Satellite Engineering for Thailand

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Abstract

This paper presents the development of Thailand space technology from beginning until present-day, and includes the vital direction and guide line for the future development. The paper also describes the basic principles in satellite engineering area such as bus systems, payload systems and orbital elements. This aims to provide the background, and corrects the understanding to participant and anyone who interests the satellite engineering. The last section of this paper describes the designing procedure in satellite manufacturing, and includes the ThaiPaht-2 project.

Keywords: Satellite Engineering, designing procedure in satellite manufacturing, ThaiPaht

1. Introduction

Human has interested in space since the ancient time. The ancient people studied the locations of star in the sky and its constellations relative to its motions for life living and astrology. The astrology has influenced in life living of people until the present day.

As that time, the new scientists such as Galileo and Copernicus pointed out that the Earth is not the centre of the solar system. This argument was against the belief of people and religion, and caused those scientists in troubles for many years. Since the people have been educated, the science of astronomy has been accepted, and believed that Earth is not the centre of the solar system.

In the past, human always fascinated to travel into space, but their obstruction was that there was no existing space ship or space vehicle at that time. Until 1903, Russian mathematician, Konstantin Tsiolkovsky, published his article described a rocket which can travel into space using liquid fuel. Since then, many scientists studied on the use of liquid fuel, and developed the modern rocket which can be used to travel into space.

In 1957, Russia marked on the space history, the ever first satellite called Sputnik was launched into space and orbit around the Earth successfully.

Although, the Sputnik had not much capability and reentry into atmosphere after a couple months in orbit, but it was the beginning of new era of space activities. This leads to technology development and wide spread use until the present day.

Thailand commenced the utilisation of space in 1966 by enrolling as a member of Intelsat for international communications, and a member of Inmarsat for mobile communications.

Thailand's ministry of transportation conceded a satellite project to a private company, called ThaiCom for domestic and international communications. At the present time, there are 5 ThaiCom satellites in the orbit, but only 4 satellites are currently operating.

Thailand first used space imaging taken by satellites for natural resource observations in 1971 by collaborating with NASA in the project of ERTS (Earth Resource Technology Satellite). At the beginning, we only received the satellite image from NASA, but however, later on we received the satellite image from India and France.

The satellite development of Thailand began in 1996, on the TMSAT (Thai Micro Satellite) project which is under the collaboration of Mahanakorn university of technology (MUT), United Communication limited (UCOM) and university of Surrey. 12 Thai engineers (11 from MUT and 1 from UCOM) participated in technology transfer program at CSER (Centre for Satellite Engineering Research), university of Surry, UK. Thai engineers were educated and trained to build a small satellite, TMSAT. It took a year to finish the program (in 1997). TMSAT was the ever first satellite built by Thai engineer. TMSAT was launched into space on 10 July 1998 by Zenith-II launcher from Baikanur, Kazakstan. Later on, in October 1998, TMSAT was renamed as ThaPhat given by the King. The objective of ThaiPhat mission was for education, the use of satellite image, and store-forward communication.

In 2003, Thailand's ministry of science and technology purposed the small satellite project, THEOS (Thailand Earth Observation System) by procuring from France. The first launched date was set in 2007, but it was postponed several times. At last, it was launched into space on 1 October 2008.

Furthermore, ministry of information and communication technology collaborated with China to develop and build the Ka-band payload for Small Multi-

Mission Satellite (SMMS) satellite. It was launched into space on 6 September 2008 from the south part of China.

Every country tries to develop its own space technology due to the plenty of natural resources on the planets in the solar system. However, as we know that each subsystem of space technology is extremely expensive. Therefore, the way of purchasing space technology is not the long-term development. If we choose this way, we have to purchase all the time. Furthermore, this will cause the lack of country's competency in space competitions.

Therefore, it is necessary to develop own technology in order to gain the knowledge and expertise of people who work in this area. In addition, the long-term budget of development would reduce to one third. In past 10 years, China and South Korea are a good example. They develop their own space technology and export those technologies to other countries in Asia and Europe.

2. Satellite System

Satellite system consists of ground segment and space segment. The ground segment has a substantial role to communicate and control the satellite to operate under the desired mission. The ground station which uses for these purposes, could be the fixed station or mobile station. The launch site is also included in the ground segment.

The space segment is the space vehicles that operate under the mission objectives such as navigation remote sensing, communication, military purposes, space science and astronomy.

Each artificial satellite was built and operated in such a different activity which depends on the objective of the mission. However, in general, the satellite modules consist of bus and payload.

Satellite bus is substantial subsystems which required for each satellite to operate following the basic functions. The bus subsystems are the structure subsystem, power subsystem, attitude determination and control subsystem (ADCS), telemetry telecommand and tracking subsystem (TT&C), onboard data handling (OBDH) subsystem, thermal control subsystem, and propulsion subsystem. Basically, most of LEO (low Earth orbit) and MEO (medium Earth orbit) satellites may not require the thermal control subsystem. However, the propulsion subsystem is specifically required for the missions which have to change the orbit in space.

Satellite payload is such a module that used specifically for the mission objective, for example, the multi-spectrum camera modules for remote sensing satellite or Earth observation satellite, transponders or communication payload for communication satellite, telescopes or scientific instruments for scientific satellite or astronomical satellite, atomic clock on navigation satellite.

3. Satellite Orbit

As there is unclear criterion of the boundary of Earth's atmosphere and space, therefore, the allowing region in space for space activities is still obviously undefined. The selection of orbit's altitude is depended on the objective of individual mission. However, the space environment is one substantial factor for high altitude missions. Therefore, the mission designer has to take this factor into account.

In general, we could distinguish the satellite orbit into three levels associated with altitude.

3.1 Low-Earth Orbit (LEO)

Generally, a LEO is defined as the orbit from the Earth's atmosphere up to the inner of Van Allen radiation belt. However, the commonly known definition for LEO is between 160 km up to 2,000 km, above the Earth's surface. As this orbit is inside the Van Allen belt, the satellites will be protected from the high-energy particles come along with solar wind. However, a region known as "South Atlantic Anomaly" where Earth's inner Van Allen belt closes to the Earth's surface, the radiation intensity is greater than elsewhere. The LEO for operational satellites can be categorised by using the orientation of orbital plane; polar orbit and inclined orbit.

3.3.1 Polar Orbit

The polar orbit is an orbit that satellites pass over both North and South poles of the Earth. Polar orbits are generally used for earth observation and weather monitoring. As the Earth rotates itself while the satellites orbit around the Earth, then satellites can take images around the globe.

3.1.2 Inclined Orbit

An inclined orbit is an orbit that its orbital plan makes an angle to the equatorial plan, generally from zero to 180 degrees. If the orbit combines altitude and inclination that causes a satellite on that orbit ascends or descends over any given point of the Earth's surface at the same local mean solar time, we call this as a Sun-synchronous orbit which is very useful for Earth observation mission.

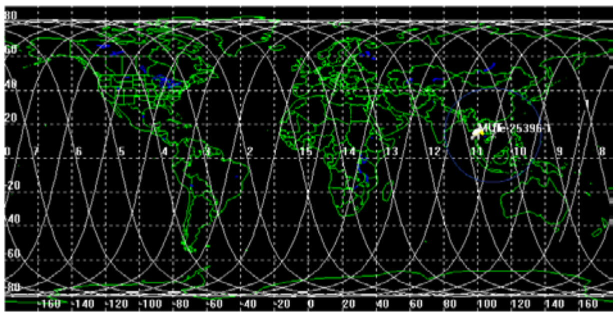

Figure 1. Satellite ground track of ThaiPah-1

3.2 Medium-Earth Orbit (MEO)

A MEO is defined as the region of space around the Earth above LEO and below geostationary orbit (altitude of 35,786 km). Some reference calls this MEO as intermediate circular orbit (ICO). The most common use for satellites in 20,000 km altitude is for navigation, such as the GPS, GLONASS and Galileo constellations. The orbital period is about 12 hours.

3.3 Geostationary Orbit (GEO)

A geostationary orbit (or Geostationary Earth Orbit - GEO) is an orbit above the Earth's equator, which has a period equal to the Earth's rotational period, and its orbital-eccentricity is zero approximately.

The satellites on the GEO appear motionless in the sky. This makes the GEO an orbit of great interest to operators of communications and weather satellites. As the limitation of the location around the equatorial plane for placing the GEO satellite, the non-operated satellites or end-of-life satellites will be transfer to the graveyard orbit also called a super GEO orbit, junk orbit or disposal orbit, altitude 300 – 400 km higher than GEO.

3.4 Conventional Orbit Propagators

As the satellites are orbiting around the Earth, its locations with respect to the Earth are changing all the time. In order to communicate to those satellites, the ground control station has to known the satellite's location.

There was a research activity for modelling the mathematic model to propagate the space-object location. It categorised satellite's orbit into two groups: near-Earth satellite and deep space satellite. The near-Earth satellite was defined an orbit which its period is less than 225 minutes. The orbit propagator for this group was called "Simplified General Perturbation (SGP)". The deep space satellite was defined an orbit which its period is greater than 225 minutes. The orbit propagator for the second group was called "Simplified Deep Perturbation (SDP)".

In the current time, the military organisation called NORAD (North American Aerospace Defense Command) makes use of radar to track all the objects in the space. The tracked data over period of given time was reprocess and generated into two line element (TLE) format. The detail of each parameter is described in [7]

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1 25396U 98043C 07225.74731988 +.00000122 +00000-0 +71717-4 0 08858
2 25396 098.4223 274.6600 0003507 051.3198 308.8309 14.23737884472474
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Figure 2. TLE of Thaipath-1

4. Satellite Designing

4.1 System Requirements

At the beginning of satellite project, it is necessary for mission designers to define the mission requirements and constraints, for example, the coverage area, capabilities of Earth observation system, pointing accuracy, budgets and construction period.

4.2 Conceptual Design

Once the mission requirements and constraints are defined, the following step is a conceptual design. In this step, the mission designers and engineering team will define the whole satellite from top level to segment level. Furthermore, the mission designers have to take the tradeoff of each part into account, including the launch opportunities.

4.3 Preliminary Design

The next step is to design all subsystems which are defined in the conceptual design. The functional link between subsystems will be defined, and transformed the requirements of each subsystem into the form of hardware specifications. The refine procedure will be exploited for technical correction. Once the preliminary design is concluded, the prototype will be synthesised for procurement and construction planning.

4.4 Detailed Design

Once the preliminary design is finished, the following step is to design each subsystem in deep detail. The complete designing has to follow the structure and thermal analysis planning, construction and integrate planning, testing planning and in-orbit-operation planning.

5. ThaiPaht-2

The ThaiPaht-2 is the consecutive project of ThaiPaht-1. An objective is to build and train a Thai-engineer team for constructing a satellite in Thailand. The mission requirement is to develop the S-band communication payload and Earth observation system.

5.1 S-band communication payload

A S-band communication payload is developed to perform the wideband CDMA at high speed 8 Mbps. This payload will be used as the prototype of Third Generation Mobile Satellite project. The knowledge and expertise which gained from this project will be exploited to industrial for developing a ground control segment in the future.

5.2 Earth Observation System (EOS)

An Earth observation system (EOS) is developed to take the image. The capability requirements are 10 metre for multi-spectrum, 5 metre panchromatic, and 40 km swath width.

The developed multi-spectrum EOS makes use of four push-broom scanning cameras to response 4 bands of wave length (red, green, blue, and near infrared). The data of taken image will be processed by the onboard processing of camera head which is similar to the image processing module onboard ThaiPaht-1.

The panchromatic EOS makes use of a single push-broom scanning camera which provides a high resolution of spatial information.

As the result of the conceptual design and preliminary design, the requirement of EOS is listed as follows,

- swath width 40 km (orbit at 670 km altitude)
- onboard memory 20 Gbyte for each camera head
- 2 high speed link to onboard data handling
- 1 high speed link directly to RF transmitter

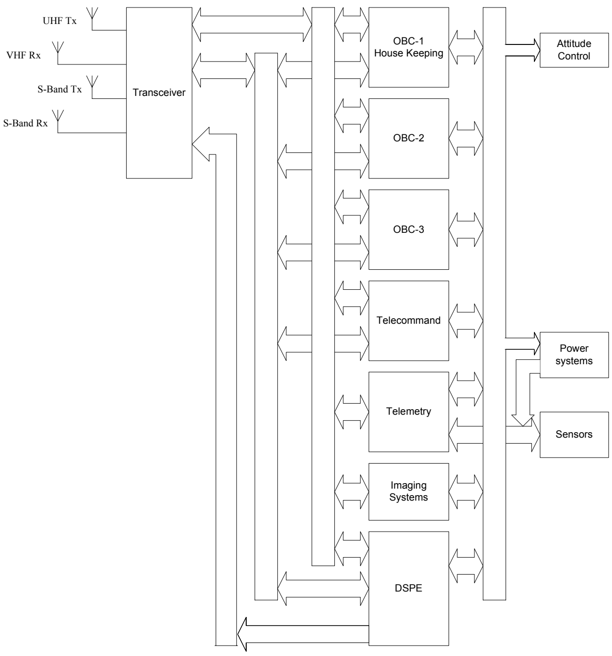

Figure 3 diagram of ThaiPaht-2

5.3 Orbit/Attitude Design and Analysis

From the results of the orbit/attitude design and analysis for Thaipaht-2, the requirements are listed as follows

- Sun synchronous orbit at 670 km and 98 degree inclination
- passing time : descending node at 10:00AM at equator
- revisit: 3 days
- three axis attitude control system
- attitude accuracy 0.5 to 1.0 degree
- attitude sensors **:**
  (1) 3-axis magnetometer (plus 1 redundancy)
  (2) fine Sun Sensors (plus 1 redundancy)
  (3) 3 course Sun Sensors
  (4) 3 gyros
- attitude actuators
  (1) 3-axis magnetic Torquer (plus 1 redundancy)
  (2) 3 momentum wheels

5.4 Power Analysis

The primary source of ThaiPhat-2's power system consists of four panels of (80×40 cm^2) GaAs which attach around satellite body. From calculation, each panel will provide 93 watts BOL (beginning of life) approximately. The EOL (end of life) is 68 watts approximately.

From the power budget calculation, the ThaiPaht-2 takes power consumption 45 watts in normal condition, and 54 watts while taking image. The Lithium-Ion is chosen as the storage cell. The capacity 10 Ahr battery with 25% DoD (depth of discharge) is selected for operation.

5.5 Data Flow Analysis and Communication Link

The imaging data will be downloaded to ground segment using X-band communication link at 40 Mbps. The calculated link budget, Eb/No, is 10.5 dB approximately. The figure of link margin is 8.40 dB for 10 metre of ground antenna. The transmission time for 40×200 km image size is about 2 minutes.

6. Conclusions

If we study the background of the successful countries in space activities, those countries makes use of space technology for terrestrial applications. This leads to advance technology development for industrial interests. At the beginning of development, those countries do not have their own space technology. They have to invest in every new part which relative to space technology. Once they have their own space technology and gain their knowledge and expertise, the cost of development for other programs was significantly reduced. Furthermore, the benefit from the use of space technology will return back in such a way of economic aspects and defense concern.

For Thailand, the satellites play a major roles in many aspects such as communication for broadcasting, tele-education, and tele-medecine; remote sensing for natural resources management and spatial management.

As space is a region of mutual benefit for human and world nation, it is necessary for Thailand to develop own space technology. As we may know that the cost of development would be only a half of the price of whole satellite. We can also exploit the knowledge and expertise to industrial interests.

To build a satellite, the multi-disciplinary in engineering expertise is required such as mechanical engineering, electrical engineering, and computer engineering. Therefore, a key to success is how to work as the team, and how to manage the project on the right direction. That is the reason why the difficulty of technology development is so high unlike the purchasing the whole satellite.

The lack of budget, encouragement and vision of involved people in space organisation are the major obstructions to develop own space technology. The moderate approach with small amount of budget may commence to develop and build the engineering model of subsystems. To build the engineering model, the commercial-grade components are adequate. The advantage of this approach is that the functional operation of subsystems and between subsystems can be tested and verified the conceptual and preliminary design.

Once the test results based on the engineering model provide a substantial information and gain knowledge and expertise of engineering team, the qualification model is the next target. To build the qualification model, the flight components are required. If the test results based on the qualification model provide confident results. We would go on to build the flight model. However, some subsystem which its designing has already proven, the engineering model and qualification model can be wrapped up as a single model. This moderate approach can be used the expertise from the people who work in the industrial and university. This is a value added of the own technology development.

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