radiation effect**

The radiation of electromagnetic field from the Sun effects to the satellites out of the visible light, there are also the thermal spectrum such as Ultra Violet (UV), X rays and Gamma rays. The space crafts and astronauts will be effect directly from the Sun. This effect is depend to the wavelength of the visible light face with the space crafts in which we can use to produce the electricity power for satellites and space crafts by solar cells.

However this radiation would effects in positive and negative way as mention below:

- **Heating the satellites**

The thermal radiation or infrared from the Sun reflect to the surface of satellite or space craft will make that side hot which would be good or bad is depend on the characteristic of thermal surface. Normally the electronic equipment in the satellite is working in the temperature about 20°C.

For the vacuum in space normally would be very cold about -200°C. Sometime the thermal from the Sun will make these equipment warmer to the level can work normally, but it would accumulate the thermal over appropriate. Therefore when we design the satellite or space craft, we have to consider carefully about the balance between the thermal and working temperature appropriate in various case.

- **Immunization outside surface and electronic equipment in the satellites**

Normally the electromagnetic spectrum affect somewhat to the satellites in short period. However when the satellites locate long period in the orbital slots, the Ultra Violet rays from the Sun would immunize the outside surface of satellites.

Out of this the rays would damage the solar cell and electronic equipment inside the satellites. In addition when there occurs Solar Flares, the spectrum of radio frequency would interfere the communication equipment inside the satellites.

- **Sun light pressure**

The light from the Sun face with the solar cell would have the pressure from the photons about 5 Newton per 1 square kilometer. This force is not much if we compare with air resistance but it would also affect long period.

## 6.5 The effect from Particles

The most dangerous in Space Weather would be the affect from the particles. The original of these Particles are from various sources such as:

- **Solar Cosmic Rays (SCR)**

Solar Cosmic Rays are the particles from the Sun as a part of Solar Wind in the rate of  $1 \times 10^9$  kg/s and during the Solar Flares occurs, the number of Particles increase largely.

- **Galaxy Cosmic Rays (GCR)**

The particles from Galaxy Cosmic Rays (GCR) are look like that we find in the Solar Wind, but its original are from outside the Solar System, it is the Solar Wind from the star of other system or the remaining of Big Bang explode which is the original of the Universe.

Most of Galaxy Cosmic Rays (GCR) will have the mass and power more than Solar Cosmic Rays (SCR) and will have more power to destroy the Van Allen Belt which protect our planet from this rays.

- **Van Allen Belt Rays (VABR)**

The Scientists prefer to mention about the effect from the charged particles and the extent of electromagnetic spectrum together in the condition of Radiation due to the effect from two sources are similar as mentioned in Van Allen Belt (topic number 5) we find that Van Allen Belt effected mainly from the charged particles.

These charged particles are moving in this Belt and lay into the direction of the north pole and south pole as we have seen the multi-color light over the sky on north pole namely "Aurora" as mentioned in 5.8.

When the satellites or space-crafts locate in their orbits will face with these high power particles from Solar Wind, from the stars of various Galaxy would damage directly the satellites and space-crafts as mention below:

### **(1) Charging**

The large number of charged particles from Solar Wind arrive in Van Allen Belt will get rid of in the area of Magneto tail. When the satellites orbiting pass this region will be charging for its various parts of surfaces unequitable.

When the surfaces were charged more than the neighbor region, it will recharge immediately damage to the surface, destroy the material of the surface, immunize the Solar Cell Panel, loss power, stop working or destroy permanently the electronic circuits.

### **(2) Sputtering**

These charged particles have high velocity when facing with satellites it will look like sand blasted in atom level. After long period sputtering will destroy the thermal buffer cover outside the surface of satellite and damage various measurement equipment.

### **(3) Single Event Phenomenon (SEP)**

The high power particles can be invade inside of the satellites then damage the electronic components. This phenomenon namely Single Event Phenomenon (SEP). In addition there are another event occurs when the high power particles facing with the memory of Computer in the satellites which cause the bit of data keep in the memory alternate (bit flop) from 0 to 1 or from 1 to 0. This event would impact the satellite works misleadingly, could not solve and eventually drop out from its orbital slot.

## **Conclusion**

It is difficult to prevent this phenomenon perfectly, the wall of satellite or spacecraft could produce by the material to protect invade some part of these particles. The satellite controller has to consider the possibility occurs of this event, try to avoid and prevent this phenomenon.

## **Reference**

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**Welcome all comments and suggestions to my e-mail: skhamone@gmail.com  
In order to update and disseminate to the public in the future.  
Mr. Singthong Khamone, Deputy Director of Satellite Communication Division,  
Department of Radio Frequency, Ministry of Post and Telecommunication, Laos.  
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