Chapter

System Designs of Microsatellites: A Review of Two Schools of Thoughts

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Abstract

Microsatellite has been considered as disruptive technologies in satellite engineering. Its development cost and time provide advantages for new kind of Earth observations, telecommunications, and science missions. The increasing trend of microsatellite launches and operations means that the approach was so successful that it could create funding sustainability. Major contributing factors of its success were due to the system design of the microsatellites. This chapter discusses two microsatellite system design approaches, namely Technical University of Berlin heritage and University of Surrey heritage. Both Universities provide approaches for system design and build of microsatellite systems. The design approaches are being compared along with lessons learned. The choices of microsatellites to be compared in this chapter will be those that are manufactured about the same time such that the technology compared is mostly the same and flown in-orbit. The chapter shows that the differences between the two system design approaches are on the choice of main computer and associated link configuration and in the attitude control modes. Another major different is in the satellites' structure design. For some satellite's components, incoming technologies have made the design choices from the two schools of thoughts converged.

Keywords: satellite design, system design, microsatellites, TU Berlin, University of Surrey

1. Introduction

Microsatellite has typical weight between 20 and 170 kg at launch as auxiliary payload. It is initially made as technology experiment and education tools by universities. Nowadays, microsatellite becomes a common space platform for commercials and emerging space nations. The commercial mission is typically Earth observation, data collecting platform (text-based communication), including ships and aircraft tracking. Studies done by Swartout [1] show that between 2009 and 2012, about 8–12 satellites with mass above 50 kg as auxiliary payload were launched yearly. The data also show that the trend seems to be steady. Bunchen and De Pasquale [2] noted that 105 satellites with mass of 11–50 kg were launched between 2000 and 2013.

Surrey Space Technology Limited (SSTL), a subsidiary company under University of Surrey, is one of the companies that initiated the use microsatellite technology as commercial Earth observation satellite platform. It built a constellation of five satellites named Disaster Monitoring Constellation (DMC) in 2003, with payload of 3-band multispectral imager of 30-m resolution, which was intended for wide-swath land coverage imaging. After the first constellations decommissioned, it built the second generation with better resolution (20 m). The first launch of DMC-2 constellation was done in 2009 [3].

Since 2013, Skybox/Skysat has deployed 15 satellites that carry 1-m panchromatic imager and 2-m 4-band multispectral imager [4]. Unlike DMC, which mission objectives are to observe wide areas with nadir pointing scanning mode, it aims to provide frequent repeat very high resolution images using massive numbers of highly maneuverable satellites. Another commercial Earth observation microsatellite constellation mission is prepared by Axelspace. The company planned to have 50 satellites launched starting 2017. The satellite carries imager with 2.5-m panchromatic and 5-m multispectral [5, 6]. **Figure 1** shows the configurations of the Skybox and Grus satellites, which show that Skybox uses single lens and parabolic data downlink antenna, while Grus uses two lenses and horn-type data downlink antenna.

In addition to Earth observation missions, microsatellite constellation also being built for Low Earth Orbit (LEO) telecommunication mission. OneWeb and Telesat are two companies that will launch hundreds of microsatellites in coming years [7, 8].

The use of microsatellites for commercial purposes means that the technology is mature enough to ensure good return-of-investment. One of the major aspects that contribute to the success of microsatellite technology is its system design. Therefore, the objective of this chapter is to provide insight into microsatellite system design. The chapter addresses the question related to limitation in weight and size, and how the satellite designer manages to meet the mission requirements.

Out of many microsatellites developers, two system designs of microsatellites, namely Technical University (TU) Berlin heritage and University of Surrey heritage, are selected for comparison in this chapter, due to their very different design approaches. To be comparable, the choices of microsatellite system to be compared are the ones that manufactured about the same time, so that the technology available is mostly the same. The microsatellites also have to have in-orbit experience, so its design success can be measured. Data mining resulted that the satellite operation year chosen is between 1999 and to date. For TU Berlin system, the choices are DLR-TUBSAT, MAROC-TUBSAT, Indonesian LAPAN-TUBSAT, LAPAN-ORARI, and LAPAN-IPB. Meanwhile, for University of Surrey system, the choices are Korean KITSAT-3, STSat-1 and STSat-3, as well as Turkish BILSAT-1 and RASAT.

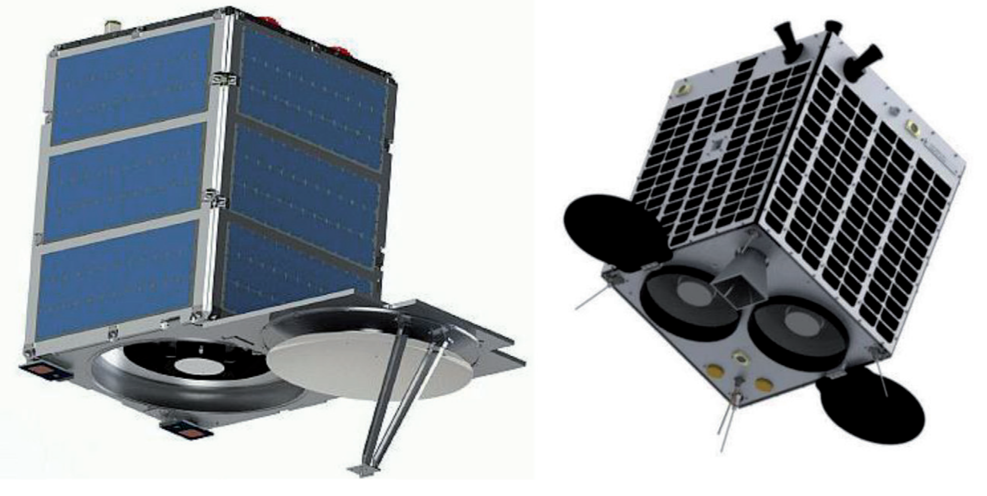

Figure 1.
Google Skybox satellite and Axelspace's Gruz satellite design.

This chapter is divided into five sections, with the first section introducing the background and objectives of the chapter. The second section explains how the satellite design samples for the University of Surrey heritage were selected, and what satellite design parameters were used in the comparison. Section 3 displays the satellite design parameters for TU Berlin heritage. Section 4 provides analysis from the comparison of the two-design heritage, in term of parameters noted in the previous two sections. Section 5 summarizes the analysis and provides recommendation for further studies regarding the subject.

2. University of Surrey heritages

University of Surrey is known as one of the pioneers in the design and build of microsatellite in the 1990s. It started launching microsatellite in 1991 with amateur

	KITSAT-3	BILSAT-1
Operation	1999–2003	2003–2006
Bus		
Solar panel	3 GaAs (2 deployable) @ 50 × 85 cm, (150 W)	4 GaAs @ 60 × 60 cm (58 W)
Battery	NiCd; 10 V; 8 Ah	NiCd; 28 V; 4 Ah
Reaction wheel/Gyro	3 + 1 Teldix DR01/FO laser	4 SSTL/MEMS
Thruster	—	Pressurized gas + resistojet
Star sensor	1	2 Altair
Sun sensor	2 axis	4 × 2 axis
Horizon sensor	2 axis	
Magnetotorquer/meter	3-axis air coils/3-axis fluxgate	3-axis air coils/2 × 3-axis fluxgate
Telemetry, Tracking, and Commanding (TTC)	VHF uplink; UHF downlink	S-band
Data TX	S-band 3.3 Mbps	S-band 8 Mbps
Main computer/link config.	2 × microprocessor/CAN	2 × microprocessor/CAN
Attitude control computer	1	1
Payload data handling	Microprocessor based	FPGA based
GPS	—	SSTL SGR
Payload		
	3-band imager w/ 570-mm lens	2 × 3-band imager w/150-mm lens
	Radiation dose sensor	Pan imager w/300 mm lens
	High energy particle sensor	Store and forward communications
	Scientific class magnetometer	8-band low resolution imager
		CMG
Size (cm)	50 × 60 × 85	60 × 60 × 60
Mass (kg)	110	130

Table 1.
Sample for the University of Surrey microsatellite system design.

radio missions. To simplify the satellite design, the first microsatellite generation has passive attitude control system, that is, using gravity gradient telescopic boom. The university provided microsatellite development and building capabilities to many emerging space countries, including Thailand, Malaysia, South Korea, Algiers, Turkey, and Nigeria. At the time, such countries started to use remote sensing satellites, mostly from the United States and European, for various land-based applications. Therefore, they required remote sensing payloads to include in their satellite missions. Such mission elevates the design requirements to active attitude control system and higher data rate downlink system.

Thailand's Mahanakorn University collaborated with the University of Surrey to jointly develop TMSat that was launched in 1998 [9]. TMSat focuses on remote

	STSAT-1	**STSAT-3**	**RASAT**
	2003–2008	2013–2015	2011–2017
Bus			
Solar panel	3 GaAs (2 deployable); 160 W	3 GaAs (2 deployabl e); 275 W	4 GaAs; 52 W
Battery	NiCd; 14 V; 12 Ah	Li-ion; 20 V; 20 Ah	Li-ion; 28 V; 9 Ah
Reaction wheel/Gyro	4 /FO laser	4 /FO laser	4 /MEMS
Thruster	—	Hall thrust	—
Star sensor	1	2 SaTReC	1
Sun sensor	4 panels +2 cell	Coarse and fine	4 analog
Horizon sensor	—	—	—
Magnetotorquer/meter	3-axis/3-axis fluxgate	3-axis/3-axis	3-axis/2 × 3-axis fluxgate
TTC	S-band	S-band	S-band (primary) and UHF/VHF (emergency)
Data TX	X-band 3.2 Mbps	X-band 10 Mbps	X-band 100 Mbps
Main computer/link config.	Microprocessor/CAN	Leon2-FT (triple redundancy)/CAN and space wire	2 × microprocessor/ CAN and space wire
Attitude control computer	1	1 AIU (attitude interface unit)	1
Payload data handling	FPGA based	FPGA based	FPGA based
GPS	1	1	1
Payload			
	Far UV imaging spectrograph	2× Multiband IR imagers	Pan imager w/840 mm lens
	Space physic sensor	Spectrometer	3-band imager w/420 mm lens
	Data collection system		
Size (cm)	66 × 55 × 83	102 × 103 × 88	70 × 70 × 55.4
Mass (kg)	106	175	95

Table 2.
Sample for the University of Surrey microsatellite heritage system design.

sensing and amateur radio mission. Since Thailand did not continue building its subsequent satellites, TMSat is not selected as satellite design heritage sample in this chapter.

Singapore's Nanyang Technology University (NTU) collaborated with the University of Surrey to jointly develop satellite subsystem for UoSAT-12. However, the satellite is not a microclass and therefore is not selected as a sample for the University of Surrey's satellite system design in this chapter. The satellite subsystem from NTU is a communication payload with S-band downlink and L-band uplink, which provides the Internet protocol communication operating at 1 Mbps. Since the experience with the University of Surrey only in subsystem design and development, the subsequent NTU satellite, that is, XSAT, is also not considered as the University of Surrey heritage satellite [10, 11].

South Korean experience with the University of Surrey satellite design is when Satellite Technology Research Center (SaTReC), an institution under Korea Advanced Institute of Science and Technology (KAIST), jointly built KITSAT-1 and KITSAT-2 and launched it in 1992 and 1993. Both satellites have store-forward communication amateur payload and low-resolution imagers. Since the KITSAT-1 and KITSAT-2 development time does not match with other microsatellite design sample, only the design of KITSAT-3 is used in this chapter. SaTReC then developed STSAT series as its second generation microsatellites. Since STSAT-2 experienced launch failure, only STSAT-1 and STSAT-3 are selected as satellite design samples [12–15].

Turkey's experience with the University of Surrey satellite design is when its space research institute, TUBITAK-UZAY (previously named BILTEN TUBITAK-ODTU), jointly developed BILSAT-1. The satellite was part of DMC-1 constellation [16–19]. After BILSAT-1, the institute then built its second generation microsatellite, RASAT. Therefore, both microsatellites are used as sample for the University of Surrey design heritage [20–23].

Fifteen satellite bus design parameters are selected for the comparison, including 14 mechatronics component parameters in the satellites' design. For the University of Surrey satellite heritage, the parameters are tabulated in **Tables 1** and **2**. Structure design from four of the five microsatellites is shown in **Figures 2** and **3**. Payload parameters also noted in **Tables 1** and **2** to explain the similarity (or differences) in the mission requirements and their impacts to satellite bus parameters. The weight and dimensions are, in additional of drawings, noted in to explain the satellite

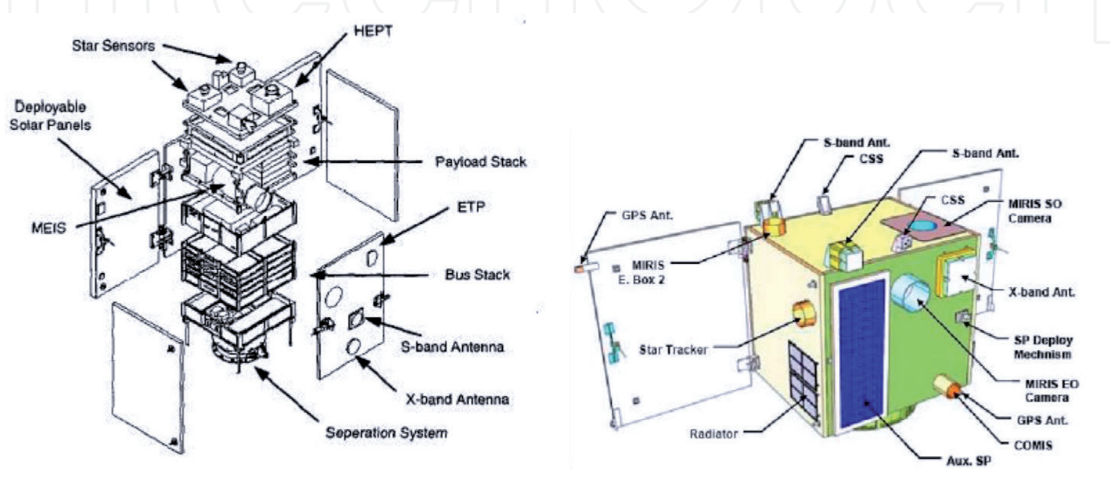

Figure 2.
Mechanical design of KITSAT-3 and STSAT-3.

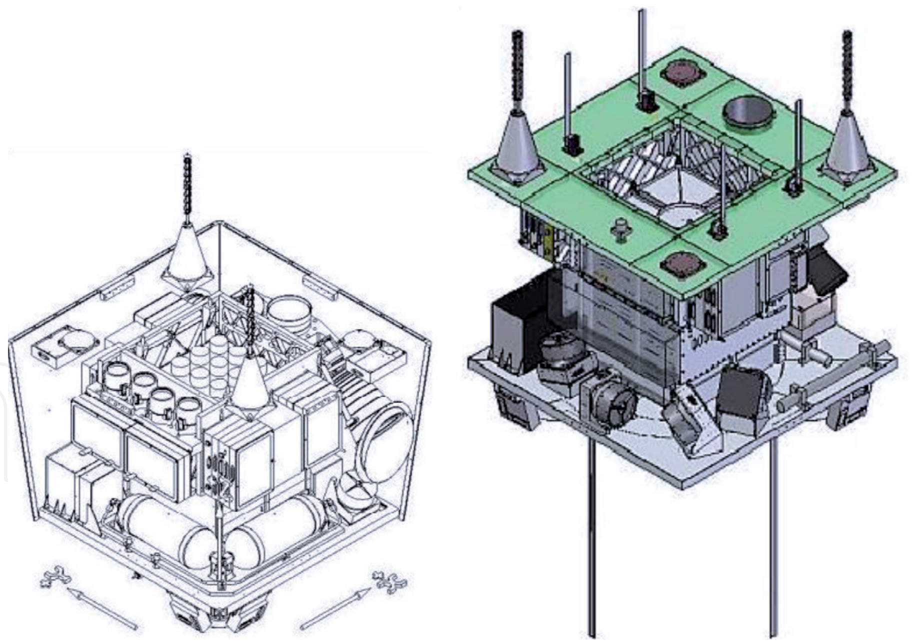

Figure 3.
Mechanical design of BILSAT-1 and RASAT.

structure design aspects. The satellite operation years are noted in the tables to show the context of available technology.

As shown in **Figures 2** and **3**, the University of Surrey heritage satellites use electronic trays for its satellite bus electronics. The aluminum trays also function as load bearing structure, so that the rest of the satellites components, such as reaction wheels and attitude sensors, can be laid out around them. After all components integrated, the solar panels and/or other outside panels that are made of lighter materials can be used to cover the satellites.

3. Technical University of Berlin heritages

Technical University (TU) of Berlin had launched six microsatellites between 1991 and 2007. During such time, the university had provided microsatellite development capacity building to Morocco and Indonesia. However, only Indonesia (Satellite Technology Center) had developed its second generation of microsatellites. **Tables 3** and **4** provide samples of microsatellite systems used for the comparison considering the development and operation time of the satellites. The microsatellite parameters from the TU Berlin heritage shown in **Table 3** are from DLR-TUBSAT and MAROC-TUBSAT, and in **Table 4** are from LAPAN-TUBSAT and two Indonesian built satellites, that is, LAPAN-ORARI and LAPAN-IPB. Additionally, the four satellite structure drawings are presented in **Figures 4** and **5** [24–29] for the comparison of structural design.

The author should describe the key differences among the four structure designs presented in **Figures 4** and **5**.

As shown in **Figures 4** and **5**, for the TU Berlin satellite heritage, the components are laid out in boxes. For DLR-TUBSAT and Maroc-TUBSAT, they are modular boxes (ACS, payload, power, etc.). Meanwhile, in LAPAN's satellite series, the boxes are integrated in lower and upper compartments of the same structure. The boxes were made from aluminum plates and therefore function as load bearing structure. The solar panels are directly attached to the outer part of the boxes.

	DLR-TUBSAT	MAROC-TUBSAT
Launch	1999–2007	2001–2006
Bus		
Solar panel	4 Si @32 × 32 cm, (14 W)	4 Si @32 × 32 cm (14 W)
Battery	NiH_2; 10 V; 12 Ah	NiH_2; 10 V; 12 Ah
Reaction wheel/Gyro	3 IRE 203/FO laser	3 + 1 IRE 203/FO laser
Thruster	—	—
Star sensor	—	IRE
Sun sensor	4 panels +1 cell	6 single cell
Horizon sensor	—	—
Magnetotorquer/meter	1 axis coil + 1 rod/–	1 axis/3-axis sensor
TTC	2 UHF w/omni antennas	2 UHF w/omni antennas
Data TX	S-band analog	S-band 256 kbps
Main computer/ link config.	32 bit microcontroller/star	32 bit microcontroller/star
Attitude control computer	—	—
Payload handling	Multiplexer	Recorder
GPS	—	—
Payload		
	B/W video cam. w/16 mm lens	NIR imager w/72 mm lens
	B/W video cam. w/50 mm lens	
	B/W video cam. w/1000 mm lens	
Size (cm)	32 × 32 × 32	32 × 34 × 36
Mass (kg)	45	47

Table 3.
Sample for the Technical University of Berlin microsatellite system design.

4. Analysis

4.1 Power generation and storage

Tables 1 and **2** show that the Korean satellites have employed deployable solar panel (which is also shown in **Figure 1**), since the mission required high power and used direct energy transfer (DET) mode. Such approach is very much different than those used by KITSAT-1 and KITSAT-2, which have body-mounted solar panels. On the other hand, Turkish satellites use body-mounted solar panels and therefore do not have the requirement of one side of the satellite always facing the sun for battery charging.

Tables 3 and **4** show that all TU Berlin heritage use body-mounted solar panels. It uses Si panels for its first three satellites, then opted to higher capacity GaAs panels in LAPAN-ORARI and LAPAN-IPB. Generally, the power budget for the University of Surrey heritage satellites is higher than the TU Berlin heritage, even in the ones with body-mounted solar panels. As shown in **Figure 5**, in LAPAN-IPB, one of the sides has two 46 × 26 cm solar panels. The side is projected to be Sun pointing most of the time.

Battery chosen to be used in the early University of Surrey heritage satellite design is NiCd, while in TU Berlin's satellite design is NiH_2. NiCd batteries require

	LAPAN-TUBSAT	LAPAN-ORARI	LAPAN-IPB
	2007–2013	2015-now	2016-now
Bus			
Solar panel	4 Si @43 × 24 cm, (14 W)	4 GaAs @46 × 26 cm (30 W)	5 GaAs @46 × 26 cm (30 W)
Battery	NiH_2; 14 V; 12 Ah	Li-ion; 16 V; 19.5 Ah	Li-ion; 16 V; 36 Ah
Reaction Wheel/Gyro	3 IRE 203/FO Laser	3 + 1 IRE 303/FO Laser	3 + 1 IRE 303/FO Laser
Thruster	—	—	—
Star sensor	Vectronics (VTS)	VTS, IRE	VTS, LAPAN
Sun sensor	4 panels +2 cells	6 single cells	6 single cells
Horizon sensor	—	—	LAPAN (IR camera based)
Pitch sensor	—	—	LAPAN (CCD based)
Coil/magnetometer	3 axis/–	3 axis/VFMS-51	3 axis/fluxgate scientific class
TTC	2 UHF w/ omni antennas	2 UHF w/ omni antennas	2 UHF w/omni antennas
Data TX	S-band analog	S-band 5 Mbps	X-band 105 Mbps
Main computer/link config.	32 bit microcontroller/ star	32 bit microcontroller/ star	32 bit microcontroller/ star
Attitude control computer	—	—	—
Payload handling	Multiplexer	Digital and analog switcher + recorder	FPGA based
GPS	—	VGPS-51	VGPS-51
Payload			
	Color video cam. w/50 mm lens	Color video cam. w/1000 mm lens	4-band imager w/300 mm lens
	Color video cam. w/1000 mm lens	4 M pix cam. w/1000 mm lens	4 M pix cam. w/1000 mm lens
		AIS (ship monitoring system)	AIS (ship monitoring system)
		APRS (amateur text message)	
		Amateur voice repeater	
Size (cm)	45 × 27.5 × 45	47 × 38 × 50	50 × 57.4 × 42.4
Mass (kg)	54.7	74	115

Table 4.
Sample for the Technical University of Berlin microsatellite heritage system design.

charging controller mechanism ensuring that the battery is completely drained before being charged. This is because partial charging can induce memory effect, which can decrease the battery capacity to its last partial charge state. For NiH_2 batteries, they tend to have large packaging due to its cylindrical shape, as shown in DLR-TUBSAT and LAPAN-TUBSAT drawing (**Figures 4** and **5**), but its charging mechanism is very simple (can do trickle charging). As soon as Li-ion battery technology available, both designs opted out Li-ion battery for its easy handling (no memory effect) and higher power-to-mass ratio.

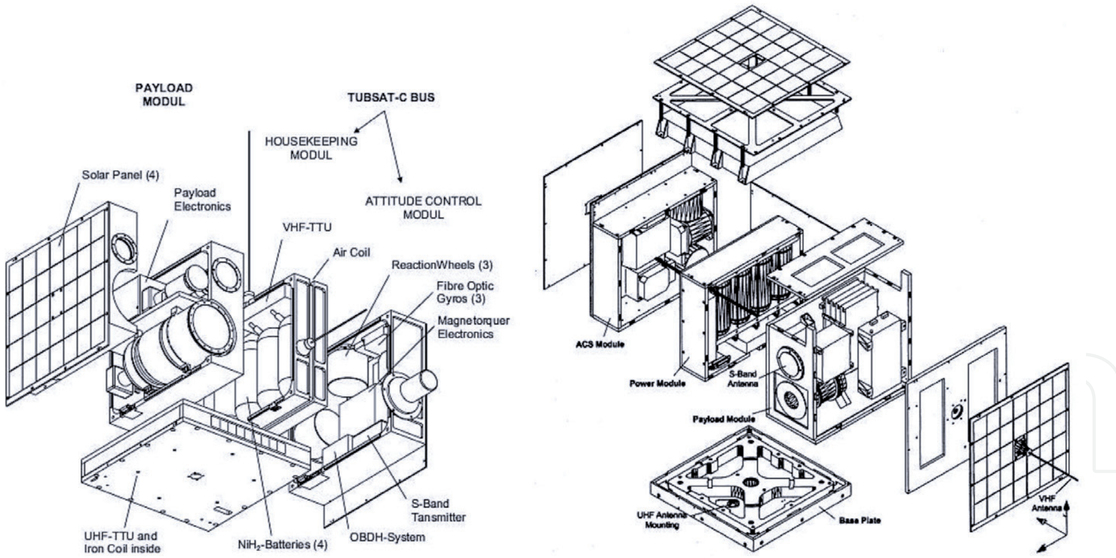

Figure 4.
Mechanical design of DLR-TUBSAT and MAROC-TUBSAT.

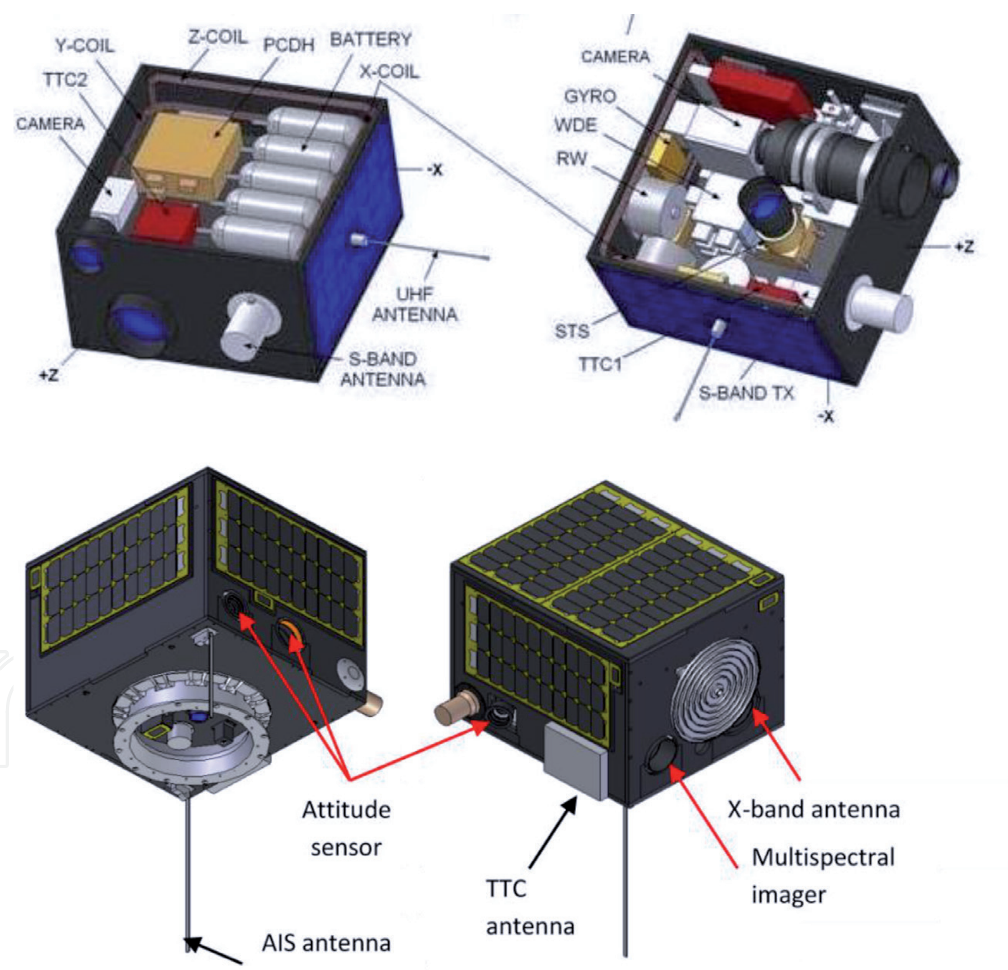

Figure 5.
Mechanical design of LAPAN-TUBSAT and LAPAN-IPB.

4.2 Main computer

On the choice of main computer, the University of Surrey heritage uses microprocessor, such as 32-bit PowerPC 603, while the TU Berlin heritage uses microprocessor, such as 32-bit SH series. Advantage of using microcontroller is having shorter booting time, so that it can recover quickly in the event of latch-up and needs to be restarted. The advantage of microprocessor is its ability to handle more complex and parallel jobs. To anticipate any anomaly in the operation, the use of microprocessor is usually done by using redundancy (i.e., a second processor will take over the operation in the event of anomaly). In the University of Surrey satellite design heritage, the electronic components are connected to main computer with dual line of controller area network (CAN). Meanwhile, the TU Berlin satellite design heritage uses star configuration with dedicated line to each component from the main computer, using RS232 or 422.

4.3 Attitude control subsystem

Tables 1 and **2** show that the University of Surrey satellite design heritage uses separate attitude control computer that integrates attitude sensors, including sun and star sensors with all reaction wheels and gyros. This is done so that the attitude control system can work in closed loop all the time. Such approach is necessary for the microsatellite design with deployable solar panels, such as KITSAT-3, STSAT-1, and STSAT-3 since failure of sun pointing could be disastrous for the satellite. As shown in **Tables 3** and **4**, in the TU Berlin satellite design heritage, none of the satellites have separate attitude control computer. In the design, each reaction wheel-gyro pair directly connected to the main computer, and therefore, closed loop with star and sun sensors can only be done using the main computer resources.

Differences are also found in the attitude control sensor between the University of Surrey design heritage. The Korean microsatellites use fiber-optic gyro, while the Turkish microsatellites use MEMS gyro. Meanwhile, in all TU Berlin microsatellites, fiber-optic gyros are used.

For attitude control actuators, all the selected satellites use reaction wheels and air coils for angular momentum dumping/generation. Figures and data showed that TU Berlin heritage satellites use reaction wheels in 3-axis configuration. For LAPAN-ORARI and LAPAN-IPB satellites, they used redundant wheel at satellite major inertia axis that noted as 3 + 1 as shown in **Table 4**. For the University of Surrey heritage satellites, only KITSAT-3 uses reaction wheels in 3-axis configuration. The rest of the satellites uses tetrahedral configuration (noted as 4 as shown in **Table 1**).

The TU Berlin's attitude control design was chosen to reduce computational burden for filtering out reading noise/jitter in the attitude control sensors. The TU Berlin heritage satellites offer two options for attitude control mode, in addition to regular closed loop, including (1) interactive mode for the satellite with video camera payload, such as DLR-TUBSAT and LAPAN-TUBSAT, and (2) angular momentum management mode for the satellite with line imagers, such as Maroc-TUBSAT and LAPAN-A3. The angular momentum management mode is supported by their structure design, that is, solid aluminum box, which created maximum inertia properties at 1 axis and very little cross-product inertias [30, 31]. Such design has been successfully performed highly stable open-loop angular momentum management operation as published by Utama [31] and Mukhayadi [32].

4.4 Propulsion subsystem

From a selected set of satellite designs shown in **Tables 1**–**4**, only BILSAT-1 and STSAT-3 have thrusters. The objective for BILSAT-1 thruster is to maintain the satellite orbit separation in the constellation, so that the image coverage could be optimized. In STSAT-3, the plasma thruster is part of in-orbit qualification process for the low power plasma thruster technology developed by KAIST.

4.5 TTC

For Telemetry and Telecommand, the University of Surrey heritage satellite stopped using low frequency (UHF and VHF) after KITSAT-3. Such usage in RASAT is only in emergency situation. Meanwhile, in the TU Berlin heritage, UHF TTC is still used until LAPAN-IPB. The advantage of using low frequency for TTC is on its omni-directional antenna. Therefore, the satellite can always be contacted by its ground station, regardless of its attitude. The cost of the satellite's control ground station is also much lower. However, the risk for frequency noise for its operation is also higher.

4.6 Payload

The payload profiles for both satellite design heritages showed that the platforms are suitable for both Earth observation, science, and low data rate communication missions. All of the selected satellites, except Korean STSAT-1, are Earth observation missions, which are considered important by stakeholder of satellite developer in Korea, Turkey, and Indonesia. KITSAT-3, BILSAT-1, RASAT, and LAPAN-IPB are for land cover that can be applied for estimating crop yield. The payload data showed that combining mission is typical for microsatellite applications. The multiband infrared (MIRIS) payload in STSAT-3 is used for Earth and space observation. LAPAN-ORARI has three kinds of missions, including Earth observation, communication, and ship data collecting platform.

4.7 Mission data downlink

The quantity and quality of the payload in **Tables 1–4** showed that mission data are increasing with time, which increase the required downlink data rate. For the University of Surrey heritage, the data rate started with 3 Mbps in KITSAT-3 and increased to 100 Mbps in RASAT. For the TU Berlin heritage (the digital transmission cases), the data rate started with 256 kbps in Maroc-TUBSAT and increased to 100 Mbps in LAPAN-IPB. In the early missions, the mission data downlink is transmitted in S-band, and as the data rate requirement increases, the downlink has been shifted to X-band.

4.8 Payload computer

Payload computer is typically separated from satellite main computer, which mainly manage the satellite bus. As the payload data rate increased, the payload processing electronics is also evolved, from microcontroller/microprocessor to FPGA based, which is known to be able provide high computing power with less risk from space radiation as compared to high capacity microprocessor.

4.9 Orbit determination

None of the microsatellite has ranging system. Therefore, in early missions, their orbit determination is mainly depending on NORAD's data. The use of GPS for Position-Navigation-and-Timing by the University of Surrey heritage satellites started with BILSAT-1, while for the TU Berlin heritage satellites, it started with LAPAN-ORARI. The accuracy of orbit determination becomes crucial in Earth observation mission, as part of the parameters used in satellite image geometric correction.

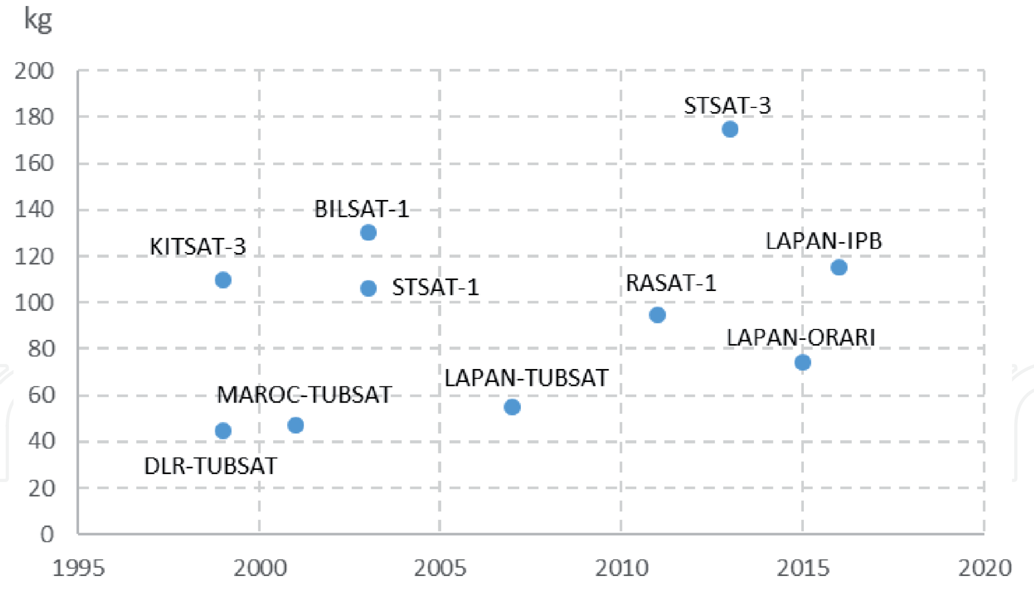

Figure 6.
Microsatellites' weight versus launch year.

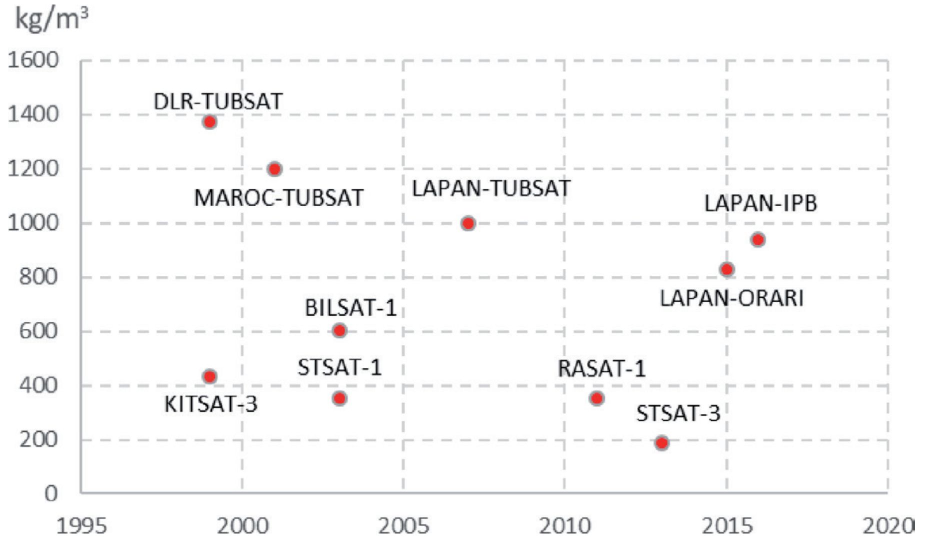

Figure 7.
Microsatellites' density versus launch year.

4.10 System level parameters

Figure 6 shows the weight of each microsatellite sample. It shows that the weight of TU Berlin heritage satellites grows in time. This is due to the increase in mission quantity and complexity, which therefore requires more components in the satellites (bigger batteries, more attitude sensors, larger lens for imager payload, etc.). For the University of Surrey satellites heritage, such pattern is not found. The density of (weight/volume) the satellites is shown in **Figure 7**, indicating that the TU Berlin heritage satellites are more compact than the University of Surrey heritage satellites. For the University of Surrey satellites heritage, the design uses maximum volumetric envelope for maximizing the solar panel area.

5. Conclusions

The chapter has discussed the differences between the University of Surrey design heritage microsatellites and the TU Berlin heritage microsatellites. Five sample satellites from each satellite design heritage are compared, including 15 bus parameters, payload profiles, and satellite weight and volume at launch. From the comparison, it is found that major differences in the satellite bus are in the choice of main computers and their associated link configuration and in the attitude control modes that also affect the design. Another major difference is in the satellites' structure design, which resulted in much higher density in the TU Berlin heritage satellites than the University Surrey heritage satellites. In the early design, there are differences in the choice of satellite's batteries. However, as soon as Li-ion batteries became available, both design heritages used such technology. In answering the increasing needs in payload data handling, both design heritage use FPGA-based payload data handling and high downlink data rate in X-band. GPS is also the technology adopted by both design heritages for orbit determination and imager's ancillary data.

For further studies on the topic, it is suggested that comparison to be done on the power budget of the satellites and on the operation performance parameters of the satellites with similar missions.

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