THEOS-2 Orbit Design: Formation Flying in Equatorial Orbit and Damage Prevention Technique For the South Atlantic Magnetic Anomaly (SAMA)

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Abstract

Geo-Informatics and Space Technology Development Agency (GISTDA) has initiative THEOS-2 project after the THEOS-1 has been operated for more than 7 years which is over the lifetime already. THEOS-2 project requires not only the development of earth observation satellite(s), but also the development of the area-based decision making solution platform comprising of data, application systems, data processing and production system, IT infrastructure improvement and capacity building through development of satellites, engineering model, and infrastructures capable of supporting research in related fields. The developing satellites in THEOS-2 project are THAICHOTE-2 and THAICHOTE-3.

This paper focuses the orbit design of THAICHOTE-2 & 3. It discusses the satellite orbit design for the second and third EOS of Thailand. In this paper, both THAICHOTE will be simulated in an equatorial orbit as a formation flying which will be compared the productive to THAICHOTE-1 (THEOS-1). We also consider a serious issue in equatorial orbit design, namely the issue of the geomagnetic field in the area of the eastern coast of South America, called the South Atlantic Magnetic Anomaly (SAMA).

The high-energy particles of SAMA comprise a radiation environment which can travel through THAICHOTE-2& 3 material and deposit kinetic energy. This process causes atomic displacement or leaves a stream of charged atoms in the incident particles' wake. It can cause damage to the satellite including reduction of power generated by solar arrays, failure of sensitive electronics, increased background noise in sensors, and exposure of the satellite devices to radiation. This paper demonstrates the loss of ionizing radiation damage and presents a technique to prevent damage from high-energy particles in the SAMA.

Key Words: THEOS-2, THAICHOTE-2, THAICHOTE-3, South Atlantic Magnetic Anomaly, Ionizing Radiation, Geomagnetic Field

I. INTRODUCTION

Thailand Earth Observation Satellite (THEOS) or THAICHOTE-1, named by The King Bhumibol Adulyadej, the first low earth orbit satellite of The Royal Thai Government, was launched on the 1st October 2008 and had been operated by Geo-Informatics and Space Technology Development Agency's(GISTDA)engineers [1].The THAICHOTE-1 is operating at 820km altitude, 98.7° inclination as sun-synchronous orbit. Currently, the THAICHOTE-1 properly works and provides the geo-informatics data to ground as normal. The lifetime 5 years is over since 2013. Nevertheless, THAICHOTE-1 is still in daily operation. GISTDA engineers have determined the long-lifetime of THAICHOTE-1 by checking for the amount of fuel manoeuvring left which is possible for 10 years at least [2].

However, The Royal Thai Government has established the National Space Policy Committee (NSPC) with the mandates for setting policy and strategy and to consider plan and budget allocation on Thai space development; in order to promote and aid the utilization of space technology that is congruent with the current situation and useful for the economic, social, science, technology and education development and national security. THEOS-2 project is one of the space infrastructures that will be used to support the THEOS at terminate. At present, the NSPC has assigned GISTDA as the main organization and Executive Director of GISDA as the chairman of the Negotiation Sub-committee. The Sub-committee will collect information and negotiate with the countries of high potential in geo-informatics and space technology.

THEOS-2 project is not to procure a high resolution satellite as the same but is to reform the Earth Observation Satellites System. The project has the following principle and objectives:

- Being the National Earth Observation System Development Project funded by the government and developed through technology transfer from the supplier country
- Being the National Science and Technology Infrastructure for Capacity Building on Geo-Informatics and Space Technology
- Being the National Cooperative Project among space-related agencies, GIS developer and user organizations and organizations having their missions on applying geo-informatics on 7 sectors comprising of Multi Scales Land Use Planning and Administration, Water Resource Management, Disaster Management, Agricultural Zoning & Crop Management, Natural Resources and Ecosystem Management, Infrastructure Management and Social Benefits and National Security. All of these sectors

are interlinked in economic, social and environment aspects. The above mentioned organizations will get involved in the development since the beginning.

Project components and deliverables are mainly 2 satellites for constellation, Assembly Integration & Testing facilities and Applications for 7 sectors as mentioned above, in this regards, there are a lot capacities building under an EM satellite project also.

The 2 satellites are THAICHOTE-2 (THC-2) and THAICHOTE-3 (THC-3) which are focused for this paper. This paper proposes the formation flying of 2 satellites at equatorial orbit with 5°, 15° and 30°inclination and demonstrates the comparison of time revisiting and area coverage between the satellites in THEOS-2 (THC-2 and THC-3) and THEOS-1 as well as analyse the effect of intense magnetic field when the satellites fly through the South Atlantic Anomaly (SAA) and finally, provides a damage prevention technique which will be described in this paper respectively.

II. SATELLITES IN THEOS-2 PROJECT

Specification

For THEOS-2 project, the 2 satellites have been required in difference of size and resolution by THC-2 resolution 0.5m/pixel (weight depends on design) and THC-3 resolution 5-10m/pixel and weight about 50-100kg. The scope of both specifications as follow:

Table 1: Scope of THAICHOTE-2

Specification	
Mass	TBD
Altitude	≈700km
Inclination	(assume equatorial orbit)
Optical Sensor Resolution	Panchromatic 0.5m/pixel
Swath	≥24km
Revolution	14+4/7 rev./day
Repeat Cycle	7 days at Nadir
Accuracy	3-axis stabilization ≤0.01°
Communication	S-band, X-band
Propulsion System	TBD
Lifetime	Operational 5 years Re-entry ≤25 years

Table 2: Scope of THAICHOTE-3

Specification	
Mass	50-100kg
Altitude	≈700km
Inclination	(assume equatorial orbit)
Optical Sensor	Multispectral
Resolution	5-10m/pixel
Swath	≥50km
Revolution	14+4/7 rev./day
Repeat Cycle	7 days at Nadir
Accuracy	3-axis stabilization ≤0.1°
Communication	S-band, X-band
Propulsion System	Electric thruster or DV
Lifetime	Operational 3-5 years Re-entry ≤25 years

Above tables scoping the specification of both satellites are tentative which will be used to simulate the constellation as formation flying. However, the specifications need to be based on mission requirements. These specifications are based on the security requirement (THC-2) and agriculture, deforestation, fishery, construction and disaster monitoring requirements (THC-3). Therefore, the repeat cycle need to be designed as first priority.

Repeat Cycles Design

In this paper, the algorithm of repeat cycles is provided. As mentioned about the mission requirements, the highest frequency of monitoring event is the agriculture, which GISTDA needs to collect the data for analysis, researches and development. For example, if we know the timing of rice growth, we can know the time of harvesting season, then the Government can estimate the amount of rice in that year. However, GISTDA researchers require the information of satellite images updated within 2 weeks of repeat cycles. The repeat cycles consist of number of fully repeat orbits (REP) plus the remained orbits (REM) which can compute from the orbital period (T). Express an example as follows:

$$\textit{Orbital period (s)} = 2\pi\sqrt{\frac{a^3}{\mu}} \quad (1)$$

$$\textit{Number of orbit / day} = 86400 / T \quad (2)$$

Where a (SMA) is semi-major axis in km (earth radius (R_E): 6,378.136 km + altitude (ALT)) and μ is the universal parameter constant: 398600.445 km^3/s^2, result of the number of orbit/day is xx.yyyy which xx is REP and .yyyy is REM respectively. For example, if the desired altitude is 702.42 km that meaning a is7080.556 km, the number of orbit/day is 14.5714 rounds/day which REP is14 rounds and REM is 0.5714 round. In this example, the 14.5714 (14 + 0.5714) is 14 + 4/7 rounds/day which REM is 4/7 and then the day of repeat cycles is 7 days which is the required number (REN). The algorithm is provided as follows:

Algorithm 1.1 : RepeatCycles → Altitude

```
Number of orbit / day (ORB) = REP + REM
                            = REP + INT / REN

REN_EX = REN - 1
for INT = 1 : REN_EX
  REM(INT) = INT / REN
end

    for INT = 1 : length(REM)
      for REP = REP_MIN : REP_MAX
        ORB = REP + REM(INT)
        T = 86400 / ORB
```

$$\text{SMA} = \sqrt[3]{\frac{\mu}{(2\pi/T)^2}}$$

$$\text{ALT} = \text{SMA} - \text{RE}$$

end

end

The above algorithm is to find the altitude from the day of repeat cycles. The below algorithm is to find the day of repeat cycles from altitude as follows:

Algorithm 1.2 : Altitude → RepeatCycles

```
Semi - major axis (SMA) = RE + ALT
T = 2π sqrt(SMA^3 / μ)
ORB = 86400 / T
DIR = mod(ORB,1)
for INT = 1 : 9999
  Temp = INT / DIR
  DIN = mod(Temp,1)
    if DIN ≤ 0.005 or DIN ≥ 0.995
      REP = ORB - DIR
      REN = Temp - DIN
    end
end
```

After we have known the altitude from the day of repeat cycles, we can design the swath and camera lens according to the resolution respectively which will be not described in this paper. In this paper, we will use the information of specification in Table 1 and 2 for orbit simulation.

Satellite Formation Flying

THC-2 has a Panchromatic Camera and THC-3 has a Multispectral Camera, therefore they have to move as a parallel formation flying due to the needs of military mapping. In this case, the equations of motion of satellite formation flying are proposed by Schweighart & Sedwick [3].They presented a set of ordinary differential equations including J_2 gravitational perturbation. The equations are as follows:

$$\begin{aligned} &\ddot{x} - 2(nc)\dot{y} - (5c^2 - 2)n^2 x = 0 \\ &\ddot{y} + 2(nc)\dot{x} = 0 \\ &\ddot{z} + q^2 z = 2lq\cos(qt + f) \end{aligned} \tag{3}$$

THC-2 will be defined as a main satellite and THC-3 will be defined as a crew. In order to solve these equations, the initial conditions should be considered. Thus, the transformation by Laplace operators is applied on the equations, and then we have [4]:

$$\begin{aligned} x(t) = x(0) &+ \frac{2(nc)\dot{y}(0) + (5c^2 - 2)n^2 x(0)}{n^2 c_2^2} \\ &+ \left(\frac{\dot{x}(0)}{nc_2}\right)\sin(nc_2 t) \\ &- \frac{2(nc)\dot{y}(0) + (5c^2 - 2)n^2 x(0)}{n^2 c_2^2}\cos(nc_2 t) \end{aligned} \tag{4}$$

$$\begin{aligned} y(t) = y(0) &- \frac{2c\dot{x}(0)}{nc_2^2} \\ &+ \dot{y}(0)t \\ &- \frac{4(nc)^2 \dot{y}(0) + 2c(5c^2 - 2)n^3 x(0)}{n^2 c_2^2} t \\ &+ \frac{4(nc)^2 \dot{y}(0) + 2c(5c^2 - 2)n^3 x(0)}{n^3 c_2^3}\sin(nc_2 t) \\ &+ \frac{2c\dot{x}(0)}{nc_2^2}\cos(nc_2 t) \end{aligned} \tag{5}$$

$$\begin{aligned} z(t) = &\frac{\dot{z}(0)}{q}\sin(qt) + z(0)\cos(qt) \\ &- \frac{l}{q}\left[l - qt\left(\cos(f) + \cot(qt)\right)\right]\sin(qt)\sin(f) \end{aligned} \tag{6}$$

Eq. (4) gives the relative position of satellites in the formation which is in a circular orbit under J_2 perturbing force. The relative velocities of this formation flying are:

$$\begin{aligned} \dot{x}(t) = &\frac{2(nc)\dot{y}(0) + (5c^2 - 2)n^2 x(0)}{nc_2}\sin(nc_2 t) \\ &+ \dot{x}(0)\cos(nc_2 t) \end{aligned} \tag{7}$$

$$\begin{aligned} \dot{y}(t) = \dot{y}(0) &- \frac{4(nc)^2 \dot{y}(0) + 2c(5c^2 - 2)n^3 x(0)}{n^2 c_2^2} \\ &- \frac{2c\dot{x}(0)}{c_2}\sin(nc_2 t) \\ &+ \frac{4(nc)^2 \dot{y}(0) + 2c(5c^2 - 2)n^3 x(0)}{n^2 c_2^2}\cos(nc_2 t) \end{aligned} \tag{8}$$

$$\begin{aligned} \dot{z}(t) = &-qz(0)\sin(qt) + \dot{z}(0)\cos(qt) \\ &+ \frac{l}{q}\left[\left(q^2 t\cos(qt) + q\sin(qt)\right)\cos(f) - q^2 t\sin(qt)\sin(f)\right] \end{aligned} \tag{9}$$

This paper will not describe the undefined parameters which have already been defined in [4]. These linearized differential equations will be used to determine the relative position and velocity of THC-3 which we can use to find the discrepant distances between both satellites as well as fuel manoeuvring estimation.

III. EQUATORIAL ORBIT SIMULATIONS

After we have known how to design the repeat cycles and how to determine both satellites as a formation flying, which these things are based to design following our mission requirements, we can now move forwards to the orbit design. In design of the parallel formation flying, THC-2 is the main satellite and THC-3 is apart from THC-2 about 300m as mentioned which is shown in Figure 1 as follows:

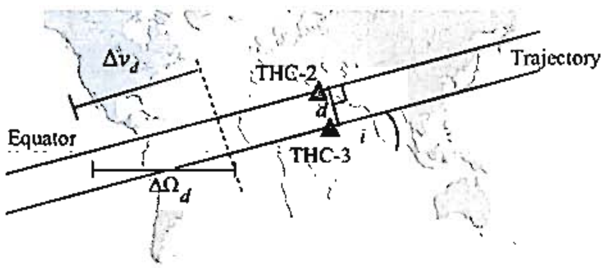


Fig. 1: Parallel Formation Flying

Where $\Delta\Omega$ is the different of the right ascension of ascending node between THC-2 and THC-3, Δv is the different of true anomaly, i is the inclination and d is the distance between both satellites, the $\Delta\Omega$ can be calculated basically as follows:

$$\Delta\Omega_d = \frac{d}{\sin i} \tag{10}$$

$$\Delta\Omega = \left(\frac{\Delta\Omega_d}{R_E + ALT}\right) * \left(\frac{180}{\pi}\right) \tag{11}$$

$$\Delta v_d = d\frac{\sin(90° - i)}{\sin i} \tag{12}$$

$$\Delta v = \left(\frac{\Delta v_d}{R_E + ALT}\right) * \left(\frac{180}{\pi}\right) \tag{13}$$

Equations 10 and 12 are based on cosine method and then changed to angle by Equations 11 and 13.In this paper, we will simulate the equatorial orbit by inclination of 5°, 15° and 30°respectivelybecause we need to clearly compare the goods of orbit design between THEOS-2 and THEOS-1. Figure 2 expresses the parallel formation flying by STK (free license) which defines the orbit elements by Equations 10 – 13 as follows:

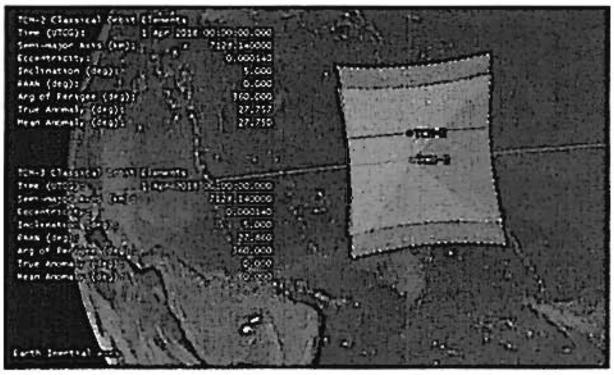


Fig. 2: Example of Parallel Formation Flying of 5° Inclination

5° Inclination Simulation

TheTHAICHOTE-1 (THC-1) is at 820km altitude and 98.7° inclination as sun-synchronous orbit. This subsection will simulate the THC-2 and THC-3 as a parallel formation flying at 700km altitude (repeat cycles ≈7days) and 5° inclination. The satellite control ground station of THAICHOTE satellites is Si Racha-CGS which is in Chon Buri province. The visible revisits of 3 satellites in a day have been shown in Figure 3 as follows:

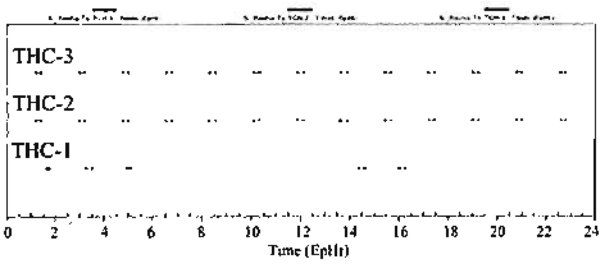


Fig. 3: Times of Re-visibility (5°)

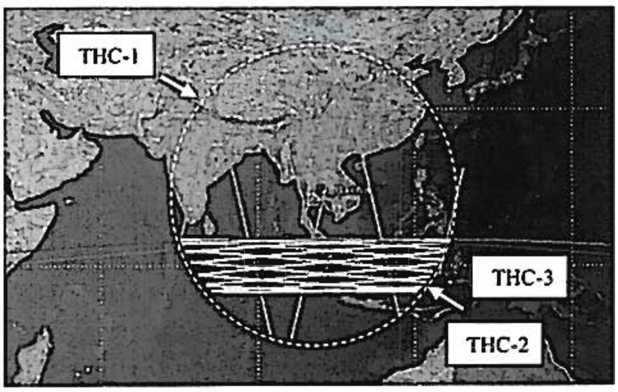


Fig. 4: Visible Area Covered at Nadir (5°)

Figure 4 shows the comparison of visible area covered of 3 satellites at Nadir. Notice that the revisits of equatorial orbit at 5° inclination is more frequently visited than the polar orbit but the visible area covered is less than.

15° Inclination Simulation

This subsection is to simulate the THC-2 and THC-3's orbits by 15° inclination with the same conditions. The times of revisits show in Figure 5 and the visible area covered shows in Figure 6 as follow:

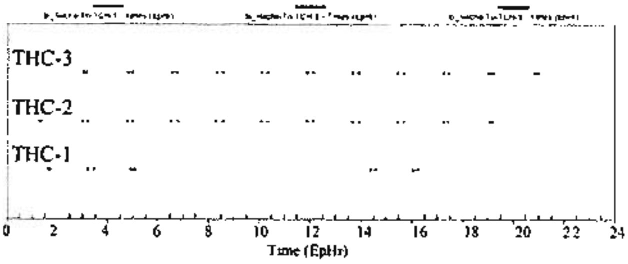


Fig. 5: Times of Re-visibility (15°)

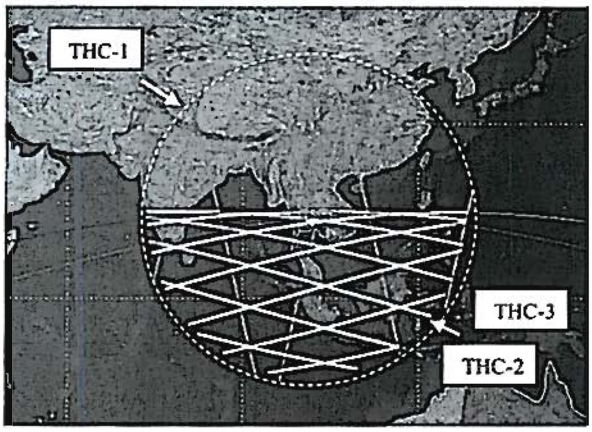


Fig. 6: Visible Area Covered at Nadir (15°)

30° Inclination Simulation

This subsection is to simulate the THC-2 and THC-3's orbits by 30° inclination with the same conditions. The times of revisits show in Figure 7 and the visible area covered shows in Figure 8 as follow:

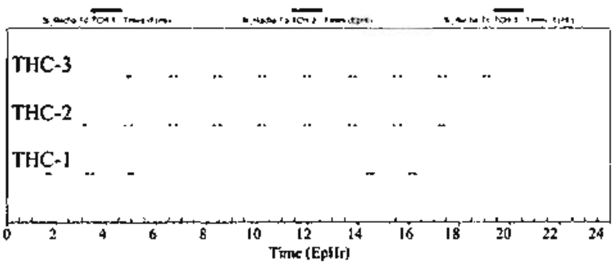


Fig. 7: Times of Re-visibility (30°)

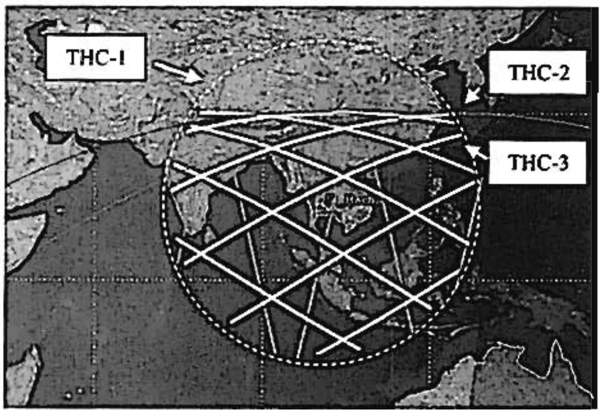


Fig. 8: Visible Area Covered at Nadir (30°)

Figures 3 – 8 have described the difference between THEOS-1 and THEOS-2 already, which we can notice that the satellites in low inclination cannot cover Thailand at Nadir but many revisits. Table 3 summarizes the different things between the satellites in high and low inclination.

Table 3: Comparison of THEOS-1 and THEOS-2 On-Orbits

	THEOS-1	THEOS-2		
Altitude	≈820	≈700		
Orbit Type	Sun-synchronous	Equatorial		
Inclination	98.7°	5°	15°	30°
Area Covered (Thailand)	100%	20%	50%	100%
Revisits/Times In A Day	4-5	12-13	10-11	8-9
Number of Orbits/In A Day	≈14+5/26	≈14+4/7		
Number of Orbits/Repetition	369	102		
Repeat Cycles (Days)	26	7		

The information in Table 3 can be used to consider the orbit design. The necessaries of world-mapping and country-mapping are important in terms of disaster monitoring and military security respectively. However, the world-mapping takes a long time by one optical remote sensing.

The next section is to describe the barrier of equatorial orbit by focusing to the high geomagnetic field in the coast of South Atlantic Ocean, known as the South Atlantic Anomaly (SAA).

IV. SOUTH ATLANTIC MAGNETIC ANOMALY

In South Atlantic Ocean, the magnetic field measured around the coast, as well known named the South Atlantic Magnetic Anomaly (SAMA), is unusually low. The SAMA is one of the most outstanding features of the intense geomagnetic field. The SAMA area of influence coincides with a region in space of intensive radiation close to Earth. The SAMA causes damage to the satellites in low altitude and particularly to low inclination.

The trapped particles are related to the magnetic field. Figures 9 and 10 represent a world map at 700km altitude of the trapped proton (>10 MeV) and trapped electron (>1 MeV) distributions respectively by SPENVIS as follow:

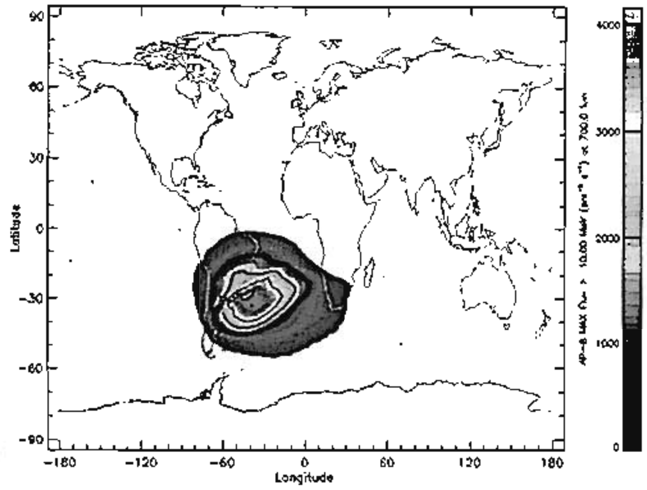


Fig. 9: World Map of the AP-8 MAX Proton Flux >10 MeV at 700 km altitude

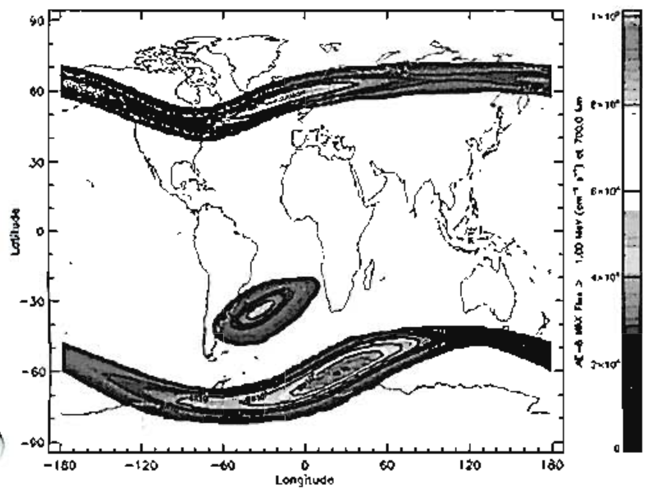


Fig. 10: World Map of the AP-8 MAX Electron Flux >1 MeV at 700 km altitude

The SAMA of proton and electron is shown in above figures. Proton fluxes are negligible outside the SAA, but electron fluxes can be very high at high latitudes where field lines from the outer electron belt reach down to low altitudes.

Ionizing Radiation Damage to Satellite

The particles associated with ionizing radiation are the trapped radiation belt particles (or Van Allen belts) as shown the effects in Figures 9 and 10. The Earth's magnetic field concentrates large fluxes of high-energy, ionizing particles including electrons, protons, and heavier ions as mentioned. The Earth's magnetic field provides the mechanism that traps these charged particles within the South Atlantic Ocean. Results from the ionizing radiation damage are a variety of physical mechanisms and systems of spacecraft shown in Table 4 as follows [5]:

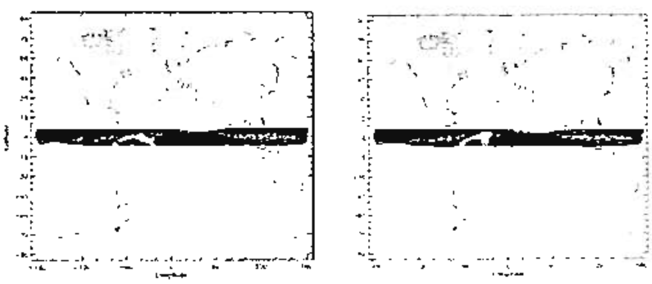
Table 4:Space Environment Effects to Satellite Subsystems

	Plasma	Ionizing Radiation	Magnetic Field
Optics	Reattraction of Contaminants, Change in Surface Optical Properties	Darkening of Windows and Fiber Optics	N/A
Communication	EMI Due to Arcing	N/A	Locating South Atlantic Anomaly
Avionics	Upsets due to EMI from Arcing, S/C Charging	Degradation: SEU's, Bit Errors, Bit Switching	Induced Potential Effects
Thermal Control	Reattraction of Contaminants, Change in Absorptance/ Emittance Properties	N/A	N/A
Propulsion	Shift in Floating Potential due to Thruster Firing Making Contact with the Plasma	N/A	N/A
Electric Power	Shift in Floating Potential, Current Losses, Reattraction of Contaminants	Decrease in Solar Cell Output	Induced Potential Effects
Structure	Mass Loss from Arcing and Sputtering, Structure Size Influences S/C Charging Effects	N/A	Induces Currents in Large Structures
Materials	Arcing, Sputtering, Contamination Effects on Surface Properties	Degradation of Materials	N/A

The trapped particles are subjected to optical payloads, navigations system or avionics and the degradation of solar cell as well as materials

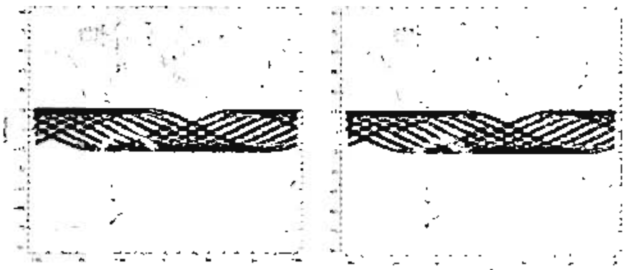
Trapped Ionizing Radiation On-Orbit

This subsection is to show the influence of ionizing radiation focusing on proton and electron for THC-2 and THC-3 at 700 altitude and inclination of 5°, 15° and 30° respectively.



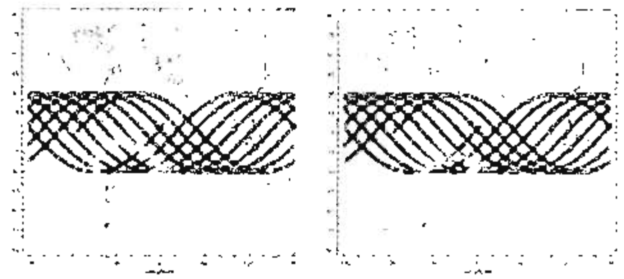
a.) Proton Flux b.) Electron Flux

Fig. 11: World Map of Integral Flux On-Orbit 5° inclination



a.) Proton Flux b.) Electron Flux

Fig. 12: World Map of Integral Flux On-Orbit 15° inclination



a.) Proton Flux b.) Electron Flux

Fig. 13: World Map of Integral Flux On-Orbit 30° inclination

Figures 11 to 13 show the difference of inclination at 700 altitudes for THC-2 and THC-3 equatorial orbit design. In Figure 11, it can easily notice that every orbit has to pass the SAMA region. In Figure 12, even if some orbit does not orbit through the intense magnetic region, but most of orbits have to visit. Figure 13 clearly shows when the inclination increased, many orbits do not pass the intense magnetic region, however, do not forget the Figure 10 because there are the very high electron fluxesat high latitudes where field lines from the outer electron belt reach down to low altitudes. Figure 14 shows the simulation of THAICHOTE-1 orbit at the inclination of 98.7° as follows:

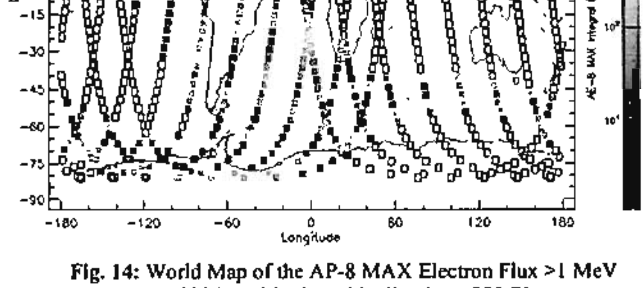


Fig. 14: World Map of the AP-8 MAX Electron Flux >1 MeV at 820 km altitude and inclination of 98.7°

Figure 14 shows the simulation of THAICHOTE-1 that always orbits through the special intense magnetic field where traps the radiation belt particles including electrons, protons, and heavier ions as mentioned.

V. DAMAGE PREVENTION TECHNIQUE

This section is to demonstrate a technique for damage prevention our satellites, THC-2 and THC-3 in equatorial orbits from the SAMA region. Normally, the shielding protection of electric circuits against the ionizing radiation effects always uses to protect satellites and instruments. Even if some technique also uses a technique of board reset and/or power-on reset effort, but the storming protons, electrons and heavier ions in SAMA region can destroy the satellite and instrument immediately whenever satellite flies through the region because it may be subjected to an unequal flux of ions and those protons and electrons.

This paper proposes a damage prevention algorithm that will be embedded into a part of On board Computer (OBC). The algorithm points to control the satellites by shutting down the avionics system of the satellites before the SAMA region and start the systems again after the region. The importance is how to know when the satellite closes to the special region, the intense magnetic field area, SAMA. The time and space variation of SAMA depends on the morphological behavior of the whole field. The SAMA center has been taken as the locus of minimum intensity in the South Atlantic. The anomaly center is computed from spherical harmonic expansions of the geomagnetic potential, i.e. geomagnetic field models such as DGRF, IGRF or GUFM1. The DGRF and IGRF models provide sets of Gauss coefficients up to spherical harmonic degree $n = m = 10$ (or 13, for IGRF 2000 onwards) and GUFM1 up to $n = m = 14$. Components X, Y and Z of the geomagnetic field can be expressed as functions of time (t) and spherical coordinates (r, θ, λ) by [6]:

$$X(r,\theta,\lambda,t) = \sum_{n=1}^{\infty}\sum_{m=0}^{m}\Big[g_n^m(t)\cos m\lambda + h_n^m(t)\sin m\lambda\Big]\frac{dP_n^m(\theta)}{d\theta}\left(\frac{a}{r}\right)^{n+2} \quad (14)$$

$$Y(r,\theta,\lambda,t) = \frac{1}{\sin\theta}\sum_{n=1}^{\infty}\sum_{m=0}^{m}\Big[mg_n^m(t)\sin m\lambda + mh_n^m(t)\cos m\lambda\Big]P_n^m(\theta)\left(\frac{a}{r}\right)^{n+2} \quad (15)$$

$$Z(r,\theta,\lambda,t) = \sum_{n=1}^{\infty}\sum_{m=0}^{m}\Big[g_n^m(t)\cos m\lambda + h_n^m(t)\sin m\lambda\Big]P_n^m(\theta)\left(\frac{a}{r}\right)^{n+2} \quad (16)$$

Where $P_n^m(\theta)$ is associate Legendre polynomial, $g_n^m(t)$ and $h_n^m(t)$ are field models Gauss coefficient. The total field is simply obtained as follows:

$$B = \sqrt{X^2 + Y^2 + Z^2} \quad (17)$$

Figure 15 shows the geomagnetic filed total intensity map following the above equations as follows:

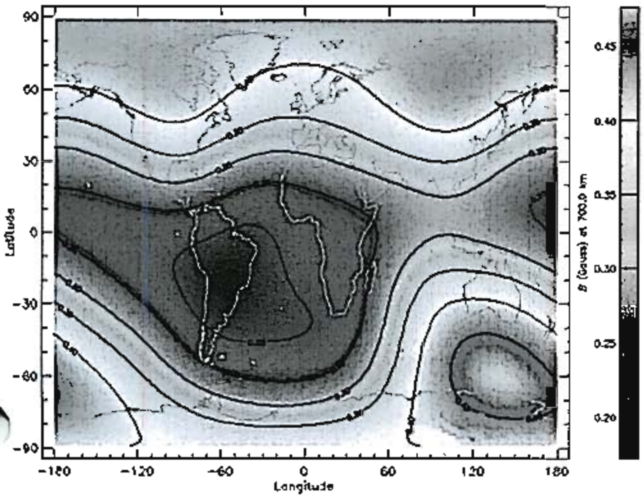
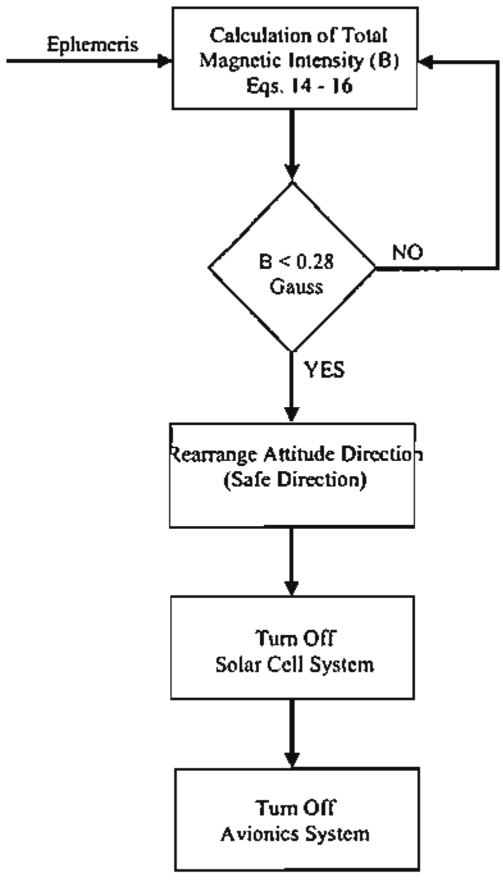
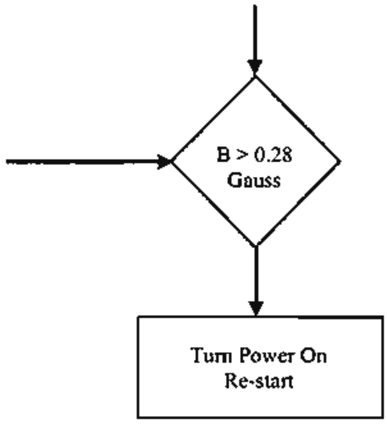


Fig. 15: Geomagnetic Field total Intensity at 700 km altitude

The geomagnetic field is shown in Figure 15 as mentioned which can compute by Equations 14 – 16. The anomaly magnetic field is shown in SAA region.

Algorithm 2 : Prevention Technique





The technique is to calculate the total magnetic intensity, when B is lower than 28,000 nT, then the avionics system will be turn off, and will be turn on again when B is greater than 28,000 nT. This technique is not difficult but after re-starting, the navigation system needs to also be activated and take a few minutes for GPS data acquisition.

However, we can compute the prevention timing by ground station, and then upload the plan to the satellite, therefore the satellite operators have to concentrate for the many orbits in a day (equatorial orbit).

VI. CONCLUSION

This paper focused the orbit design of THAICHOTE-2 & 3. It discussed the satellite orbit design for the second and third EOS of Thailand. This paper had simulated the satellites by equatorial orbit and performed as a formation flying. We also considered a serious issue in equatorial orbit design, namely the issue of the geomagnetic field in the area of the eastern coast of South America, called the South Atlantic Magnetic Anomaly (SAMA) as expressed.

The high-energy particles of SAMA comprised a radiation environment which could travel through THAICHOTE-2 & 3 material and destroy the avionics system of them. A technique of radiation ionizing prevention had been proposed. The technique was to calculate the total magnetic intensity as shown in Eqs.14-16, and then determine the criteria of low magnetic intensity (B) as shown in Figure 15. The criteria was B < 28,000 nT that was the magnitude scalar of the intensity of SAA region. The THC-2 and THC-3 that were designed for an equatorial orbit flied through the special region, the algorithm would be activated. In the algorithm, the solar cell circuit panel must be shut down, and then avionics system respectively. As mentioned, this procedure has to take time for initiate navigation system as GPS data acquisition.

The future work is to apply this algorithm with a micro-satellite of GISTDA, which it is a near future project. The micro-satellite is not only for optical remote sensing but also aim to develop for scientific. Even if the micro-satellite is not designed for equatorial orbit, but definitely pass the SAA region inevitably.

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