BAŞKENT UNIVERSITY
INSTITUTE OF SCIENCE AND ENGINEERING
MASTER OF SCIENCE OF DEFENCE ELECTRONICS AND SOFTWARE WITH THESIS

CUBESAT DESIGN THAT INCLUDES TEMPERATURE MEASUREMENTS OF SURFACE OF CLOUD, LAND AND SEA ON CONTINUOUS THERMAL IR BAND

BY

ALI OZAN KOSE

MASTER OF SCIENCE THESIS

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This study, which was perpared by Ali Ozan KOSE, for the program of Defence Electronics and Software with Thesis has been approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in the Institute of Science and Engineering by the following committee.

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To My Family…

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ÖZET

Ali Ozan KÖSE

TERMAL IR BANTTA ARALIKSIZ BULUT, KARA VE DENİZ YÜZEYİ SICAKLIK VERİLERİMİ ELDE EDECEK KÜP UYDU TASARIMI

Başkent Üniversitesi Fen Bilimleri Enstitüsü
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Bu araştırmada, termal Infrared (IR) bantta aralıksız bulut, kara ve deniz yüzeyi sıcaklık verilerini elde edebilen küp uydu tasarımının gerçekleşmesi hedeflenmektedir. Bu hedef doğrultusunda Infrared (IR) sensor yardımıyla yüksek çözünürlükte ve görünür bantta bulut, kara ve deniz yüzeyindeki sıcaklık verileri elde edilebilecektir. Gerekli çözünürlük ve örneklem mesafesindeki bulut haraketlerinin sentezlenmesi ile rüzgar veya hava akımlarının saptanması ve veri aktarımının sağlanması amaçlanmıştır. Detaylı araştırmalar ve incelemeler sonucunda kullanılmak için Infrared (IR) kamera seçilmiştir. Devamında Infrared (IR) özellikli kameradan en iyi sonucu elde edebilmek için içerisindeki Infrared (IR) sensor ve bunu destekleyen elektronik yapının hedefe uygun olduğu saptanmıştır. Bu saptama, dünya yüzeyinde görevini sürdüren meteorolojik uydulardan faydalanılarak yapılmıştır. Gerekli tercihlerin yapılmasının ardından dünya üzerindeki rüzgar veya hava akımlarının tespit ve veri aktarım denemeleri mikro uydu tasarımına başlanmıştır. Gerekli yeryüzü ölçümleri, yeterli niteliğe sahip infrared (IR) kamera eşliğinde yapılmıştır. Tezin bu aşamasının başarılı bir şekilde tamamlanarak devamındaki aşamada Alçak Dünya Yörüngesi'nde (Low Earth Orbit) varlık gösteren küp uydular düzeyinde bulut hareketlerinin sentezlenmesiyle rüzgar veya hava akımlarının saptanması ve veri aktarılması ilk kez gerçekleştirilmiş olacaktır.

ANAHTAR SÖZCÜKLER: Alçak Dünya Yörüngesi (ADY), Infrared (IR), Küpuydular, Meteoroloji

ABSTRACT

Ali Ozan KÖSE

CUBESAT DESIGN THAT INCLUDES TEMPERATURE MEASUREMENTS OF SURFACE OF CLOUD, LAND AND SEA ON CONTINUOUS THERMAL IR BAND

Baskent University Institute of Science & Engineering
The Department of Defense Technologies and Systems
2020

Main aim of this thesis is realization of the cubesat with handling temperature measures from the surfaces of cloud, land and sea in thermal infrared (IR) band continuously. In the direction of this target, temperature measures from the surfaces of cloud, sea and land will gain in high-resolution and visible band by infrared (IR) sensor. The result of synthesizing of cloud movements with the necessary resolution and sample distance, the detection of air currents or wind and data transferring are aimed. Infrared (IR) camera has been chosen with the result of detail researches and reviews. Continue on, the infrared (IR) sensor that located inside of the camera and electronic structure that support it are detected for the target to obtain the best results from the camera which has infrared (IR) properties. This identification has been made from the meteorological satellites that still on the mission of Earth's surface. After the necessary choices has been made, the tries of air currents or wind and data transferring of Earth's surface with starting of the cubesat design has been take placed. The necessary surface measures are made by the infrared (IR) camera which has enough qualifications. Successfully completing part of this study, in the following session detection of air currents or wind and data transferring from the result of synthesizing cloud movement will have been realized with showing the existence in Low Earth Orbit (LEO) at the level of cubesat.

KEY WORDS: Low Earth Orbit (LEO), Infrared (IR), Microsatellites, Meteorology

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SYMBOLS AND ABBREVIATIONS

CDH	Communication and Data Handling
TCS	Thermal Control Subsystem
EPS	Electrical Power Subsystem
FSW	Fligth Software
GCS	Ground Control System
WIDESAT	Wind Detection Satellite
IR	Infrared
LEO	Low Earth Orbit
HD	High Definition
GPS	Global Positioning System
PCB	Printed Circuit Board
AC	Alternating Current
DC	Direct Current
IEC	International Electrotechnical Commission
eMMC	Embedded Multimedia Card
CSP	Cubesat Space Protocol
ADACS	Attitude Determination and Control System
LED	Light Emitting Diode
Gs	Gravity shock
Co	Corporation
TT&C	Tracking, Telemetry and Command Data
GS	Ground Station
OBC	On-Board Computer
PWM	Pulse Width Modulation
UART	Universal Synchronous Asynchronous Receive/Transmit
USB	Universal Serial Bus
XCTU	Xtra Intermodal
SSH	Secure Shell
CVS	Comma Separated Values
UMTS	Universal Mobile Telecommunications System
LGS	Local Ground Station
LNA	Low Noise Amplifier
DDC	Data Distribution Center
BPSK	Binary Phase Shift Keying
LHCP	Left Hand Circular Polarized
RHCP	Right Hand Circular Polarized
ICSP	In Circuit Serial Programming
SRAM	Static Random Access Memory
EEPROM	Electrically Erasable Programmable Read Only Memory
SWD	Serial Wire Debug
RF	Radio Frequency
ID	Identification

I2C	Inter Integrated Circuit
CAN	Controller Area Network
RS	Recommended Standard
LVDS	Low Voltage Differential Signaling
SMA	SubMiniature Version A
AFC	Automatic Frequency Control
CSMA	Carrier Sense Multiple Access
CA	Collision Avoidance
TX	Transmit
RX	Receive
UHF	Ultra High Frequency
VHF	Very High Frequency
MLI	Multilayer Insulation
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
QT	Qualification Test
AT	Acceptance Test
iEPS	The ISIS Electrical Power System
GaN FET	Gallium Nitride Field Effect Transistor
MPPT	Maximum Power Point Tracking
IDE	Integrated Development Environment
RTC	Real Time Clock
PC	Personal Computer
COTS	Commercial Off the Shelf
APSK	Audio Frequency Shift Keying
FSK	Frequency Shift Keying
OQPSK	Offset Quadrature Phase Shift Keying
CCSDS	Consultative Committee for Space Data Systems
N/A	Not Applicable

1.INTRODUCTION

1.1 Goals and Motivation

Main interest of this thesis on space explorations at Low Earth Orbit (LEO). At this point, we have been aiming an issue to generate a new well-qualified and well-designed cubesat to gain temperature data on cloud, land and sea surfaces with continuous thermal Infrared (IR) band. Thermal Infrared (IR) is a band type that contains high resolution qualified and well-seen bands in its structure. These features showed that a camera which has had thermal Infrared (IR) band system can obtain data from cloud, land and sea surfaces determine and flow that data with consalidating the results of air currents.

Cubesats were used in numerous studies in the literature. Unfortunately, none of these studies have this type of problem-solve instruction. There are three aims of the this thesis Firstly, identifying main needs about the determination of wind speed with a new method. Secondly, asking itself like “How can a we obtain wind data from cloud, land and sea surfaces with using cubesat outputs?”. Lastly, answering this question with the help of wide researches, extensive talks, using special and high-talented organising process and concluding all these time periods constructively.

The contributions the space technology, especially on Low Earth Orbit (LEO), are obtaining easy and effective measuring method with using cubesats that contain thermal Infrared (IR) band cameras. So that, results from presenting thesis are showing that this study will be helpful for other works.

1.2 Thesis Structure

Organization of the this thesis is as shown on below.

Chapter 2, I started my extensive researches with initiating from infrared (IR) sensor definition. Some descriptions and terms were done. Circuit structure and its' materials, operational areas and varied application areas were stated.

Chapter 3 firstly explains cubesat description with all details. In following paragraphs, the concept of cubesat operations investigated extensively. Lastly, technical data for cubesat researched microsatellite's inner instruction.

Chapter 4 shortly describes Infrared (IR) earth observation technically.

Chapter 5 contains unique properties of Infrared (IR) region with dividing optical materials for Infrared (IR), thermal effects and reflectance.

Chapter 6 and 7 shortly appear respectively Ionospheric scintillation and tropospheric effects with a few sentences.

Chapter 8 presents tropospheric effects divide into three parts. These parts are atmospheric absorption, cloud attenuation and tropospheric scintillation.

Chapter 9 has rain and ice attenuation extensivelly with subtitles called rain attenuation, rain climate and contour maps and rain attenuation desinging

Chapter 10 shorty elucidate a definition of propagation experiments KA band on LEO satellites.

Chapter 11 planned to explore weather forecasting. This design contains traditional weather forecasting, types of weather forecasting, the importance of weather forecasting and data collection.

Chapter 12 includes wind forecasting with minor points such as data sources, wind speed forecasting techniques, short-term wind power forecasting model’s application to wind speed and wind power forecasting and regional production as the sum of the special production.

Chapter 13 has the organise of the microsatellite called Wind Detection Satellite (WIDESAT) with all details.

Chapter 14 consists of integration and test process steps of the Wind Detection Satellite (WIDESAT)

Chapter 15 explains mission operations and analysis of the Wind Detection Satellite (WIDESAT) with the help of well-examine terms.

Chapter 16 has the management side of the Wind Detection Satellite (WIDESAT).

Chapter 17 determines possible and general total cost calculations of the Wind Detection Satellite (WIDESAT).

Chapter 18 has conclusion part of the Wind Detection Satellite (WIDESAT).

Chapter 19 introduces suggestions if anyone wants to progress this thesis to further studies.

2.INFRARED (IR) SENSOR

Infrared transmissions are familiar as transmitting a signal using light across the distance. The range of visible light in the red end of the light spectrum is called as infrared light (IR). IR used to transmit a signal that carries sound in many listening devices and systems. Although IR is not influenced by radio or electromagnetic signals, and also it doesn’t transmit through walls. The main disadvantage of IR is that it can only be used for indoor practices. [1]

IR is used in distinct applications such as electrical, mechanical and building inspections. IR is also worked in photography and thermography, thermometer, biological and biomedical applications, electro-optics, photonic devices and sensors, optical fibres applications.Technology of IR provides better advantages such as low power requirements, low circuitry costs, simple circuitry, higher security, and portability. The main disadvantages of IR are short range, light and weather sensitive, and also speed. [2]

3. CUBESAT (U-CLASS SPACECRAFT)

The CubeSat Project began in 1999 from a coordination between two universities, California Polytechnic State University and Stanford University, and had the goal to provide standard specifications for small satellites. In the beginning, a CubeSat was defined as a 10 cm cube with a mass of 1kg, which corresponds to one unit (1U). The first task of the CubeSat Program was to facilitate access to space for small payloads and to reduce cost and development time by imposing a standard design. Then specifications renewed over time. Today, there are CubeSats bigger than 1U with some features noticed on below : [3]

• 1U, 100 mm x 100 mm x 113.5 mm dimensions, 1.33 kg mass

• 2U, 100 mm x 100 mm x 227 mm dimensions, 2.66 kg mass

• 3U, 100 mm x 100 mm x 340.5 mm dimensions, 4 kg mass

• 6U, 100 mm x 226.3 mm x 366 mm dimensions, 12 kg mass

It is possible to build 8U, 12U or 16U CubeSats. [3]

CubeSats are generally launch as secondary payload. Design standardizations can make their installition part of inside launchers, as well as in deployment process. During launch, these stacked inside the standard deployment system which can hold three CubeSats and can eject them after reached orbital altitude. These systems are mostly called dispenser. They can serve as an interface between launch vehicle and CubeSats. There was Poly Picosatellite Orbital Deployer that used which can hold three CubeSats. These CubeSats' whole structure exists with 1U or a single 3U. This deployer is not compatible with bigger satellites than CubeSats. [3]

Actually, CubeSats are subcategory small satellites. They comprise any satellite below 500kg. Large satellites mostly called heavier spacecraft class. This satellite classified with mass values. CubeSats situated between microsatellites and nanosatellites. [3]

Category	Mass range [kg]
Minisatellites	100 - 500
Microsatellites	10 - 100
Nanosatellites	1 - 10
Picosatellites	0.1 - 1
Femtosatellites	< 0.1

TABLE 3. 1 SMALL SATELLITE CLASSIFICATION

The standardized CubeSat Satellite platform has also allowed new actors such as small companies and universities to take part of the space field. Indeed, the low cost production of this kind of satellite has lots of interests for them. For the students, it has an educational interest because it enables them to work on real projects. It is also means to engage them in all phases of satellite evolution, action and exploitation through hands-on research and development experience. [3]

Space companies have an interest in this type of business. They can obtain desirable results with very low investments. Moreover, this is the way to check new technologies and identify the usefulness of the bigger mission. Miniaturized satellites support by low-cost platform for many types of mission. These missions include planetary space exploration, earth observations, fundamental earth and space investment. Hundred of CubeSats send to space every year regularly. This has a special meaning for space industry. [3]

4.INFRARED (IR) EARTH OBSERVATION

Infrared (IR) is a part of the electromagnetic spectrum with support of wavelength ranging from 1 μm to 1000 μm. The spectral transference of the atmosphere and the spectral sensitivity of the detectors have numerous names and parts. Terminology is a goal that dependent on the effectiveness of present nomenclature. [4]

Visible (VIS)	400 – 700 nm
Near Infrared (NIR)	700 – 1000 nm
Short Wave Infrared (SWIR)	1 – 3 μm
Mid Wave Infrared (MWIR) (First Thermal Imaging Band)	3 – 5 μm

Thermal Infrared (TIR) Long Wave Infrared (LWIR) (Second Thermal Imaging Band)	8 – 12 µm
Very Long Wavelength Infrared (VLWIR)	> 15 µm

TABLE 4. 1 SPECTRAL NOMENCLATURE VALUES

Achievement of many major and practical tasks supported by infrared (IR) spectrum with a rich and reachable technology. IR can be used for many distinct areas such as scientific, military, forensic, civilian, industrial, astronomical and microscopic applications. The most crucial application of IR interest of space exists with space-based infrared (IR) earth observation. The infrared earth observation data set supplies a unique service to analyse trends or detect irregular differences in the infrared (IR) characteristics of the land of the Earth’s or atmosphere. On-orbit Thermal Infrared (TIR) imaging radiometers supply a significant amount of data to consider temperature and emissivity profiles of scene of ground. MODIS (one of the current space mission) shows the various applications to make use of infrared data that interests many user groups. Firstly, atmospheric data that including atmospheric profiles, aerosol properties, ozone layer, cloud features, temperature and top altitude. Secondly, land data, including land surface temperature, emissivity, thermal anomalies, fires, biomass burning, vegetation cover conversion and lastly, ocean data including ocean aerosol properties. Legacy of space-based Thermal Infrared (TIR) earth observation has encouraged the growth of lots of applications and sizable user community to exploit unique characteristics of the wave band. Various missions succesfully completed that involved space based infrared (IR) earth observation. [4]

5. UNIQUE FEATURES OF INFRARED (IR) REGION

Infrared region has the specific optical pattern in its' habit of body. This design diverges from the visible region by the properties of materials and the effects of the longer wavelength. Resolution set of optics is better in the visible wavelengths than infrared (IR) while resolution is proportional to wavelength. Higher performance has been provided only if sufficient scene illumination has been supplied by the sun or other sources that infrared provide less resolution. Unfortunately, performing in the absence of external illuminations. When infrared (IR) wavelengths vary too much encountering in the visible spectrum, particle size concepts are involved in scattering of Rayleigh and Mie. These should be revised. The scattered radiation amount is function of opposite wavelength, IR penetrates into the haze and dust better than visual radiation. [4]

6. REVIEW OF BAND PROPAGATION

Radio science projects targeted precise quantification and modelling of many factors over several decades. These projects had consisted advising statements on possible mitigation techniques. Production of an interpretation of attenuation measurements with the help of each band satellite is to clarify prominent specific effects for reviewing. Each band propagation experiments performed between 1969 and 2005. These experiments have submitted a significant understanding of the challenges encountered by satellite communications. [5]

7. IONOSPHERIC SCINTILLATION

Ionosphere is the layer that consists energy radiation from the sun influences the uppermost sphere of the planet's atmosphere. This layer's features can easily change via the total number of electrons by several orders of magnitude. The effects of this varies from day to night and the transition creates rapid fluctuations called scintillations of radio signal. An orbit type called Low Earth Orbit (LEO) lies down the upper reaches of the ionosphere. [5]

8. TROPOSPHERIC EFFECTS

Tropospheric effects have shown in the planet earth's. Troposphere layer has adverse effects on microwave propagation. This propagation ending in attenuation and depolarisation. Absorption and tropospheric scintillation are some of the attenuation effects on the earth. These are significant in Ka band communications. [5]

8.1 Atmospheric Absorption

Some part of the energy is absorbed. This absorption happened with radio wave interconnection existing in molecules on the planet Earths' atmosphere. Actual absorption of the frequency mainly depends on molecule construction. Structure of molecule is a high-dominant contributor exists like oxygen and water vapor. Divided weakening effects of dry and standardized atmosphere models happen in the place called dry atmosphere model which contains gases in Earths' atmosphere. The Ka band absorption peak has the abscissa revealing around. Standard atmosphere called *zenith* weakening should be less than 0.2 dB/km. Magnitude of standard atmosphere attenuation has an effect on system utilizing at advance angles of elevation and great margins of link. [5]

8.2 Cloud Attenuation

Clouds are outcomes that condense huge amounts of vapored water and droplets of different sizes. These are the potential for contribute to attenuation at Ka band frequencies. Help of variable geometrics of droplets and distribution, type of cloud depends on frequencies that affected to different extents. Cloud accurate depletion can only be stochastically described. [5]

8.3 Tropospheric Scintillation

Tropospheric scintillation occurs in the lower atmosphere called as the boundary layer. Tropospheric scintillation opposite to ionospheric scintillation. It creates by the convective effect of turbulence. This type of turbulence can quickly change its' refractive index in different sections that causes interference in propagation features. Scintillation effects are invaded on the frequency, aperture of antenna, factors of temperature-humidity-slant path length. Scintillation values indicate their highest version in status of warm and humidity. These effects escalate at lower elevations like slant path length increase.

Effects are changeable and magnitude does not mostly gathered by observation of weather conditions with visuality such as clear sky, cloud and rain. Low-angle fading effect happens at angles of elevation less than 10 degrees approximately. Fading of the low-angle is ending in severe signal 10 dB fluctuation. This fading operates mainly for multipathing effect which is similar for reflection in communication of terrestrial. But, low-angle fading is occured from boundary layer fracture. A satellite communication band called KA band at angles of low altitude are restricted because of fast varying fluctuations with high magnitude. Both Tropospheric scintillation in common and low-angle fading have been boardly copied and resulted in comprehensive attenuation guesstimate for GEO satellites. [5]

9. RAIN AND ICE ATTENUATION

Attenuation due to rain drops called hydrometeors is dominant impairments at Ka band frequencies. Ice crystals are mainly responsible for depolarisation outcomes when the frequency currency shows under 30 GHz. On the other hand, polarisation can achieve investigations. Rain attenuation had been begun for emerging like remarkable factor at frequencies above 10 GHz. This attenuation is influencing factor in determining link availability on Ka band frequencies. Affirmation of the relationship between the happening of rain and proceeding attenuation can be needed. [5]

9.1 Rain Attenuation

Rain attenuation has capability for starting attenuation in any place between 20 and 40 dB which due to climate. It is complicate to obtain precise data on physical aspects of rain consider to raindrop size, distribution, temperature and intensity. These are similar to the problems with accurately outlining the structure of clouds. Duration of any signal fade is straight related to the type of rain since its’ depth. Empirical experiments are focusing on the statistical probability of overflow. [5]

9.2 Rain Climate and Contour Maps

Long term median rain rate knowledge is reachable on a global scale that set out made for group similar condition of the climate of locations. Each zone indicated by rainfall rate values which exceed definite percentage of time threshold. This threshold linked them to attenuation and the likelihood of outage. Boundaries are permissive and errors are likely in a unified approach from regular maps. Rain climatic zones on meteorological maps have some features that only show dramatisation of rain rates. Therefore, rain rates can never support a data of rain accumulation. Rain climatic maps take placed by direct use of

“Rainfall Rate Exceedance Contour Maps”. These had been ended in more clear coefficient valued for models. Maps like this contain average contour lines of rainfall rates of exceedance. Allowance of this effect directly, extraction of rainfall rates. Correct data obtained from meteorological services to observe intervals. Contour maps can redesign with this current knowledge. Ka band propagation investigations show that current research topics, especially in tropical climates are still very much. [5]

9.3 Rain Attenuation Modelling

Melting layer can divides as ice particles. Ice particles represent in higher parts of clouds, upper troposphere and raindrops. It regarded similar to 0 degree isotherm except for tropical regions. Height of melted layer happens above the sea and defined as the rain height. Rain attenuation has been considered to exist from the ground up to noticed altitude. Path length clarifies particular part of the slant path at fixed height between satellite and earth station. Availability and long term attenuation models came from the process that interest of comparison intentions. [5]

10. WEATHER FORECASTING

Condition of air on Earth is called weather. Processes of weather are continual and intense levels of information, multi-dimensional structure of dynamic and chaotic statements. These are doing a forecasting of air condition for formidable challenges. Forecasting process that includes measurement which ended by estimations of an unknown situation from historical data. Forecasting of weather is difficult condition. Forecasting type should be scientifically because of challenging problems on Earth. One improtant problem that metereologist are encountered is how to make an accurate prediction. Weather prediction that contains compelling and fascinating pursuits. Scientists have attempted to understand meteorological features forecasting for using distinct methods. Some features are more accurate from others. Forms of the meteorology can noticed from data which basis of scientific weather forecasting. These are interesting around the prediction state of the atmosphere to a given location. A type of weather forecasting which, experienced by a human being can be an example. They forecast frequently and their results came from collecting quantitative knowledge on atmospheres' current status and usage of scientific atmospheric processes for projects. Most of the projects show atmosphere evolving. The weather forecasting's cognitive procedure has been acquainted from the necessity of increasing data. Most of the projects that ended from human practitioners are becoming the task of details. Furthermore, most of the human forecasters use some kind of approaches based on the scientific matters. Weather processing that shows present conditions of the atmosphere which can change in the future. There are many ways to predict to air condition. Ship, aircraft, sounds of the radio, doppler radar and satellites are prominent ways to observe current weather conditions. These ways help us to sent accumulated knowledge to analyse and prepare some maps, charts and graphs for meteorological centres. Weather forecasting contains various techniques. These techniques are comparatively simple observations of the sky with high level of complexity with computerized models of mathematics. Weather forecasting generally works in a short time. Its' accuracy falls deeply more than a week. This can be remain a serious problem for the business sector because of chaotic and predictable character of weather. A person who has an informal training improves significant skills of forecasting. Farmers are the good example of forecasting. They are capable to make their short term meteorological factor forecasting. The weather is influenced directly farmers activity and effect to their livelihood. On the other hands, other occupation, such as pilots, fishermen and mountain climbers are influenced from weather forecasting. Weather process is complicate of nature. Weather forecasting has an impact on economic condition in every country. Models of accurate weather forecasting are important for agriculture activities. Weather forecasting is performed process of professionally trained by meteorologists who have highly developed skills. Metereologist estimate wetaher condition based on the scientific principle and method with advanced technological tools. An accuracy of forecasting started in 1950. This was a scientific progress outgrowth, a scientist called basic and applied, new data application and weather forecaster methods. Some technological devices, like faster computers, satellites and radars of weather can estimate weather forecasting nowadays. Other factors could have been influenced directly to elevation the accuracy of forecasting. The first factor of this tradition is augmenting the model guess scope and accuracy. The second factor is progressing capability of viewing that is managed from satellites of meteorology. A third factor is increasing accuracy with the first conditions' steady improvement that is prepared for models of forecasting. Statistical models can allow the widest difference of elements for meteorology. They modify geographical low level clarity forecasting model for specific locations. Satellites are supporting continuous sight with high-capability and atmosphere distant sensing. First conditions are the result of increased viewing numbers and better use in computational techniques. [6]

11. WEATHER FORECASTING TRADITIONS AND TYPES OF WEATHER FORCASTING

11.1 Weather Forecasting Traditions

Weather forecasting is type of estimating of the weather that using active science and technology for predicting atmospheric changing. Weather forecasting can exist in certain locations. The first step of the weather forecasters is collecting data which include high level of quantitative benefit about daily atmospheric statues. Forecasters can use an atmospheric progress of scientific comprehension for projects. Conditions of weather are important forecasts for protecting life and property.

Once upon a time, forecasting was mostly based on weather condition observation. Investigations focus on patterns of weather have resulted in various techniques about the forecasting of rainfall. Daily rainfall forecasting can perform with a computer models, computer exposition and weather pattern acquaintances. [6]

11.2 Types of Weather Forecasting

Meteorologists performed works which had been interested by a daily weather forecast. Modern computers can make forecasting accurately than other prediction methods. Weather satellites can orbit on Earth’s cloud and take pictures from space. Land and space observation perform by forecasters. Performance occurs from previous experiences that based on past values which include forecasting results. Several methods have combinations with daily weather forecasts that made by meteorologists. These methods are Persistence Forecasting, Synoptic Forecasting, Synoptic Forecasting and Computer Forecasting. [6]

11.2.1 Persistence forecasting

As a first way, persistence forecasting is the easier method than the other forecasting methods. This method based on today and tomorrow weather. It means that on today conditions of forecasting and the conditions of tomorrow. Logical way of forecasting called persistence forecasting weather while the weather in steady state like tropical province’s in summer months. This method, extensively depends on stagnant weather pattern presence. The pattern presence is very helpful about short and long range forecasting. [6]

11.2.2 Synoptic forecasting

A synoptic forecasting method that uses exact rules of forecasting. Metereologist obtain their observations and perform documentation to realize short-term forecasting. [6]

11.2.3 Statistical forecasting

Average temperatures, precipitation, such as rainfall and snowfall records in one-year period give an idea for forecasters in this method. All documentation helps meteorlogist to check within themselves. The main question is “What does it generally occur this time of the year?” for this method. Answers for this question contribute to the statistical forecasting. [6]

11.2.4 Computer forecasting

Forecasters mostly gain observation knowledge and put the digits into high level complexity equations. Ultra-high computers can work in this area. These computers helps variety of equations to models that give the condition of the weather on following days. Different equations often produce from exciting results. Meteorologists use other forecasting ways to make the “best guess” on weather conditions. Weather forecasting includes operational products. These are generally traditional ones. Therefore, they are categorized as very short-range, short-range, medium-range and long-range forecasting groups. A result from each weather forecasting describes from supreme technology, validity temporal range after emission happens, input-output time and resolution features, broadcasting requirement and actual process. [6]

12. WIND FORECASTING

Wind is a free, clean, easy-obtained, efficient renewable energy source for humanity. Integration of the wind power farms into electrical power system is still increasing dramatically in short time all over the world. Increasing to demand for wind enegry can explain the rapid exhaustion of fossil fuels, cost effects and environment worries. Wind power is the most tempting technology due to its low pollution level. There are lots of associations interest to wind energy source in the world like as The European Wind Energy Association. This type of associations’ mission is to increase wind energy capacity. Expectations on wind energy approximately 320 GW wind power to be installed for EU in 2030. 254 GW of this wind power is onshore and 66 GW of this wind power is offshore. Wind generations’ high penetration level into interconnected power system is caused by some serious problems about grid power.

Grid power problems are frequently interest elevated levels of variability, uncertainty of electricity supply, frequency control and transient stability. Guess of changes in wind energy production is the result of using persistence-type methods. Persistence-type methods employed in order to organize spinning reverse capacity for managing grid operations. Wind production correctness may not generally be guaranteed while using these methods. Wind forecasting methods and techniques can be proposed for solving problems. Wind prediction methodologies have divided into four main parts with timescales. These parts are, immediate short-term, short-term, medium-term and long-term prediction. Immediate short-term that refers to the data from a few minutes to one hour ahead. Some applications of this part are in clearing of the electricity market, grid operations and regulatory actions in real-time. Second one is short-term parts. The short-time part is all about data in the period from one hour to several hours ahead. Usage areas of short-time part are dispatch planning of economic load, reasonable decisions of load and electricity market security. The third part is medium-term that has range forecasts which show the data forecast from several hours to one week ahead. Some applications of medium-part is using in decisions of unit commitment, reserve requirement and the generator positions called ON/OFF. Last one of this wind forecast methodology is the long-term part. This part is all about to categorize the period spreading from one week to one year ahead. Main areas of this part are maintaining plans, management operations, optimal cost and feasibility studies of designing a wind farm. Forecasting models of a wind power described in numerous models. These models contain that physical, traditional statistical, artificial intelligence (AI) and hybrid models. As a first model, the physical forecasting model converts meteorological information at the certain time to the projected wind speed by using high resolution limited area. This area depends on numerical weather prediction model and statistics-based output. As a second models, the traditional statistical model that using measured wind data for rightly forecasting electric power production. These are used measures derive from autoregressive model, the average model of auto-regresess and smoothing model of exponential. The artificial intelligence (AI) forecasting model, as a third model, has an capacity to progress prediction accuracy and representing non-linear relations such as network of neural system, systems of fuzzy logic and machines of support vector. The hybrid model differs from the other models. It combines with each model advantages in prediction framework so that provide better accuracy and forecasting performance. Unfortunately, there is no efficient forecasting models or tool that can generate an exact wind power prediction.

Errors of wind power forecasts are generally considerable concern in integrative studies, unit type called attachment models and economic sending processes. Roots of forecasting main errors, mostly exist on prediction of wind, local effects, winds' non-uniformed, non-linearity of wind turbine and unprogrammed mistakes. Classification of forecast error can estimate for a normal distribution. Expectation not be satisfied in most of the common problem. If wind power predict error distribution contains of skewness and excessing of kurtosis, two distribution types called Weibull and Beta have been utilized. In statistical regression methods, it mostly called error distribution that often accepted to distribute with zero and constant variance. The error administration in most surviving wind power predict was assumed to follow a normal distribution. [7]

13.WIND DETECTION SATELLITE (WIDESAT) DESIGN

13.1 Objectives

Principal target of this meteorological satellite called the WIDESAT (Wind Detection Satellite) is recognition of the cubesat with handling temperature scales from the surfaces of cloud, land and sea. Temperature measurements will have been gained from differnet surfaces such as cloud, land and sea through thermal infrared (IR) band. Results can obtain from organised measurements, recognition and data sending of wind currents and air currents that handled with adequate resolution and sampling distance. Main proproties of the best Infrared (IR) camera should be

- Lightest and the most compact structure
- Observation in infrared (IR) band benefically
- Working in all times such as day and night times
- Remote control systems
- Continuous usage with high-level security equiments
- Special visual viewpoint for tough conditions.

There are some stages to send the metereological satellite to space. First, planned structure will have been launched to the Low Earth Orbit (LEO). After this period, the satellite will have been deployed from the rocket. Orientation of this operation will have been controlled by ground satellite control centre. Satellite has the heat shield to protection from the sun shine. Heat shield of Wind Detection Satellite (WIDESAT) will envelope entirely whole sides of its’ structure. After the WIDESAT is departed from the main rocket, it shall get rid of the aero-breaking heat shield using with spring system. This spring system will have been assisted by servo motor structure. After the separation of heat shield, the WIDESAT will have been open solar panels and orbiting with using thrusters by ground satellite control centre. Camera of the WIDESAT will have been space qualified. While orbiting process was ended, all systems’ checking operation will begin. After this operation the WIDESAT will be ready for work. Arrengement of the WIDESAT will have been fulfilled all equipments to realize aims.

Main plan of structure of the Wind Detection Satellite (WIDESAT) concluded to realize followings,

1) SENSOR SUBSYSTEM DESIGN
2) ORBITAL CONTROL DESIGN
3) MECHANICAL SUBSYSTEM DESIGN
4) COMMUNICATION AND DATA HANDLING (CDH) SUBSYSTEM DESIGN
5) ELECTRICAL POWER SUBSYSTEM (EPS) DESIGN
6) THERMAL CONTROL SUBSYSTEM DESIGN
7) FLIGHT SOFTWARE (FSW) DESIGN
8) GROUND CONTROL SYSTEM (GCS) DESIGN
9) CUBESAT INTEGRATION AND TEST

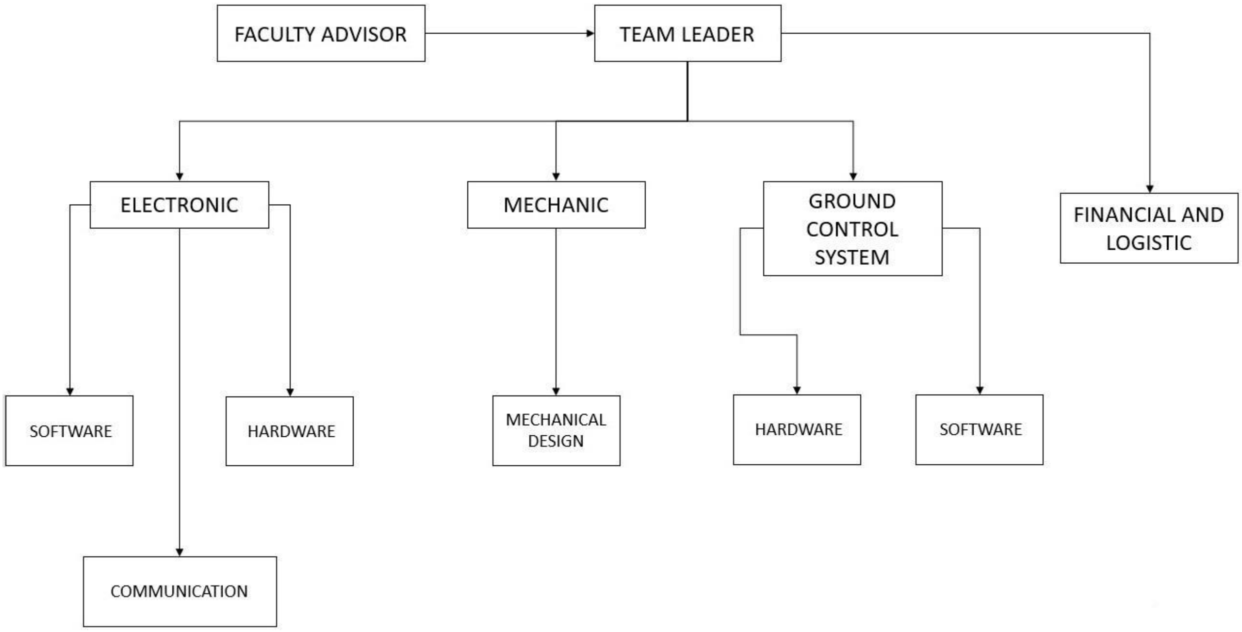


FIGURE 13. 1 TEAM ORGANIZATION

13.2 System Requirements

System requirements of the Wind Detection Satellite (WIDESAT) are,

- The total mass of the satellite should be less than 100 kg.
- The aero-breaking heat protection system will use to save probe while installed in the rocket and deployment section of the rocket. Also, it will envelope satellites' all sides while in the rocket.
- The satellite with the aero-breaking heat shield will locate in a cube shape envelope of 300.00 mm x 300.00 mm x 300.00 mm (Length x Width x Height) structure.
- Thermal range of the structure subsystem may between -40 °C and +80°C.
- The satellite with a heat protection system that fixed to main rocket will departed from the rocket payload section instantly.
- All mechanisms of the satellite should have capacity to maintain their configurations or states under all external dangerous in the air.

- Complete mechanical parts of the satellite shall contain chemicals.
- Satellite will has its' own ground satellite control centre.
- All telemetric properties of the satellite will be displayed in real time.
- The ground station of satellite will contain computer and an antenna and also ground station should portable so that user can be located along the flight time.
- Both two main parts, heat shield system and satellite should be labelled effectively.
- The satellite will use its' own power sources completely to survive observation.
- The infrared (IR) camera shall begin to capture pictures from the release of the heat shield while orbiting procedures have been ended.
- External frame of the satellite will prevent by jamming and cold welding.
- Vibratuare and structural analysis of the external structure of the satellite will complete before launching.
- Satellite's computer will radiation hardened and it shall handle each subsystem of the satellite.
- Each subsystem of the satellite will include what it needs during the task.
- Lithium-ion battery should contain withstand high energy-to-mass ratio.
- Heaters of the satellite will prevent the lithium-ion batteries from alterations high or low temperatures.

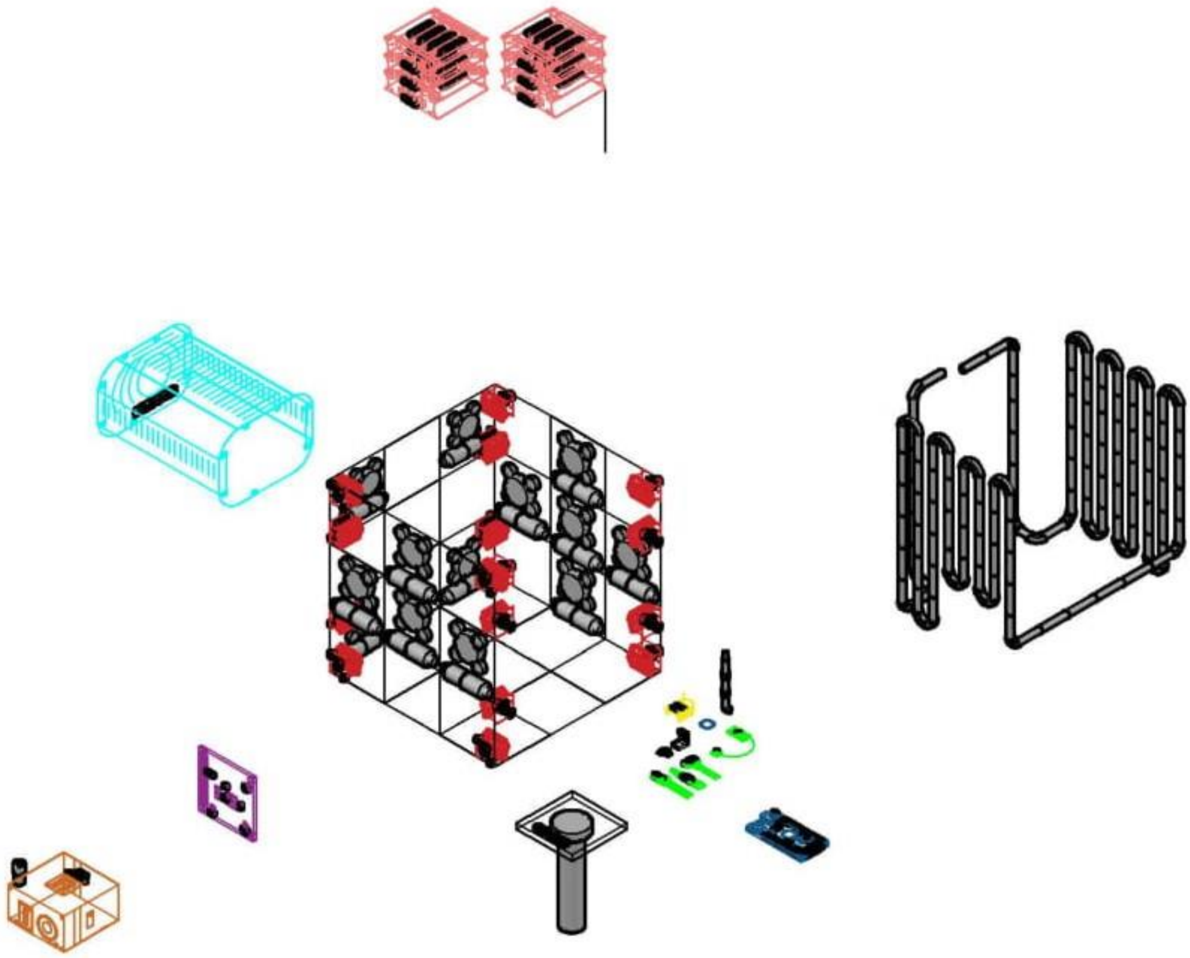


FIGURE 13. 2 PAYLOAD OF THE WIDESAT

13.3 Configuration Selection

WIDESAT will have been had a cubic shape structure with dimensions of 300.00 mm x 300.00 mm x 300.00 mm (Length x Width x Height). This structure will have been included sharp edges, low squeeze and the largest functional volume to produce.

This design should be had a spring system. Requirements of the this system are progressing suspension, no sizing difficulties, dividing easily, using for space applications, extending fastly under its own power, containing a self-supporting tube to range up to 35 feet in length, remote controll for deployment applications, including repeatable roll out system and driving by automatically or manually.

The Wind Detection Satellite (WIDESAT) configuration will have been contained servo motors. Requirements of these servo motors are light weight structure, containing high torque and output, lower power consumption, easing the heat shield separation, having an optimal processing and storage temperature, containing an optimal voltage range and humidity.

SEPARATION SYSTEM	ADVANTAGE	DISADVANTAGE
Servo motor	Light weight, High torque, Lower power consumption, High output.	Unbalanced geometry
Solenoid	Balanced Geometry	Heavy, high power consumption, Low output.
Fish line	Simple, easy to assembly, light,	Some of the fishlines have less strength. Should be carreful when selecting.
Servo & Spring	More safety way about releasing	2 or more components, Assembly can be harder

TABLE 13. 1 COMPARISON OF SEPARATION SYSTEMS

We have been decided two strategy methods,

1) Thruster will have been transport the WIDESAT after post-launch process
2) While transport section finished, reaction wheels and magnetorquers will have been started to stabilize the whole system

ORBITAL CONTROL STRATEGY	QUANTITY	ADVANTAGE	DISADVANTAGE
Thruster	16	Efficient Usage Modular Structure Powerful	Large Sizes High Weight
Reaction Wheel & Magnetorquer	33 (each)	High pointing accuracy	Storage Issues Power Comsumption High Weight

TABLE 13. 2 ORBITAL CONTROL STRATEGY

Physical layout of the Container is,

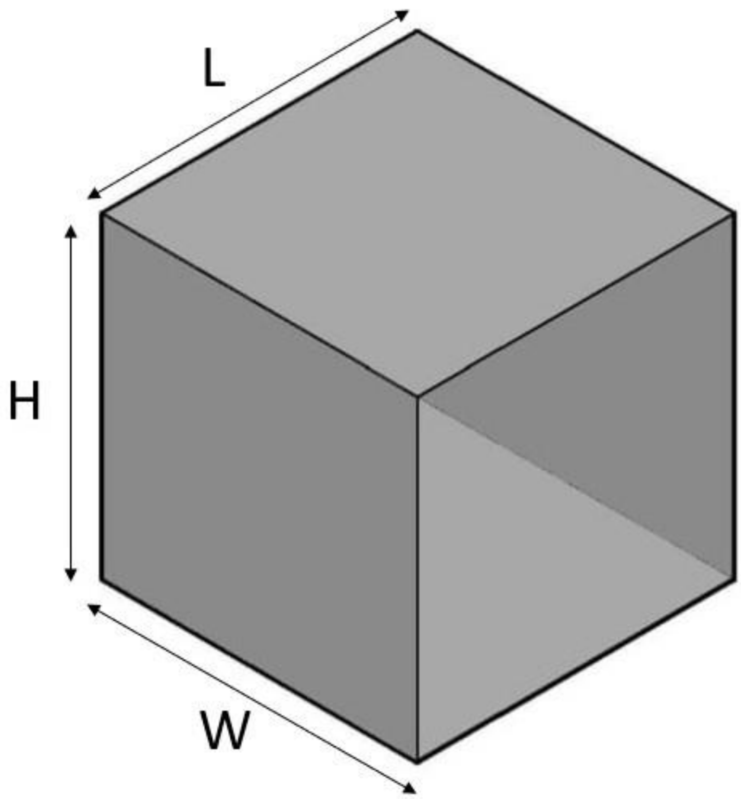


FIGURE 13. 3 PHYSICAL LAYOUT OF THE CONTAINER

Physical layout of the Payload is,

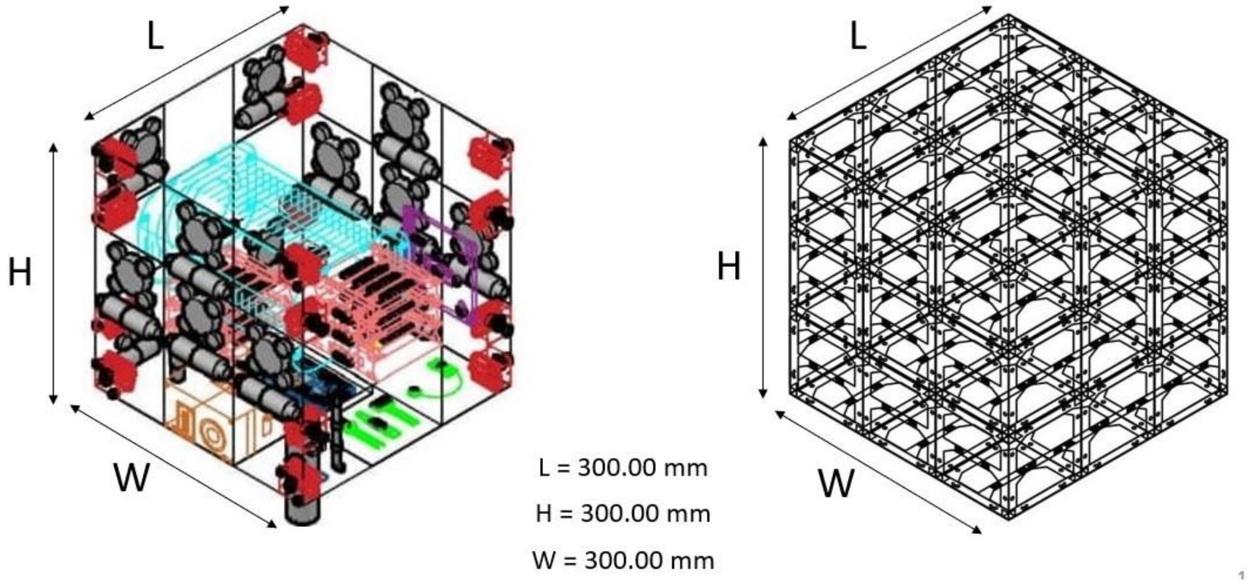


FIGURE 13. 4 PHYSICAL LAYOUT OF THE PAYLOAD

Physical layout of the Container + Payload is,

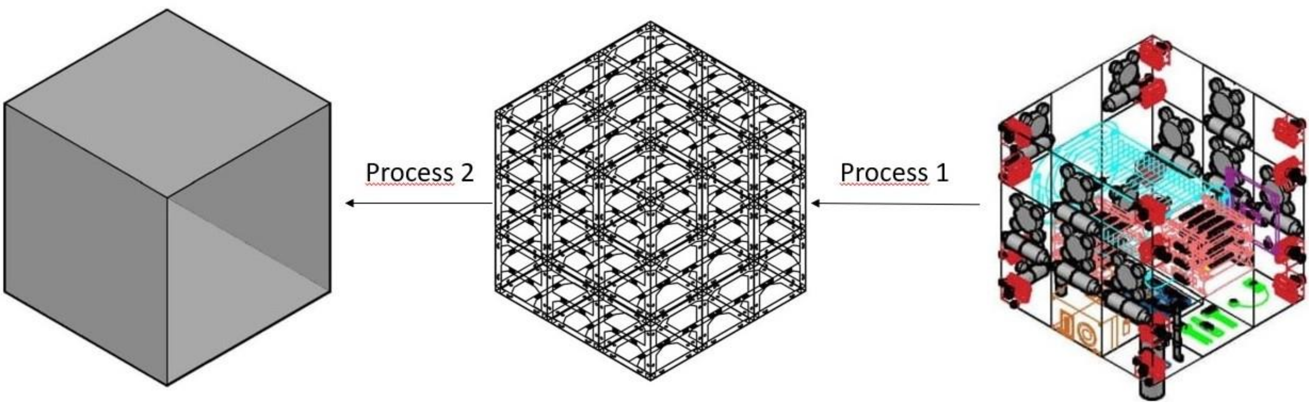


FIGURE 13. 5 PHYSICAL LAYOUT OF THE CONTAINER + PAYLOAD

Heat shield of the WIDESAT will have been contained,

- Protecting the satellite from alterations form deep warming and cooling
- Having neither heavy nor light construction

- An capability to release easily from the satellite
- Having space well-equipped structure

13.4 System Concept of Operations

NO	PRE-LAUNCH EVENT	RESPONSIBILITY
1	Make the Wind Detection Satellite (WIDESAT) ready	WIDESAT Crew
2	Setting up the Ground Control Subsystem	Ground Station Crew
3	Make antennas ready	Ground Station Crew
4	The Wind Detection Satellite (WIDESAT) communication tests	Ground Station Crew
5	Data verifying	Ground Station Crew
6	Tests of the separation mechanism	WIDESAT Crew

NO	DEPLOYMENT EVENT	RESPONSIBILITY
1	Power on the Wind Detection Satellite (WIDESAT)	Mission Control Officer
2	Integration of the Wind Detection Satellite (WIDESAT) into the rocket	Mission Control Officer
3	Confirmation of the received telemetry	Ground Station Crew

NO	ORBITING EVENT	RESPONSIBILITY
1	Controlling designated position of the Wind Detection Satellite (WIDESAT) in low earth orbit (LEO)	Mission Control Officer
2	Orbiting the Wind Detection Satellite (WIDESAT) successfully	Mission Control Officer
3	Positioning and stabilization controlling	Mission Control Officer

NO	DATA TRANSFERRING EVENT	RESPONSIBILITY
1	Controlling the camera and data transferring	Mission Control Officer
2	Sending the sample data from the camera and sensor	Mission Control Officer
3	Starting real-time data transferring after all controls done	Mission Control Officer

FIGURE 13. 6 SYSTEM CONCEPT OF OPERATIONS

Planned operations are,

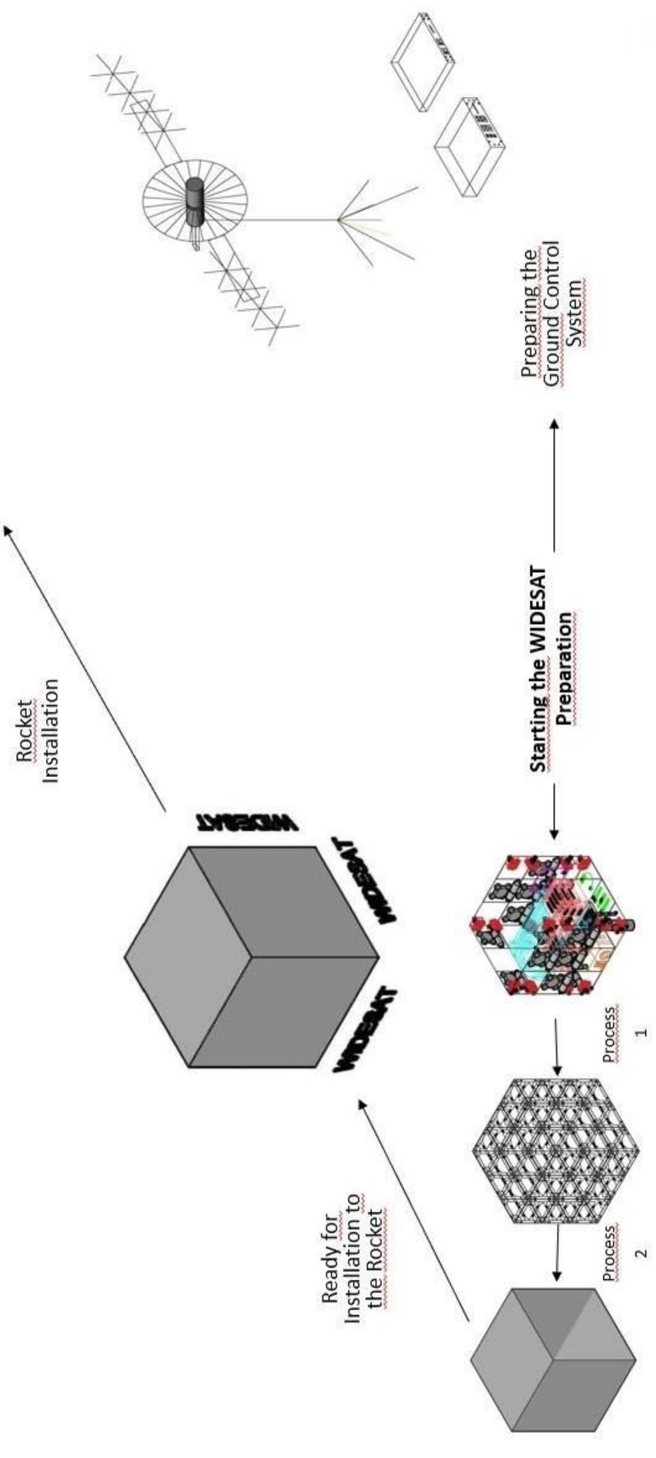


FIGURE 13. 7 PLANNED OPERATIONS-1

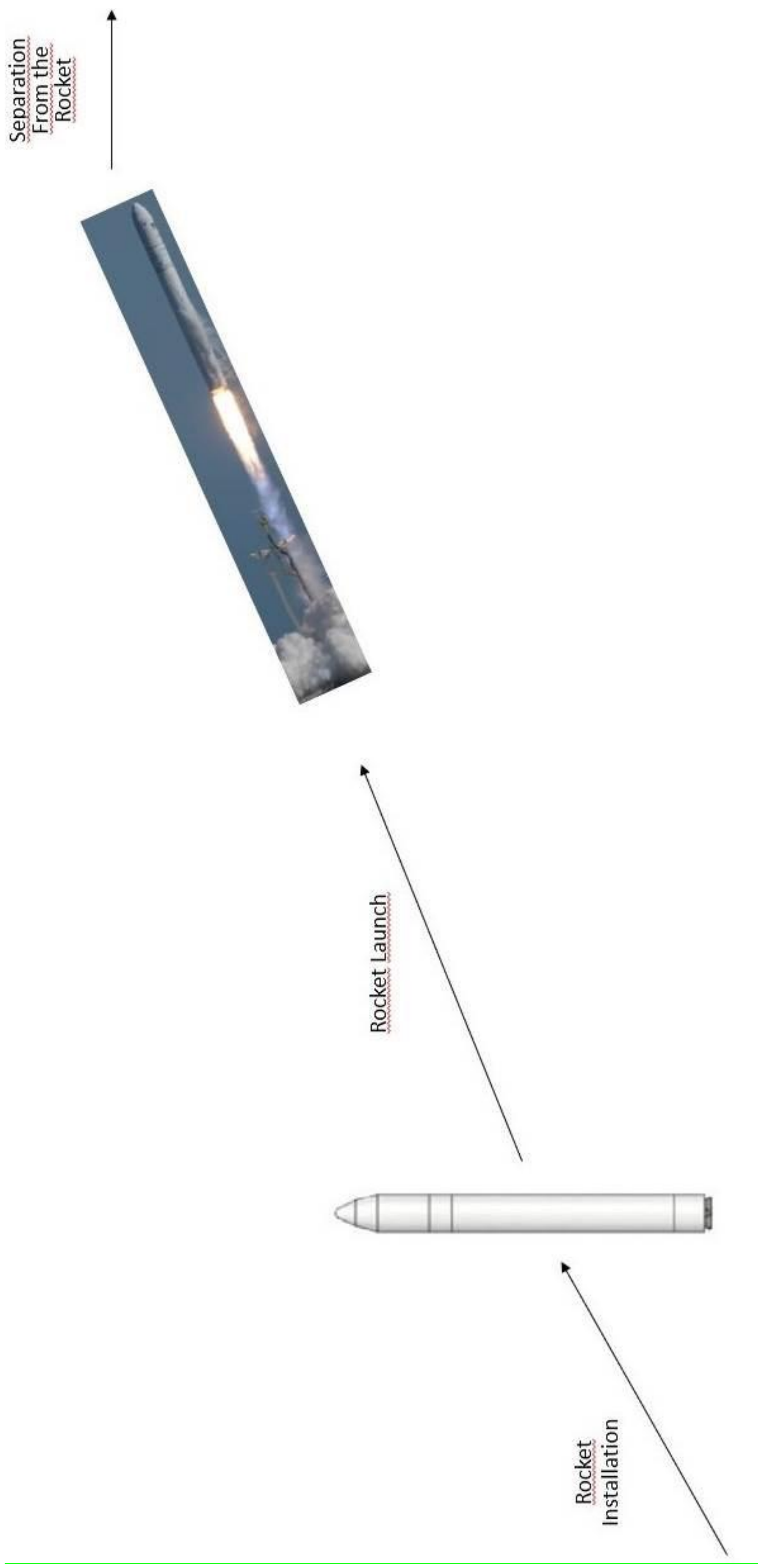


FIGURE 13. 8 PLANNED OPERATIONS-2

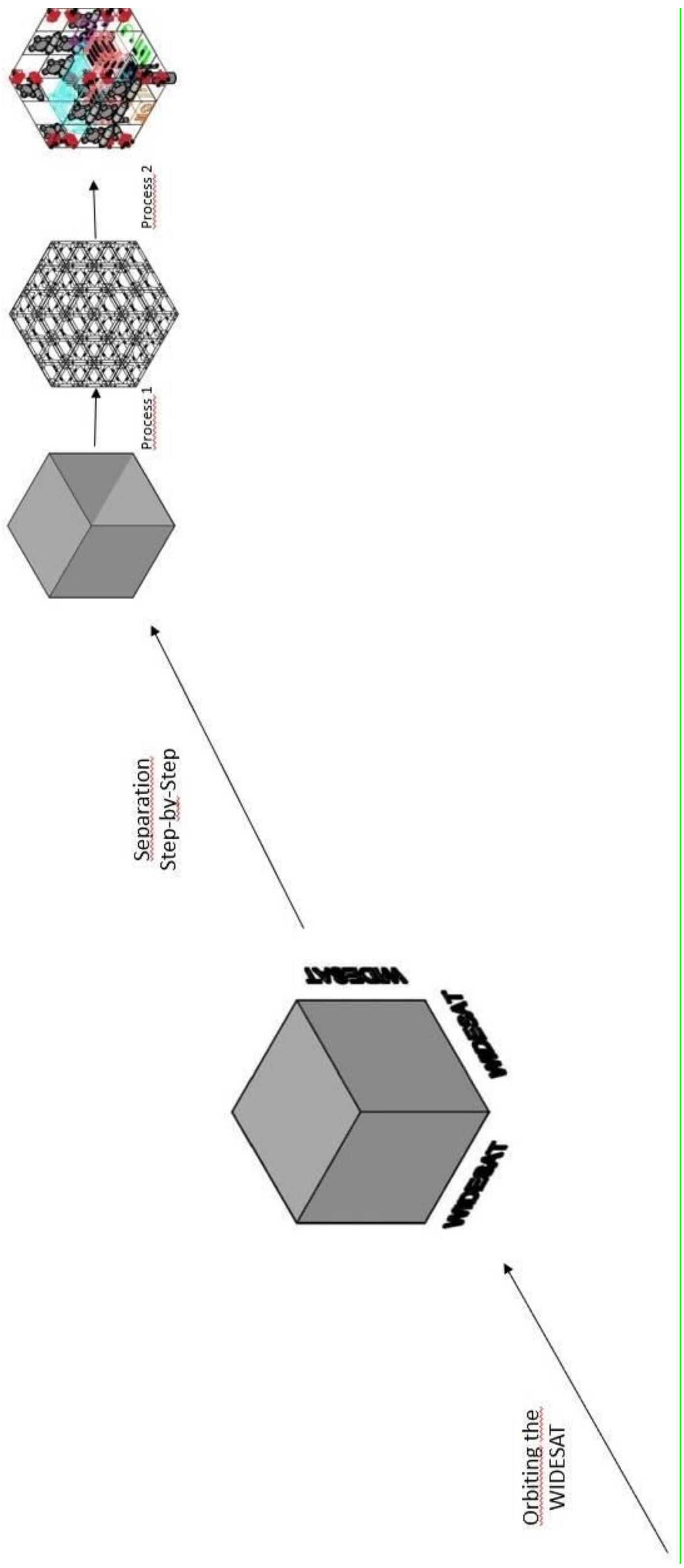


FIGURE 13. 9 PLANNED OPERATIONS-3

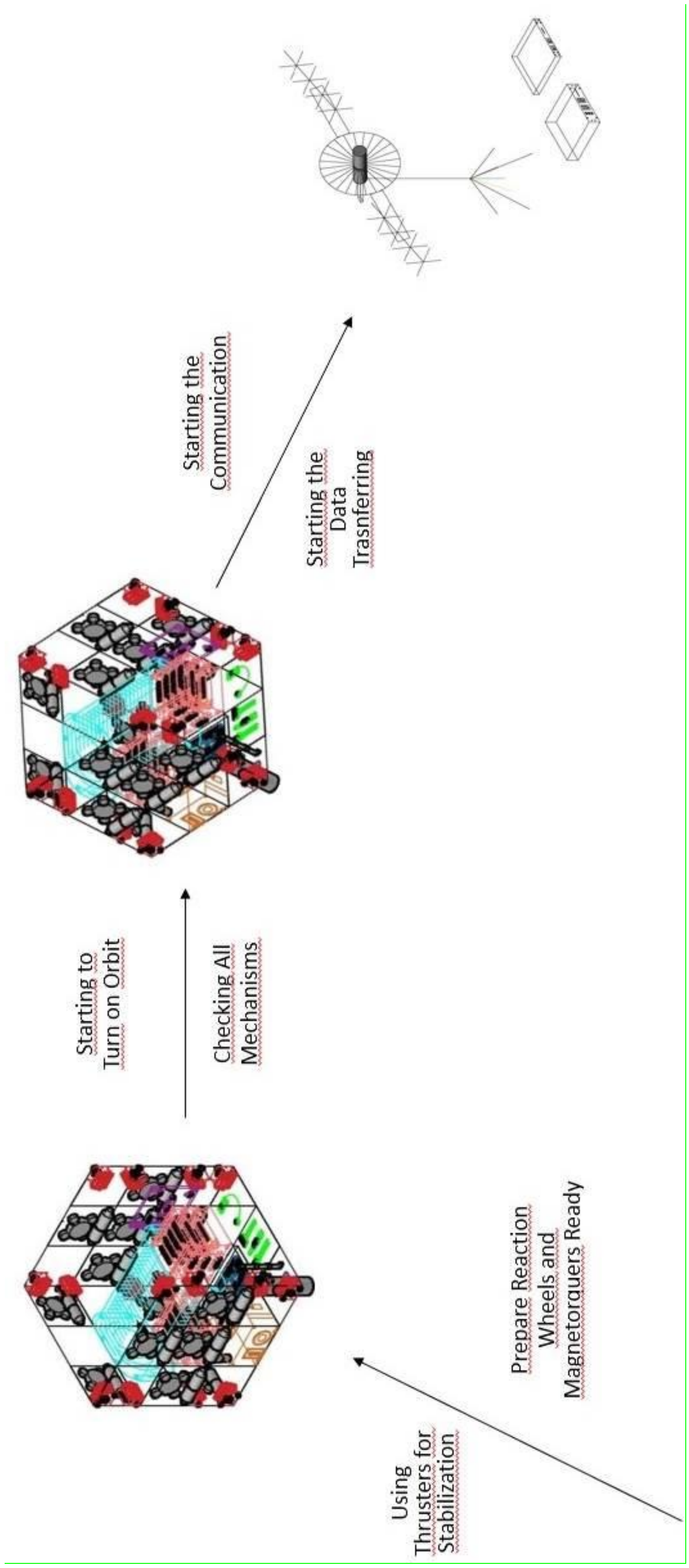


FIGURE 13. 10 PLANNED OPERATIONS-4

Manuel development plan is,

GROUND STATION CONFIGURATION	WIDESAT PREPARATION	LAUNCH	TRANSFERRING
Setting up the Ground Control Subsystem and antennas	Assembly	Launch procedures	Transferring the real-time data from the camera and sensors
Testing sensors, camera and communication	Heat shield mechanism test	-	-

TABLE 13. 3 MANUEL DEVELOPMENT PLAN

Launch vehicle is,

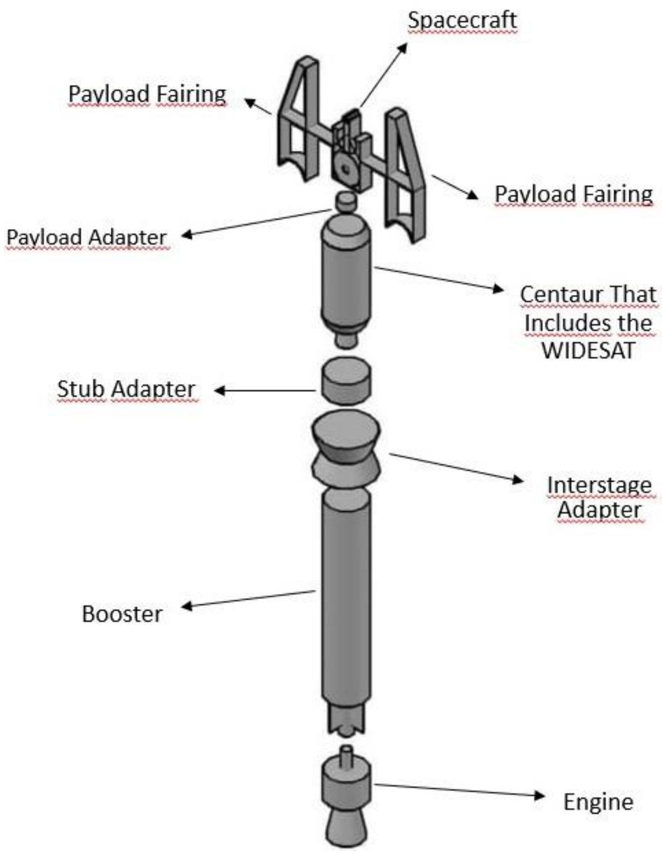


FIGURE 13. 11 LAUNCH VEHICLE

13.5 Sensor Subsystem Design

Overview of the sensor subsystem design is,

TYPE	MODEL	QUANTITY	PURPOSE
Air Pressure	PCB Model 116B	1	Air Pressure
Temperature	IST AG 300 °C Pt	1	Air Temperature
Humidity	IST P14-W	1	Measuring Humidity
GPS Location	ARDUINO GROVE – GPS MODULE	1	Location Detecting
Power Voltage	GWP Voltage Sensor T240K-0U	1	Measuring Power Source Voltage
Camera	GOZ CAMERA	1	Imaging & Transmitting

TABLE 13. 4 OVERVIEW OF THE SENSOR SUBSYSTEM

Requirements of this design are,

- This subsystem is one of the most required one for the WIDESAT.
- Measurements that come from this subsystem shall show the instant conditions.
- Instant conditions shall give an opportuinity to the WIDESAT crew that how to intervene the satellite effectively.
- All electronic parts should be enclosed and protected from the environment with the exception of sensors.
- All structures should be made to survive 15 Gs of launch acceleration.
- All structures should be made to survive 30 Gs of shock.
- The payload should measure altitude, provide position using GPS, measure its battery voltage and outside temperature.
- The camera should be integrated into the payload.
- Imaging should be in color with a minimum resolution of 640x512 pixels.

13.5.1 Air pressure sensor

The air pressure sensor will have been shown the current pressure measurements of the WIDESAT. This sensor should be reliable for space quailified conditions about Cubesat. [8]

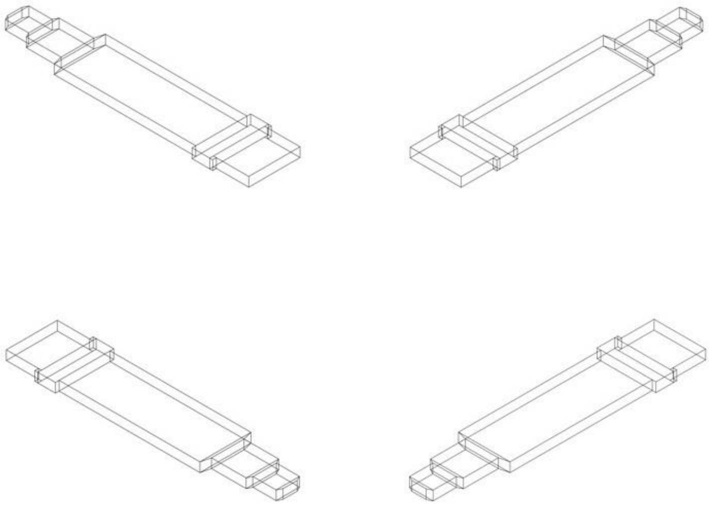


FIGURE 13. 12 AIR PRESSURE SENSOR

PCB MODEL 106B	PROPERTIES	PCB MODEL 116B
8.3 psi (57.2 kPa)	MEASUREMENT RANGE	100 psi (690 kPa)
300 mV/psi (43.5 mV/kPa)	SENSITIVITY	6 pC/psi (0.870 pC/kPa)
Quartz	SENSING ELEMENT	Quartz
-54°C to +121°C	TEMPERATURE RANGE	-240°C to +345°C

10-32 Coaxial Jack	ELECTRICAL CONNECTOR	10-32 Coaxial Jack
18.0 g	WEIGHT	20.3 g

TABLE 13. 5 COMPARISION FOR AIR PRESSURE SENSOR

After technical issue comparison as shown above, reasons of the selected air pressure sensor called PCB Model 116B are, [8]

- Suitable structure
- Flexible temperature range
- Effective measurement range
- Highest sensitivity level

FIGURE 13. 13 PCB MODEL 116B PRESSURE SENSOR

13.5.2 Air temperature sensor

The air temperature sensor will have been shown the instant temperature level of the WIDESAT. This sensor should be reliable for space quailified conditions about Cubesat. [9]

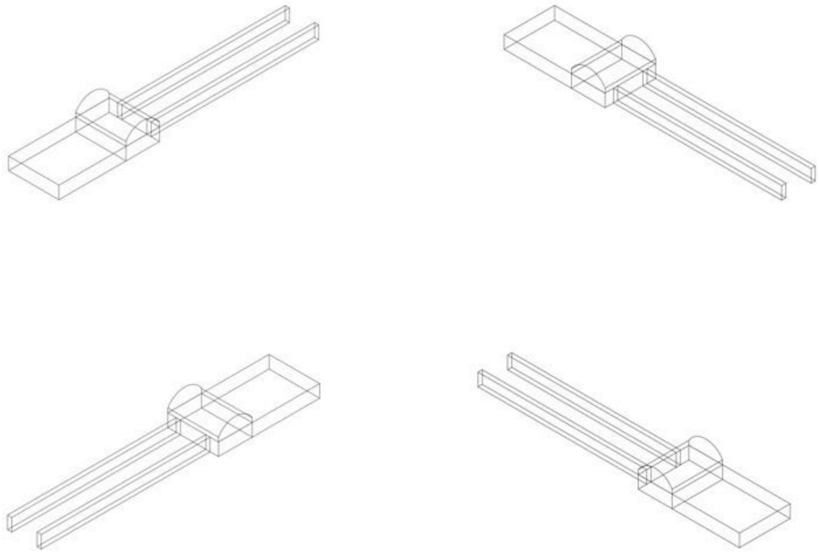


FIGURE 13. 14 AIR TEMPERATURE SENSOR

IST AG 300 °C Pt	TECHNICAL DATA	IST AG 1000 °C Pt
-200°C to +300°C	OPERATING TEMPERATURE RANGE	-70°C to +1000°C
100 Ω, 500 Ω, 1000 Ω at 0 °C	NOMINAL RESISTANCE	200 Ω at 0 °C
3850 ppm/K	CHARACTERISTICS CURVE	3770 ppm/K
IST AG Reference	TOLERANCE CLASS	IST AG Reference

Ni-flat-wire Au-coated, 0.2 x 0.4 mm	CONNECTION	Pt-wire, 7 x 0.25 mm
1 mA at 100 Ω 0.5 mA at 500 Ω 0.3 mA at 1000 Ω	RECOMMENDED APPLIED CURRENT	Max. 2.8 mA at 850 °C

TABLE 13. 6 COMPARISION FOR AIR TEMPERATURE SENSOR

After technical issue comparison as shown above, reasons of the selected air temperature sensor called IST AG 300 °C Pt are, [9]

- Customer-specific sensor available upon request
- Metallized backside available
- Excellent long-term stability
- Low self-heating
- Optimal price/performance ratio
- Prependicular wire available
- Au coated Ni-wire available

FIGURE 13. 15 IST AG 300 °C PT TEMPERATURE SENSOR

13.5.3 Humidity sensor

The humidity sensor will have been shown the exact humidity level of the WIDESAT. This sensor should be reliable for space quailified conditions about Cubesat. [10]

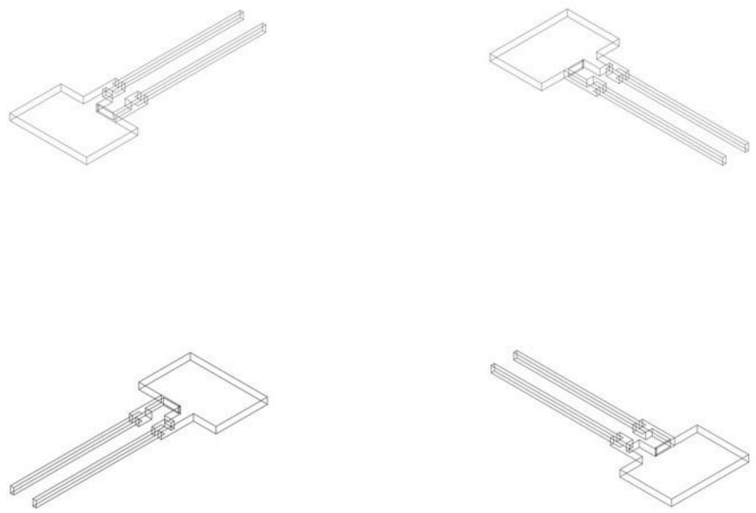


FIGURE 13. 16 HUMIDITY SENSOR

IST K5-W	TECHNICAL DATA	IST P14-W
0 % RH to 100 % RH	OPERATING HUMIDITY RANGE	0 % RH to 100 % RH
-40°C to +150°C	OPERATING TEMPERATURE RANGE	-50°C to +150°C
200 pF±50 pF	CAPACITANCE	150 pF±50 pF
0.4 pF / % RH	SENSITIVITY	0.25 pF / % RH
< 0.01	LOSS FACTOR	< 0.01

< 1.5 % RH	LINEARITY ERROR	< 1.5 % RH
1 kHz to 100 kHz	MEASUREMENT FREQUENCY RANGE	1 kHz to 100 kHz
< 12 Vpp AC	MAXIMAL SUPPLY VOLTAGE	< 12 Vpp AC
Alternating signal without DC bias	SIGNAL FORM	Alternating signal without DC bias
CuP-SIL wire post-plated with Sn, 10 mm	CONNECTION	CuP-SIL wire post-plated with Sn, 10 mm or Au/Cu-wire 0.4 mm or SMD, automatic assembly compatible

TABLE 13. 7 COMPARISION FOR HUMIDITY SENSOR

After technical issue comparison as shown above, reasons of the selected air temperature sensor called IST P14-W are, [10]

- High chemical resistance structure
- Very low drift
- Wide temperature range
- High humidity stability
- Resistance to condensation
- Rapid recovery time
- Customer-specific sensor available upon demand

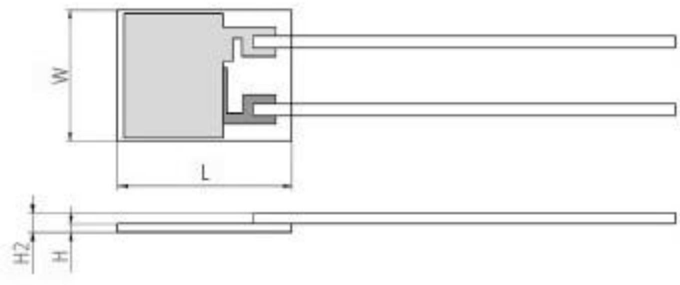


FIGURE 13. 17 IST P14-W HUMIDITY SENSOR

13.5.4 Gps sensor

The GPS sensor will have been shown the exact location of the WIDESAT. This sensor should be reliable for space quailified conditions about Cubesat. [11]

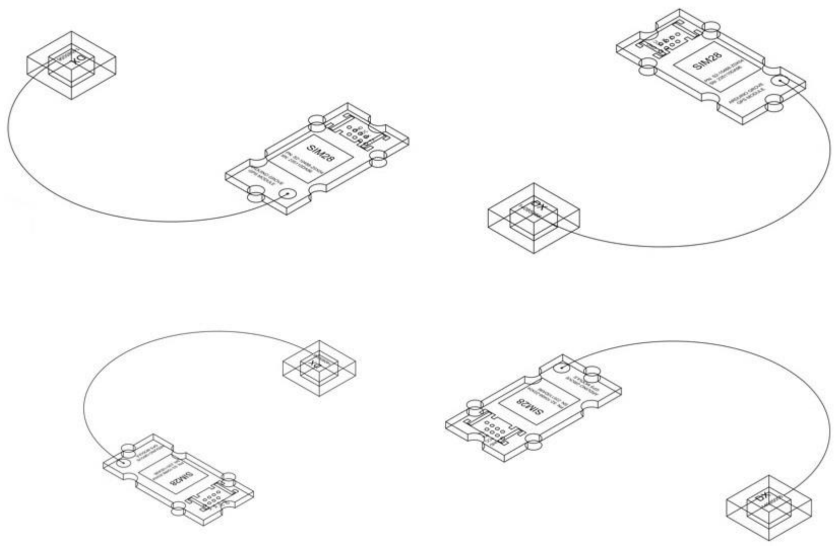


FIGURE 13. 18 GPS SENSOR

ARDUINO NEO-6M	PROPERTIES	ARDUINO GROVE – GPS MODULE
23 mm x 30 mm	SIZE	40 mm x 20 mm x 13 mm
1 Hz , max. 5 Hz	UPDATE RATE	1 Hz , max 10 Hz
Default 9,600 , max 230,400	BAUD RATE	9,600 – 115,200
-161 dBm	NAVIGATION SENSITIVITY	-160 dBm
3V – 5V	POWER REQUIREMENTS	3.3/5 V
22 tracking , 50 channels	NUMBER OF CHANNELS	22 tracking , 66 channels
Cold Start: 27s Warm Start: 27s Hot Start: 1s	TIME TO FIRST START	Cold Start: 13s Warm Start: 1-2s Hot Start: <1s
External Patch Antenna	ANTENNAS	Antenna Include
2.5 m GPS Horizontal Position Accuracy	ACCURACY	2.5 m GPS Horizontal Position Accuracy

TABLE 13. 8 COMPARISION FOR GPS SENSOR

After technical issue comparison as shown above, reasons of the selected air temperature sensor called ARDUINO GROVE – GPS MODULE are, [11]

- Better power consumption
- Scalability
- Higher maximum update rate
- Faster speed
- Having more channels
- Better GPS tracking
- Better GPS navigation
- Better distancing between measurements

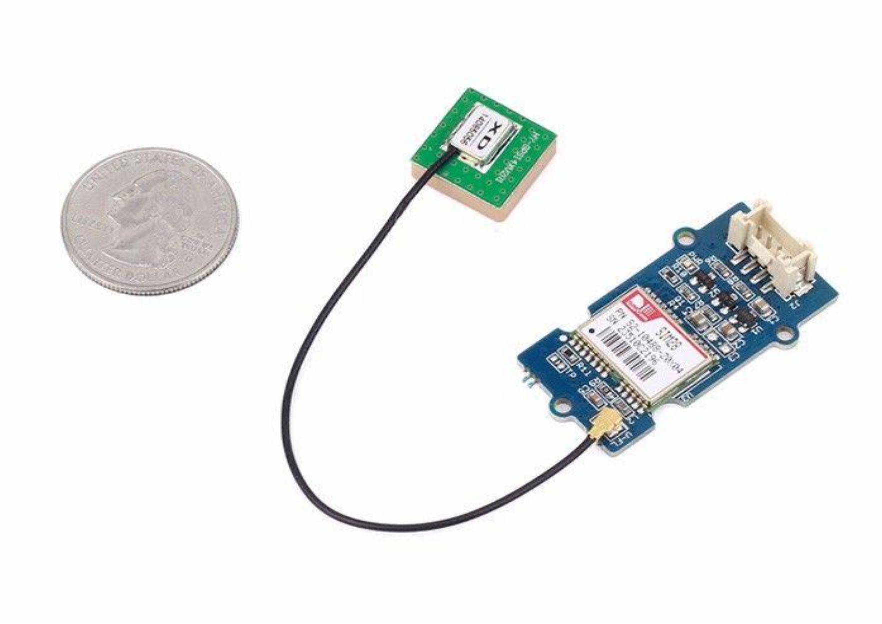


FIGURE 13. 19 ARDUINO GROVE – GPS MODULE

13.5.5 Power voltage sensor

The Power Voltage sensor will have been shown the current voltage level of the WIDESAT. This sensor should be reliable for space quailified conditions about Cubesat. [12]

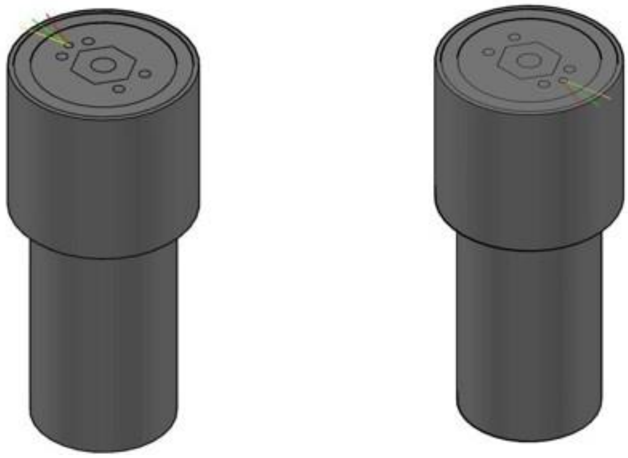


FIGURE 13. 20 POWER VOLTAGE SENSOR-1

Properties of the power voltage sensor are, [12]

- It is performed to calculate and monitor the amount of voltage in an object.
- It can notice both the AC or DC voltage level.
- The input of this sensor can be the voltage.
- The output of this sensor can be the switches, analog voltage signal, a current signal, an audible signal etc.

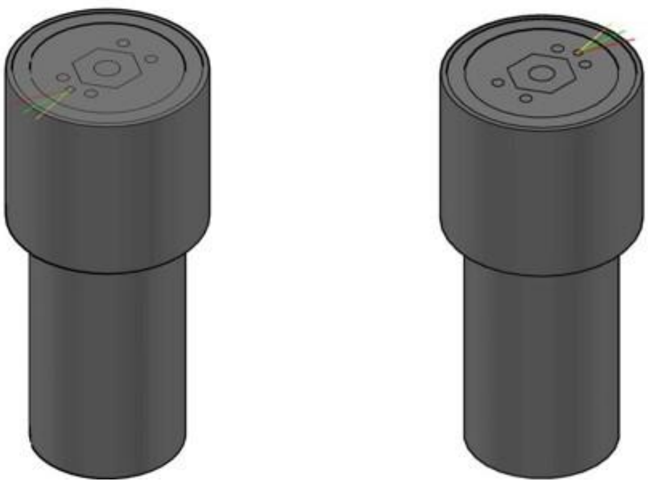


FIGURE 13. 21 POWER VOLTAGE SENSOR-2

GWP VOLTAGE SENSOR T240K-0U	SPECIFICATION	GWP VOLTAGE SENSOR T240C-0U
IEC61869-1 , IEC61869-6 , IEC61869-11	APPLIED STANDARDS	IEC61869-1 , IEC61869-6 , IEC61869-11 TYPE C CONE ACC. EN50181
20000/√3V	PRIMARY VOLTAGE	20000/√3V
1,9*Un for 8h	VOLTAGE FACTOR	1,9*Un for 8h
3,25/√3V	SECONDARY OUTPUT	3,25/√3V
200kΩ±1% , 350 pF±10%	BURDEN	200kΩ±1% , 350 pF±10%
24/50/125kV	INSULATION LEVEL	24/50/125kV
1/0,5 by using correction Cfu and φocor according IEC61869-11	ACCURACY CLASS	1/0,5 by using correction Cfu and φocor according IEC61869-11
-40°C to +80°C	OPERATING TEMPERATURE RANGE	-40°C to +80°C
-40°C to +80°C	STORAGE TEMPERATURE RANGE	-40°C to +80°C

50 or 60 Hz	FREQUENCY	50 or 60 Hz
Internal Surge Arrestor	OVERVOLTAGE PROTECTION	Internal Surge Arrestor
2 pole, shielded, twisted pair, 2m, open ends (Brown-a, Black-n)	CABLE	2 pole, shielded, twisted pair, 2m, open ends (Brown-a, Black-n)

TABLE 13. 9 COMPARISION FOR POWER VOLTAGE SENSOR

After technical issue comparison as shown above, reasons of the selected air temperature sensor called GWP Voltage Sensor T240K-0U are, [12]

- Small weight and size
- Higher personnel safety
- Very high degree of accuracy

- Non-saturable structure
- Eco-friendly structure
- Wide dynamic range

FIGURE 13. 22 GWP VOLTAGE SENSOR T240K-0U

13.5.6 Camera

Camera of the WIDESAT will have been provided by ASELSAN Co. This process will have been inspired from GOZ CAMERA. The new design camera will have been space quailified. [13]

FIGURE 13. 23 GOZ CAMERA-1

Technical and physical properties of the GOZ CAMERA are, [13]

- Including cooling dedector
- 640x512 dedector format
- x2 zooming
- Contiuous zooming optical structure
- Cooling time is less than 7 minutes
- Communication interface is RS422/RS232
- Video output is CCIR
- External power input is 13 – 33 Vdc

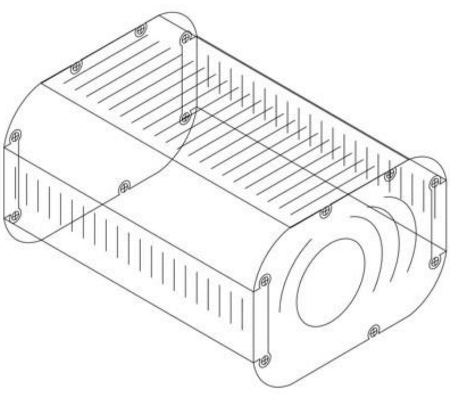
Environment conditions of the GOZ CAMERA are, [13]

- Working temperature is between -32°C and +50 °C
- Storage temperature is between -40°C and +65 °C
- Environment condition standard is MIL-STD-810G

Main points of the GOZ CAMERA are, [13]

- Long range view opportunity
- Cooling thermal camera structure
- Continuous zoom in / zoom out
- High resolution with 640x512 dedector
- Automatic focusing

FIGURE 13. 24 GOZ CAMERA-2



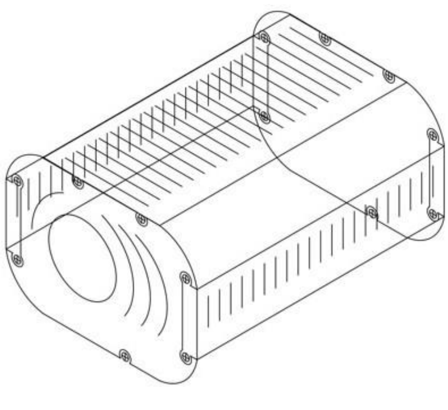


FIGURE 13. 25 GOZ CAMERA-3

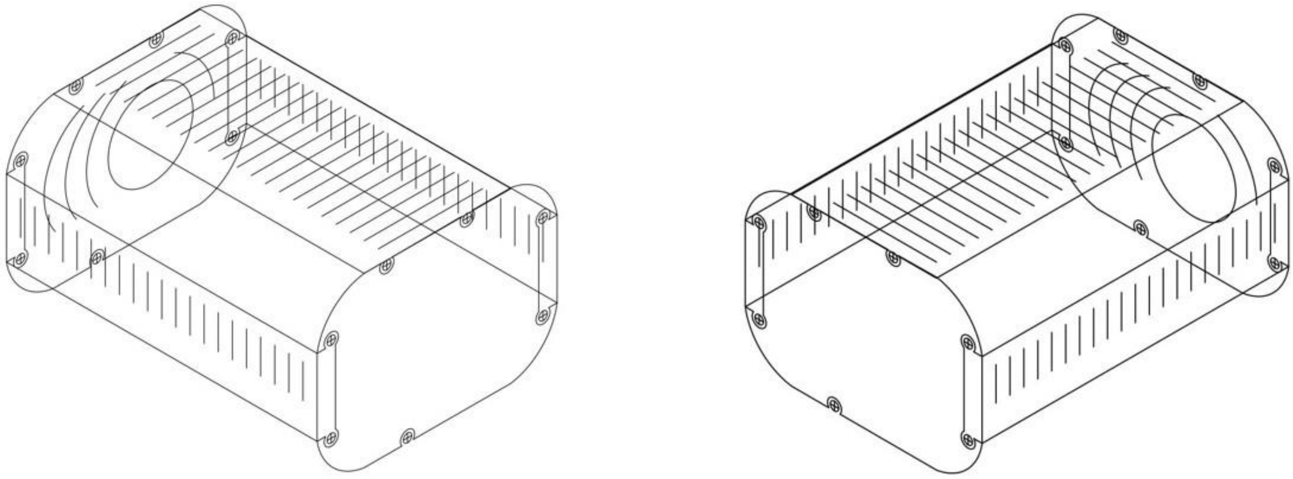


FIGURE 13. 26 GOZ CAMERA-4

Process steps of the GOZ CAMERA are,

- The command from the Mission Control Officer to designate any point on the Republic of Turkey region.
- Forwarding the WIDESAT on that points’ direction.
- After the orbiting the WIDESAT to that points’ direction, the GOZ CAMERA will have been started to getting images.
- These images will have been stored in an internal eMMC (Embedded Multimedia Card) persistent captured images.
- Following the storage process, images will have been ready to send to the Mission Control Officers’ computer via the 5.8 GHz TRUERC SNIPER Antenna.
- This sending process will have been existed by the Cubesat Space Protocol (CSP) with CAN, I2C or RS-422.
- The Cubesat Space Protocol (CSP) is about to transfer data to and from the its’s nodes on the main system bus.

- This protocol transmits data collects between individual subsystems on the WIDESATs’ bus and between the WIDESAT and the Mission Control Officers’ computer.
- While images arrived on the Mission Control Officers’ computer via the Full Ground Station Kit, the comparison process will have been started.
- The comparison process will have been occured with the database of the General Directorate of Meteorology.
- After the comparison process, last images that compared will have been stored in the Mission Control Officers’ computer.
- Last images will have been served to the customers if necessary.

13.6 Orbital Control Design

The orbital control design shall provide orbital control determinations for the WIDESAT. Some requirements are,

- This design will have been operated by one compact system.
- Measurements of the compact system will have been obtained from instant conditions.
- This obtaining method is better than obtaining method from the few components.
- The container shall release the payload at 450 km +/- 10 km.
- The payload shall be a cube structure design.
- All structures shall build to withstand launch acceleration like 15 Gs.
- All structures shall build to withstand shock value like 30 Gs.

The attitude control system calculations depend on simulation model. Benefits of this model are,

- Sufficiently accurate to represent dynamics
- Allowing algorithm validation and performance testing
- Translating to an equivalent discrete model that enables the results to be implemented in a real-time embedded system
- Used to determine adequate Proportional-Integral-Derivative controller gains

A satellite’s attitude refers to the spacecraft’s position and orientation with respect to an object, e.g. Earth. As a satellite orbits to Earth, disturbance torques are applied on it by atmospheric, magnetic and gravitational conditions. The instantaneous attitude of a satellite can be described using angle measurements with respect to an inertial frame of reference. This frame uses the velocity vector as the +x axis, the direction of the local zenith as the +z axis, and the +y axis is chosen to be perpendicular to the orbital plane in order to comply with the right hand rule. A second frame of reference, known as the satellite frame, is defined using the satellites principal axes of inertia. The satellite frame moves together with the satellite’s structure when the attitude changes. The angles necessary to rotate the inertial frame so that it coincides with the satellite’s body frame are known as the Euler angles. Rotating about the x-, y- and z-axis is known as a roll, pitch, and yaw rotations, respectively. The rotation angles are indicated as φ, θ, and ψ for the x-, y-, and z-axis respectively. It is possible to represent the attitude by another set of parameters known as quaternions. This representation is more robust because it doesn’t produce an error when the pitch angle approaches ±90°. It is more convenient to use Euler angles because attitude dynamics are simplified in order to have three independent one-axis control systems. Main objective is to define the control requirements, the modeling and simulation of disturbance torques, and the optimization of the control system’s response.

DISTURBANCE MODELING

The sizing of actuators is based on two aspects of the mission: the nature and magnitude of the disturbance torques and the requirements imposed by the payload. To analyze the disturbance torques it is necessary to use a disturbance model that estimates their magnitude throughout an orbit.

SIMULATION INPUT

A computer script based on the CubeSat Toolbox API was used to compute the disturbance torques acting on 1U CubeSat due to atmospheric drag, magnetic dipole moment, gravity gradient and solar pressure. The magnetic drag calculation is based on a tilted dipole model. The sun vector used for the solar pressure is calculated using data. The input parameters for the script were chosen in order to simulate a worst-case scenario for the disturbance torques acting on the CubeSat. The table lists the CubeSat’s mechanical parameters used in order to simulate the worst possible case within constraints imposed.

PARAMETERS	VALUE
CubeSat Type	1U
CubeSat Mass	1.33 kg
Surface Area	0.01 m²
C.G. Offset	<0.02, 0.02, 0.02> m
Dipole Moment	<0.01, 0.01, 0.01> A. m²
Inertia (Ixx, Iyy, Izz)	2.22 x 10^-3 kg. m²
Earths Angular Velocity	7.291x10^-5 rad/s
Drag Coefficient	2.2

TABLE 13. 10 MECHANICAL PARAMETERS OF THE 1U CUBESAT

A residual dipole moment of 1 A-m2 for each axis was assumed, based on the estimation that magnetic torques are the dominant source of disturbances.

Another assumption was that the CubeSat will maintain a constant attitude profile with respect to the Local Vertical Local Horizontal (LVLH) frame of reference.

The center of gravity (C.G.) offset was chosen to be the maximum allowed by the CDS's requirements (2 cm from the geometrical center) and the mass was assumed to be uniformly distributed throughout the CubeSat volume.

The altitude is calculated by subtracting the earth´s mean radius from the orbit´s semi-major axis. Orbital elements used for disturbance simulation are,

PARAMETERS	VALUE
Semi-Major Axis	6788.72 km (417.72 km altitude)
Inclination	51.64°
Right Ascension of the Ascending Node	101.33°
Argument of Perigee	20.20°
Eccentricity	6.177x10^-4
Mean Anomaly	339.94°
Earths Angular Velocity	7.291x10^-5 rad/s
Duration	24 h

TABLE 13. 11 ORBITAL ELEMENTS

The simulation was carried out for 24-hour time span. 24-hour simulation corresponds to 15.521 orbit revolutions, where each orbit has a duration of approximately 92.78 minutes.

SIMULATION OUTPUT

The disturbance simulation model calculates the disturbance torques due to atmospheric, magnetic, gravitational and solar pressure. These calculations are conducted for the x-, y- and z-axes with respect to the CubeSat's body and the Earth Centered Inertial (ECI) frame of reference. The model used for the earth's magnetic field acts the strongest on the CubeSat's z-axis.

HARDWARE DESIGN

The selected control method follows a Zero Momentum control scheme using reaction wheels and magnetorquer as actuators. The parameters that characterize the actuators are needed to reject the expected disturbance torques.

ACTUATOR	PARAMETER	RESULT	RESULT*SAFETY FACTOR
Reaction Wheel	Max. Torque	5.654x10^-7 N·m	5.654x10^-6 N·m
	Max. Momentum	8.387x10^-4 Nm·s	8.387x10^-3 Nm·s
Magnetorquer	Dipole Moment	1.118x10^-2 A·m^2	1.118x10^-1 A·m^2

TABLE 13. 12 HARDWARE DESIGN PARAMETERS

CONTROL SYSTEM MODEL

The dynamics of a satellite can be estimated by the following set of equations:

$$Tdx + Tcx = Ix\ddot{\phi} \qquad [\ 1\ ]$$

$$Tdy + Tcy = Iy\ddot{\theta} \qquad [\ 2\ ]$$

$$Tdz + Tcz = Iz\ddot{\psi} \qquad [\ 3\ ]$$

T corresponds to torque. The suffix d to external disturbance torques acting on the CubeSat. The c to the control torques generated by the reaction wheels, in the x-, y- and z-axes. I is the CubeSat's inertia, where the suffix indicates the axis it is measured about. When the CubeSat's body reference frame is placed so that its axes coexist with the structure's main axes of inertia. The products of inertia in the satellite's inertia matrix are cancelled. The model consisting of equations [1], [2] and [3] makes the assumption that the system's inertia matrix is diagonal by using the principal axes of inertia as the system's reference axes. 3-axis attitude dynamics can be treated as three individual systems that control the attitude over each rotation axis independently.

This orbital control calculation theory is to represent 1U CubeSat, all steps of this calculation will have been changed.

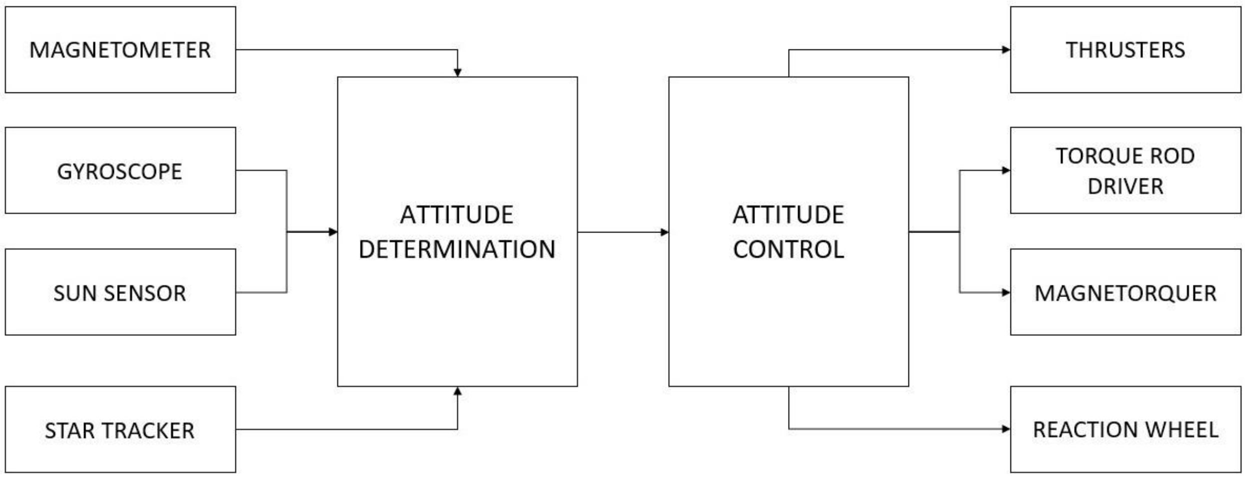


FIGURE 13. 27 WORKING DIAGRAM OF THE ORBITAL CONTROL DESIGN

Overview of the orbital control design is,

PRODUCT TYPE	MODEL	QUANTITY	PURPOSE
ADACS + Star Tracker	MAI-500 0.6-Unit CubeSat ADACS and Dual Star Tracker	1	Ensure Orbital Control
Thruster	IFM Nano Thruster	16	Allowed to Move the WIDESAT in 360 Degrees

TABLE 13. 13 ORBITAL CONTROL DESIGN OVERVIEW

13.6.1 Adacs and dual star tracker

The selected compact system called the MAI-500 0.6-Unit CubeSat ADACS and Dual Star Tracker has not got alternative due to its mechanism. This compact system includes two star trackers, three reaction wheels, three electromagnets, the 3-axis magnetometer and the ADACS computer for a stand-alone. [14]

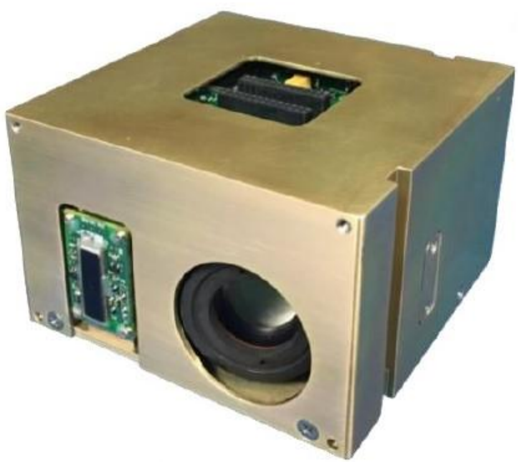


FIGURE 13. 28 ADACS AND DUAL STAR TRACKER-1

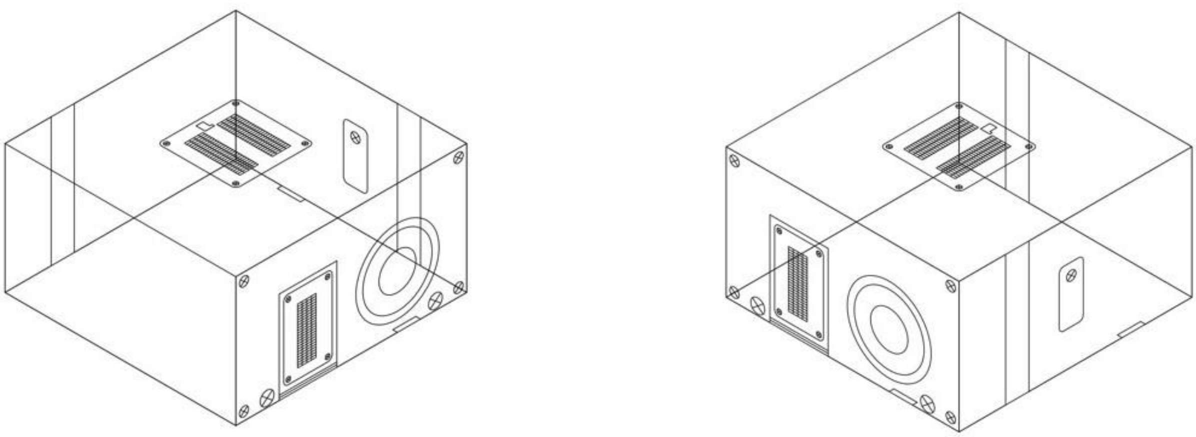


FIGURE 13. 29 ADACS AND DUAL STAR TRACKER-2

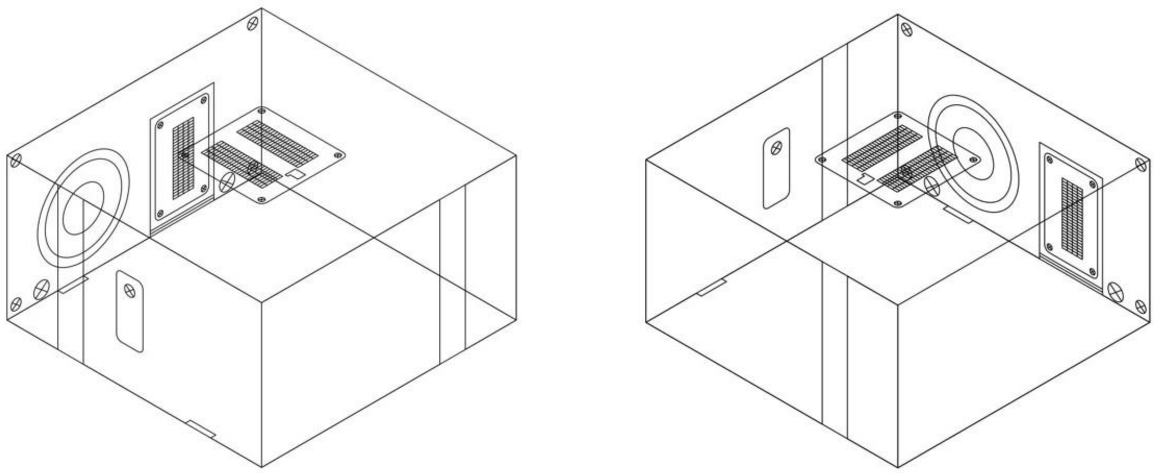


FIGURE 13. 30 ADACS AND DUAL STAR TRACKER-3

Specifications of the MAI-500 0.6-Unit CubeSat ADACS and Dual Star Tracker are, [14]

PERFORMANCE ITEM	SPECIFICATION
DIMENSIONS	10 x 10 x 6.23 cm
MASS	1049 g
MOMENTUM STORAGE @10000 RPM	11.076 mNms
MAX TORQUE	0.635 mNm
MAGNETIC DIPOLE MOMENT	0.14 Am^2
MAGNETOMETER	± 900 µT
OPERATING VOLTAGE	5.0 V

POINTING COMMAND / TLM INTERFACE	0.1 deg LVLH / 0.008 deg ECI RS232, SCI/UART
SUN SENSOR INTERFACE	6 Analog Channels (0 – 3.3V)
OPERATING TEMPERATURE	-20 TO 60 °C
LAUNCH ENVIRONMENT VIBRATION SPEC	14 G rms

TABLE 13. 14 SPECIFICATIONS OF THE MAI-500 0.6-UNIT CUBESAT ADACS AND DUAL STAR TRACKER

Power consumption properties of the MAI-500 0.6-Unit CubeSat ADACS and Dual Star Tracker are, [14]

POWER CONSUMPTION	VALUE
MINIMUM POWER	1.82 W (0.164 A)
AVERAGE POWER USE IN NADIR POINTING	2.13 W (0.226 A)
1 RW LOW SPEED MAX TORQUE POWER USE	3.05 W (0.41 A)
1 RW HIGH SPEED MAX TORQUE POWER USE	2.10 W (0.22 A)
MAX INSTANTANEOUS CURRENT	1.603 A

TABLE 13. 15 POWER CONSUMPTION PROPERTIES OF THE MAI-500 0.6-UNIT CUBESAT ADACS AND DUAL STAR TRACKER

Star Tracker properties of the the MAI-500 0.6-Unit CubeSat ADACS and Dual Star Tracker are, [14]

STAR TRACKER	PROPERTY
ACCURACY	6 / 30 as
MAX ACQUISITION TIME	250 msec
MAX SLEW RATE	1.0°/sec
STAR CATALOG	6.0 VM

TABLE 13. 16 STAR TRACKER PROPERTIES OF THE THE MAI-500 0.6-UNIT CUBESAT ADACS AND DUAL STAR TRACKER

13.6.2 Thruster

The thruster will have been allowed to move the whole system in 360 degrees on the WIDESAT. The thruster called the IFM Nano Thruster will have been branded by ENPULSION Co. [15]

Main points of the IFM Nano Thruster are, [15]

- Mature technology type
- Dynamic thrust control
- Controllable impulsing
- Redundant neutralizer cathode structure
- Safe and inert system
- Reliable thrust vectoring
- Compact building blocks

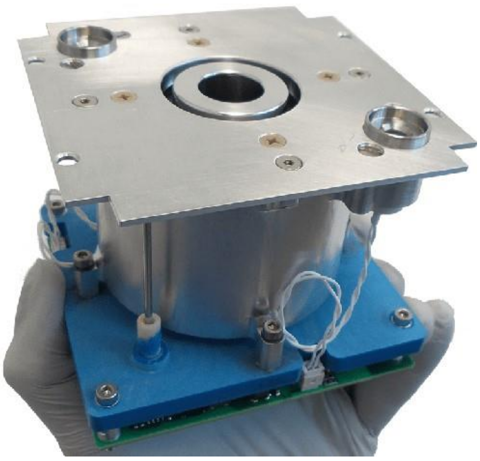


FIGURE 13. 31 IFM NANO THRUSTER-1

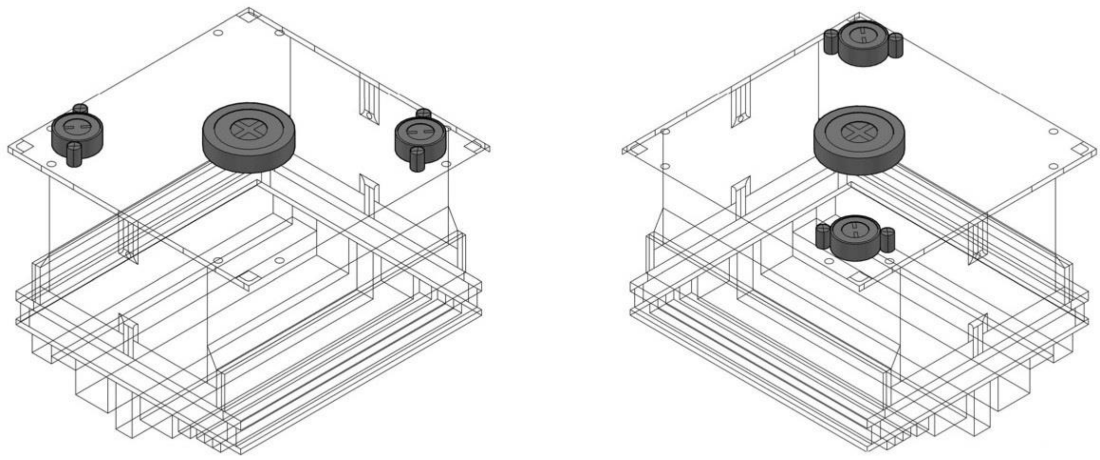


FIGURE 13. 32 IFM NANO THRUSTER-2

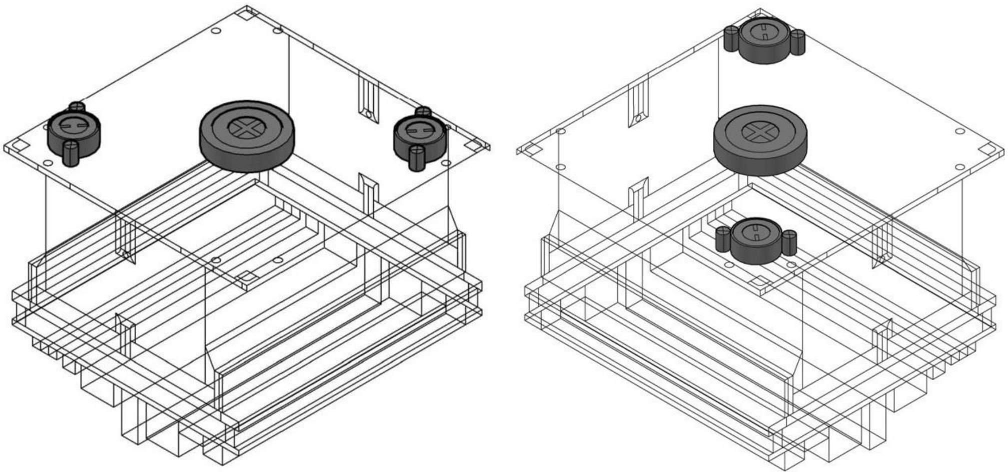


FIGURE 13. 33 IFM NANO THRUSTER-3

Some properties of the IFM Nano Thruster are, [15]

PARAMETER	VALUE
OUTSIDE DIMENSIONS	94 x 90 x 78 mm
MASS (DRY/WET)	640 / 870 g
TOTAL SYSTEM POWER	8 – 40 W
HOT STAND-BY POWER	3.5 W
COMMAND INTERFACE	RS422 / RS485
TEMPERATURE (NON-OPERATIONAL)	-50 to 120°
TEMPERATURE (OPERATIONAL)	-20 to 50°
SUPPLY VOLTAGE	12 V , 28 V or Other Voltages

TABLE 13. 17 PROPERTIES OF THE IFM NANO THRUSTER

Some performance properties of the IFM Nano Thruster are, [15]

PARAMETER	VALUE
DYNAMIC THRUST	10 µN to 0.5 mN
NOMINAL THRUST	350 µN
SPECIFIC IMPULSE	2,000 to 5000 s
PROPELLANT MASS	250 g
TOTAL IMPULSE	More than 5,000 Ns
NOMINAL THRUST POWER CONSUMPTION	35 W incl. Neutralizer

TABLE 13. 18 PERFORMANCE PROPERTIES OF THE IFM NANO THRUSTER

13.6.3 Attitude control system

This system provides attitude measures, synthesizing and creating control issues for the WIDESAT. Requirements of this system are,

- This system shall show the WIDESAT's instant location and distance from the target spot on the planet Earth.
- Attitude measurements shall come from the detection of an angle or angular rate of the spacecraft with regard to a reference frame.
- We have been discussed to use Passive Attitude Control System due to small size structure and cheapness about installing.

- The development of this system shall consist of Attitude Sensors, Magnetorquer and Reaction Wheel components.
- Printed Circuit Board (PCB) to control whole system will have been fabricated.
- The system will have been designed with power-efficient structure for operations.

Overview of the attitude control system is, [16]

TYPE	MODEL	QUANTITY	PURPOSE
Three-Axis Magnetometer	Honeywell HMC5883L Three-Axis MEMS	1	Magnetic Field Measurements
Gyroscope	ADXRS614 MEMS	1	Obtaining in Three-Axis From Three Orthogonally
Microcontroller	AT91SAM9260 32-bit ARM9	1	Managing the Attitude Control System
Torque Rod Driver	BD6212	1	Controlling General Torques
Coarse Sun Sensor	TSL1402	1	Delivering Coarse Information About The Position of Sun Relative
Magnetorquer	Magnetorquer	33	Control the Attitude of the WIDESAT
Reaction Wheel	CubeWheel Large	33	Control the Attitude of the WIDESAT
Printed Circuit Board (PCB)	-	1	Including Three-Axis Magnetormeter, Gyroscope, Microcontroller, Torque Rod Driver, Coarse Sun Sensor

TABLE 13. 19 OVERVIEW OF THE ATTITUDE CONTROL SYSTEM

Working diagram of the attitude control system is, [16]

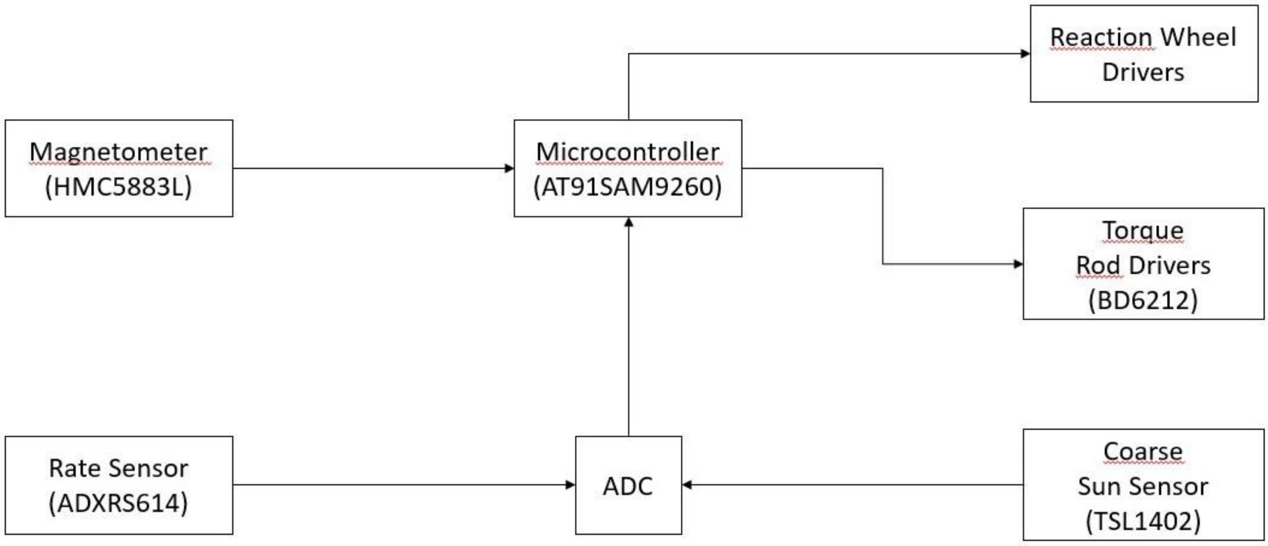


FIGURE 13. 34 WORKING DIAGRAM OF THE ATTITUDE CONTROL SYSTEM

13.6.3.1 Magnetorquer

The magnetorquer will have been controlled the attitude of the WIDESAT. The magnetorquer called the Magnetorquer will have been branded by NewSpace Systems Co. Features of the magnetorquer are, [17]

- Low cost with standardized product
- High moment output with low power consumption
- Small size
- Low mass
- Simple interface
- Not including magnetic moment

Some performance values of the magnetorquer are, [17]

NO	PERFORMANCE	VALUE
1	Magnetic Moment	1.2 Am
2	Linearity	Better than ±5% Design Range
3	Residual Moment	< 0.002 Am
4	Power	5 V
5	Random Vibration	14 Grms

TABLE 13. 20 PERFORMANCE VALUES OF THE MAGNETORQUER

Some product properties of the magnetorquer are, [17]

NO	PRODUCT PROPERTY	VALUE
1	Lifetime	> 10 Years
2	Dimensions	94 mm x 15 mm x 13 mm
3	Mounting	4 x M2 Socket Head Cap Screws
4	Mass	< 50 g
5	Interfaces	Molex Pico-Lock
6	Operating Range	-10 °C to +50 °C

TABLE 13. 21 PRODUCT PROPERTIES OF THE MAGNETORQUER

Note that, configurations of the magnetorquer are representative.

FIGURE 13. 35 MAGNETORQUER-1

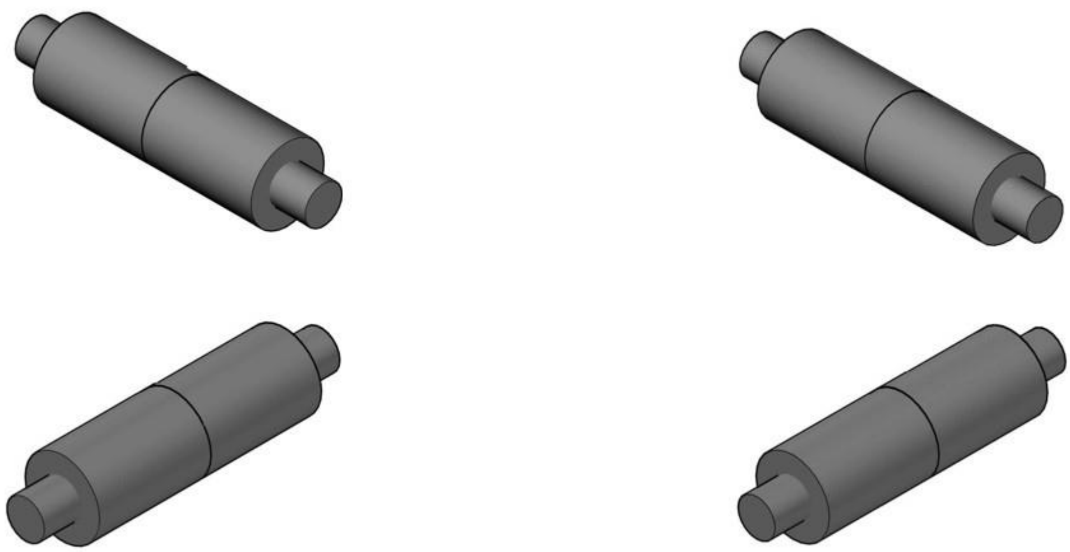


FIGURE 13. 36 MAGNETORQUER-2

13.6.3.2 Reaction wheel

The reaction wheel will have been controlled the attitude of the WIDESAT. The reaction wheel called the CubeWheel Large will have been branded by CubeSpace Co. Features of the reaction wheel are, [18]

- Use to exchange angled momentum
- Can integrates with ADACS
- Contains brushless DC motor to reduce friction
- Vacuum-rated bearings
- 12-bit angular rate feedback
- Having integrated electronics that include driver for circuit and algorithms of speed control
- Interfaces called I2C , UART and CAN
- Compact size
- 3-axes mountable structure
- Shielded by using Mu-Metal

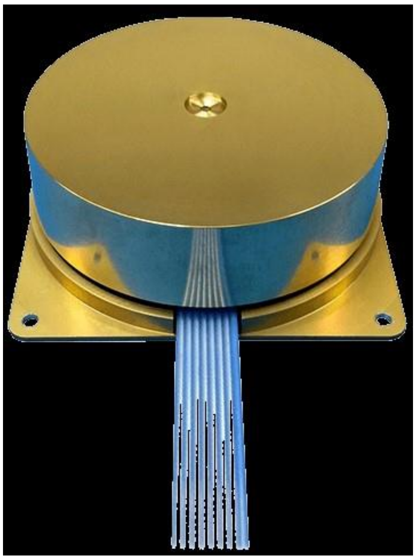


FIGURE 13. 37 REACTION WHEEL-1

Some performance values of the reaction wheel are, [18]

NO	PERFORMANCE	VALUE
1	Speed Range	±6000 RPM
2	Speed Control Accuracy	< 5 RPM
3	Max Torque	2.3 mNm
4	Momentum Storage (@6000 RPM)	30.0 mNms

TABLE 13. 22 PERFORMANCE VALUES OF THE REACTION WHEEL

FIGURE 13. 38 REACTION WHEEL-2

Some product properties of the reaction wheel are, [18]

NO	PRODUCT PROPERTY	VALUE
1	Operating Voltage	3.3 V
2	Average Power Consumption	< 180 mW (@2000 RPM, 8 V)
3	I2C Bus Voltage	3.3 V
4	Mass	200 g
5	Dimensions	57 mm x 57 mm x 31.5 mm

TABLE 13. 23 PRODUCT PROPERTIES OF THE REACTION WHEEL

Note that, configurations of the reaction wheels are representative

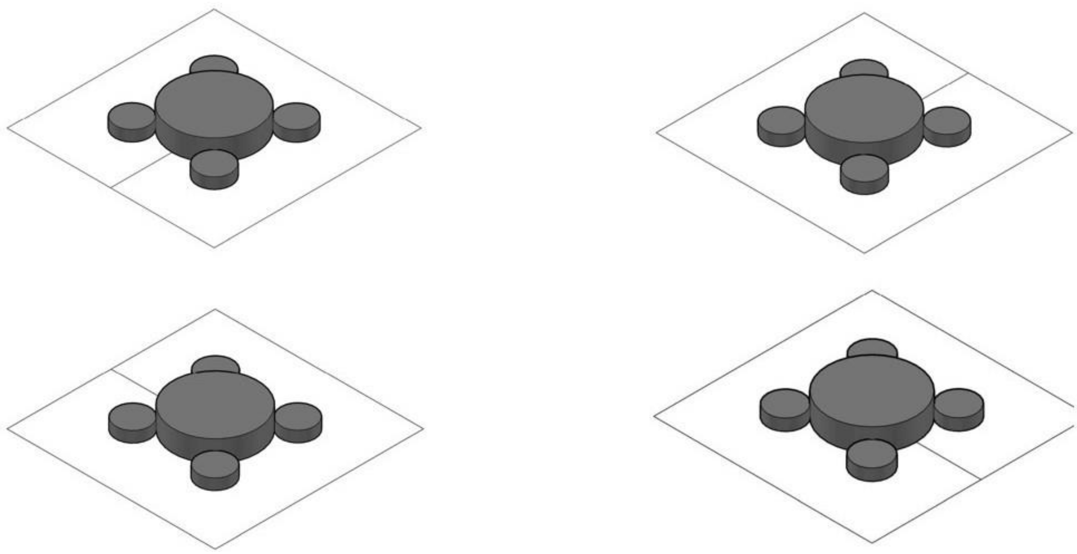


FIGURE 13. 39 REACTION WHEEL-3

13.6.3.3 Printed circuit board (pcb)

The printed circuit board called PCB is the board that includes many components. These components are Three-Axis Magnetormeter, Gyroscope, Microcontroller, Torque Rod Driver and Coarse Sun Sensor. Also, this board creates reliable coordinations to work these components effectively. [16]

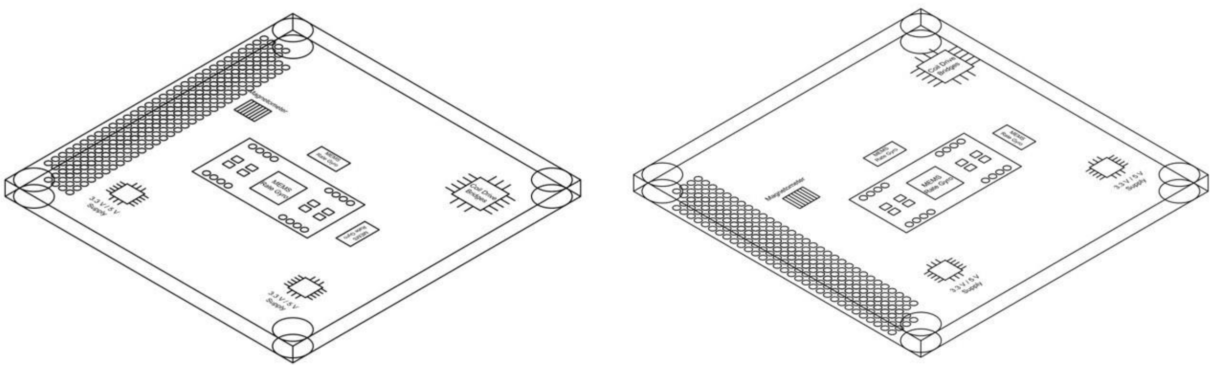


FIGURE 13. 40 PRINTED CIRCUIT BOARD (PCB)-1

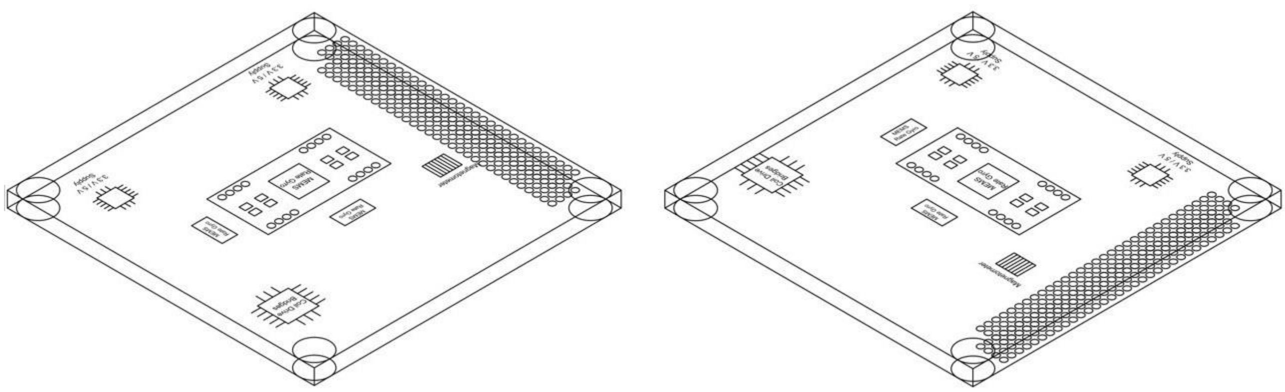


FIGURE 13. 41 PRINTED CIRCUIT BOARD (PCB)-2

13.7 Mechanical Subsystem Design

The mechanical subsystem design is one of the most important design of the WIDESAT. This design examines whole body type. So that, design should have suitable, large volume and minimum risk structure. Comparison of the design types is,

DESIGN	ADVANTAGE	DISADVANTAGE
CUBICAL	Suitable for Camera Detection Missions Large Capacity for Payload Minimum Risk With Maximum Benefit	Sharp Edges
SPHERE	Spherical Type Illustration Capability Small Size Structure	Not Enough In-Side Space in Payload Not Suitable for Launch Vehicles High Risk for Payload Structure
CYLINDER	Cylinderical Type Modifiable Capability Standard Structure	Limited Capacity Not Capable for LEO Satellite Missions Not Launch With Multiples

TABLE 13. 24 COMPARISON OF THE DESIGN TYPES

After the comparison as shown above, selected design type is Cubical. Reasons of this selection are,

- Suitable
- High Volume

- Minimum Risk
- Easy to Control
- High Installation Level

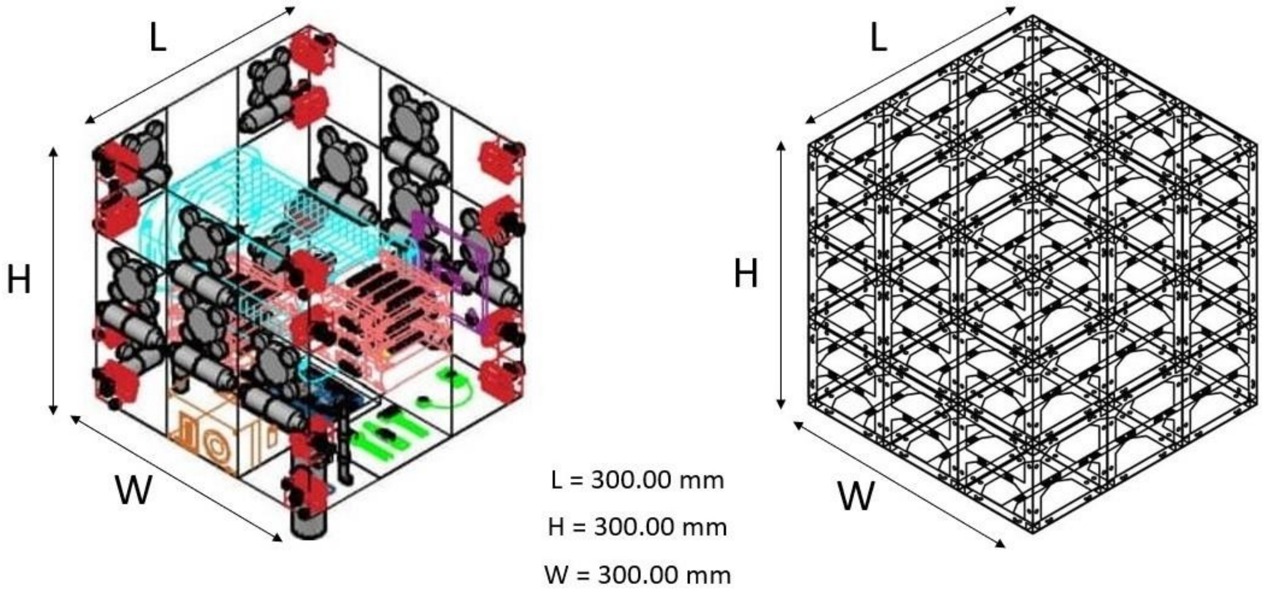


FIGURE 13. 42 CUBICAL DESIGN

Requirements of the mechanical subsystem design are,

- Total weight of the WIDESAT (payload+container) should be less than 100 kg.
- WIDESAT should fit in a cubic shape of 300.00 x 300 00 x 300.00 mm (Length x Width x Heigth).
- The container shall have sharp edges.
- The container shall be solid and fully enclose the payload. Small holes shall allow to access about turning on the payload. The end of the container where the payload deploys shall open.
- All electronic components shall enclose from the environment.
- All structures shall build to withstand launch acceleration like15 Gs.
- All structures shall build to withstand shock like 30 Gs.

- The probe shall contain an fastly accessible power switch that can be accessed without disassembling the satellite and in the stowed configuration.
- The probe shall contain a power indicator such as an LED or sound generating probes that can be easily seen without disassembling the satellite and in the stowed state.

Main material selection of the main compartment, container and cover has high value. If selected material is insufficient, the WIDESAT will have been damaged in space. Comparison of the main structure material is, [19]

MAIN STRUCTURE MATERIAL	COST	TENSILE STRENGTH (Mpa)	DENSITY (kg/m^3)	ADVANTAGES	DISADVANTAGES
Carbon Fiber	200 $/m^2	580	1330	Light , Strong, Absorbing the Electromagnetic Waves	Expensive
ABS	19.5$/kg	40	1070	Easy Manufacturing	Not Strong
Acrylic	2.7$/kg	64.8	1180	Accessible	Very Heavy
Fiberglass	4.5$/m	-	-	Light, Strong	Hard to prepare
Aluminium	1.8 $/kg	570	2700	Strong, Relatively Cheap	Heavy
Aluminium Alloy	1.8 $/kg	570	2700	Strong, Relatively Cheap	Heavy

TABLE 13. 25 COMPARISON OF THE MAIN STRUCTURE MATERIAL

After comparison as shown above, selected material is carbonfiber. Reasons of this selection are,

- High strength.
- Light
- Reliable
- Absorbing Electromagnetic Waves

Payload structure configuration of the WIDESAT is,

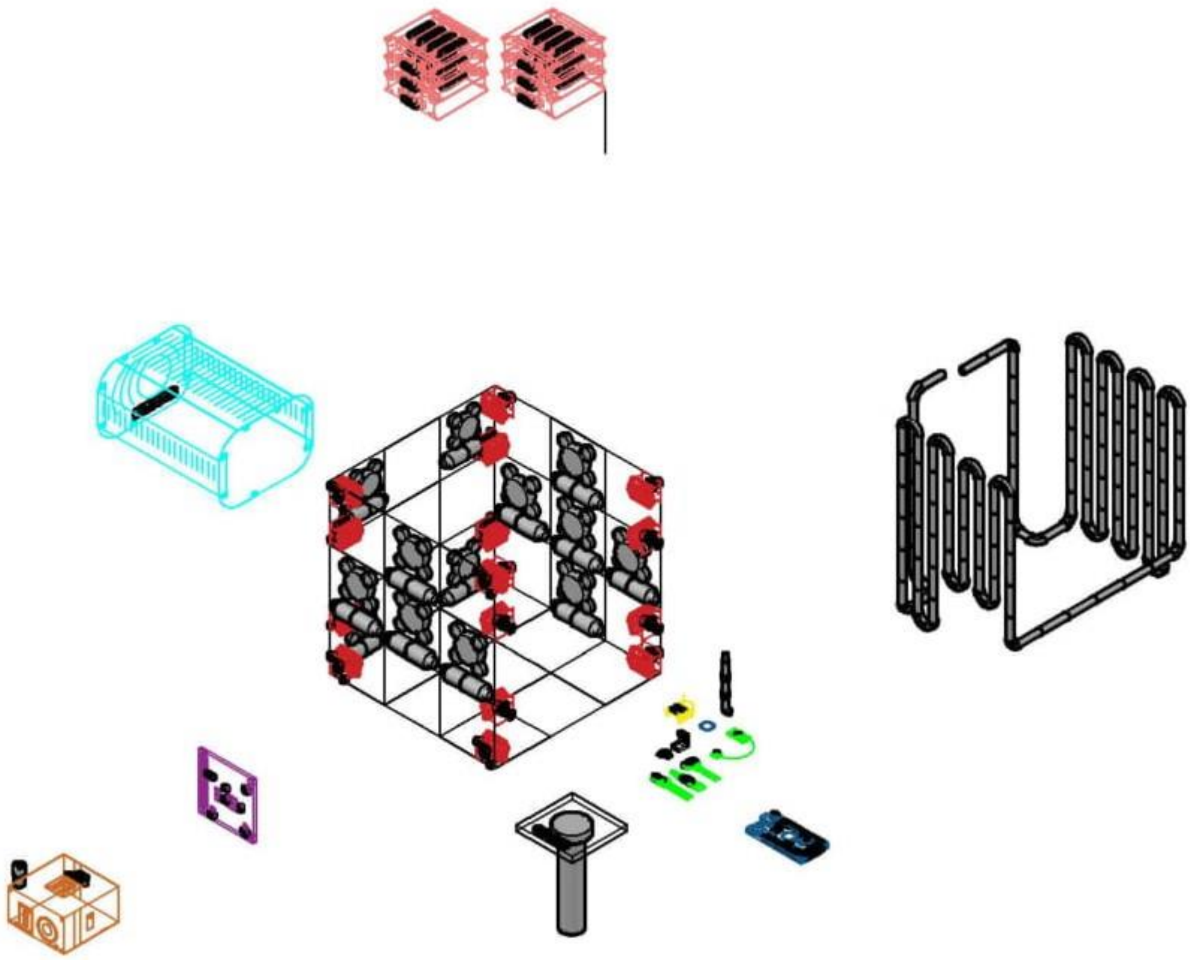


FIGURE 13. 43 PAYLOAD STRUCTURE CONFIGURATION OF THE WIDESAT-1

Note that, location of each component in the payload can change due to volume in payload

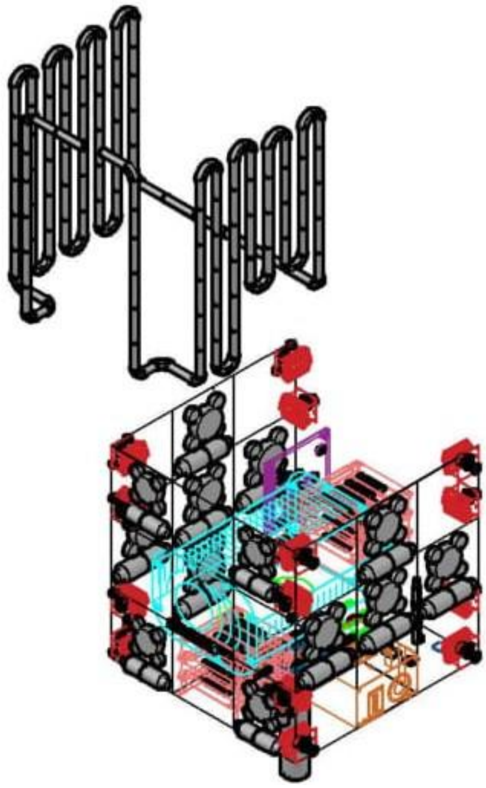


FIGURE 13. 44 PAYLOAD STRUCTURE CONFIGURATION OF THE WIDESAT-2

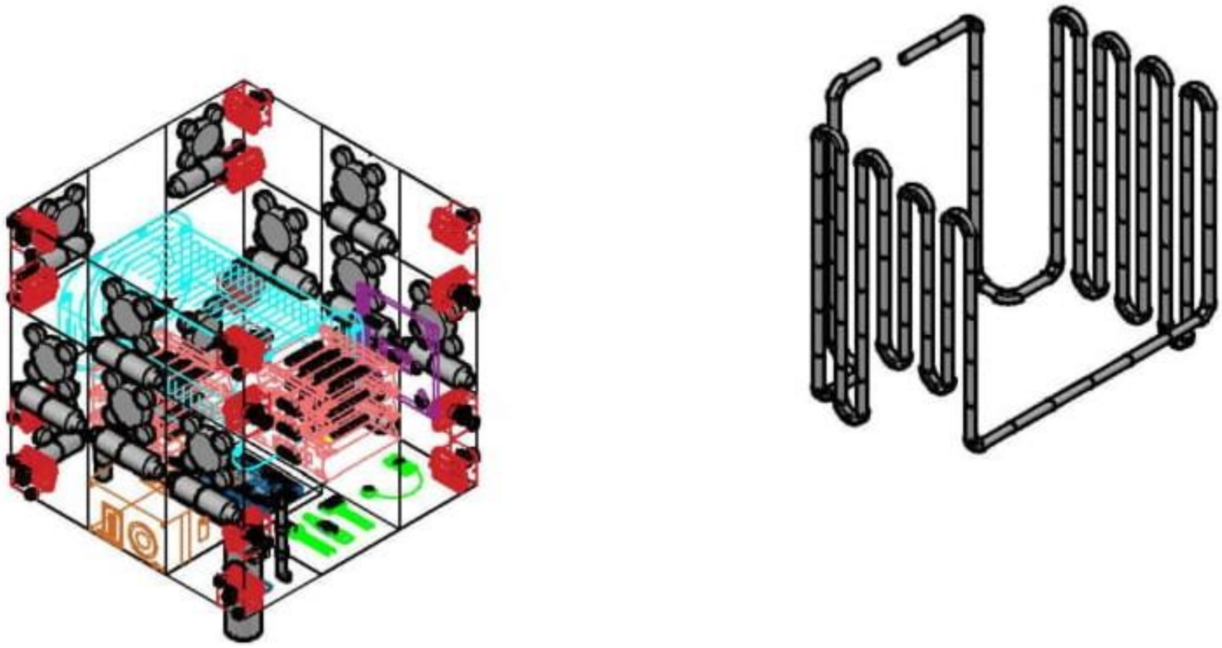


FIGURE 13. 45 PAYLOAD STRUCTURE CONFIGURATION OF THE WIDESAT-3

ADACS + Dual Star Tracker configuration of the WIDESAT is,

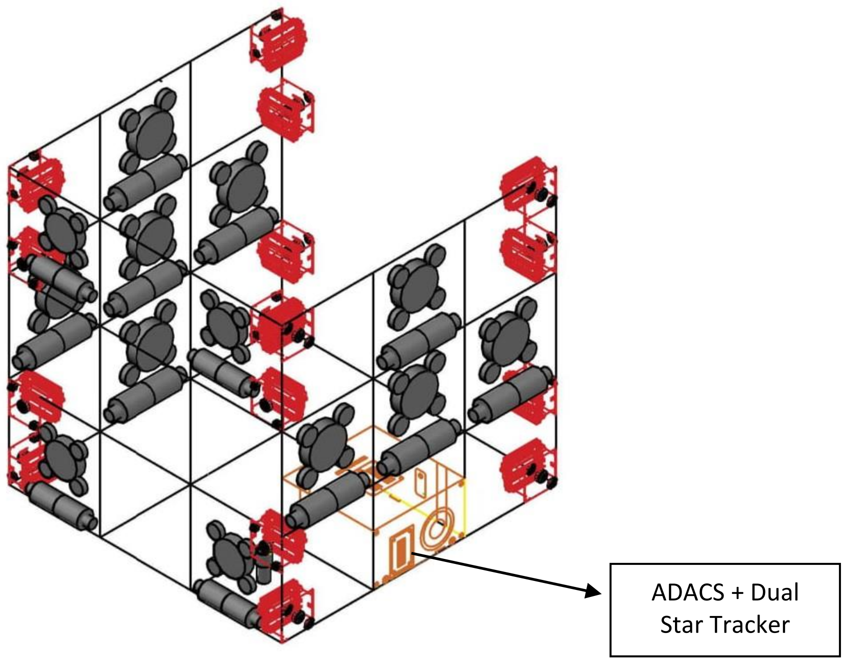


FIGURE 13. 46 ADACS + DUAL STAR TRACKER CONFIGURATION OF THE WIDESAT-1

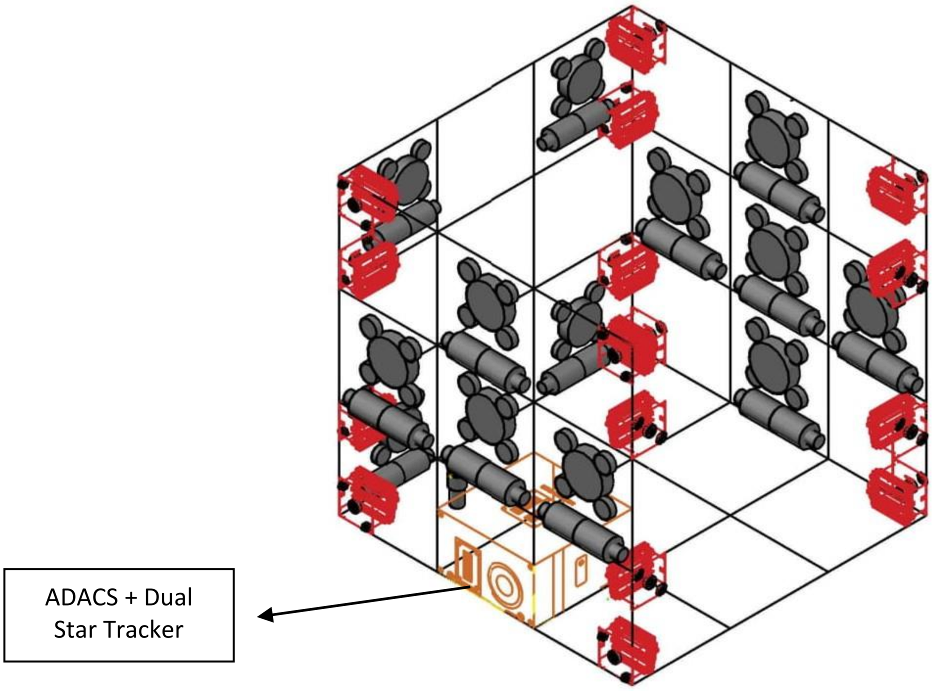


FIGURE 13. 47 ADACS + DUAL STAR TRACKER CONFIGURATION OF THE WIDESAT-2

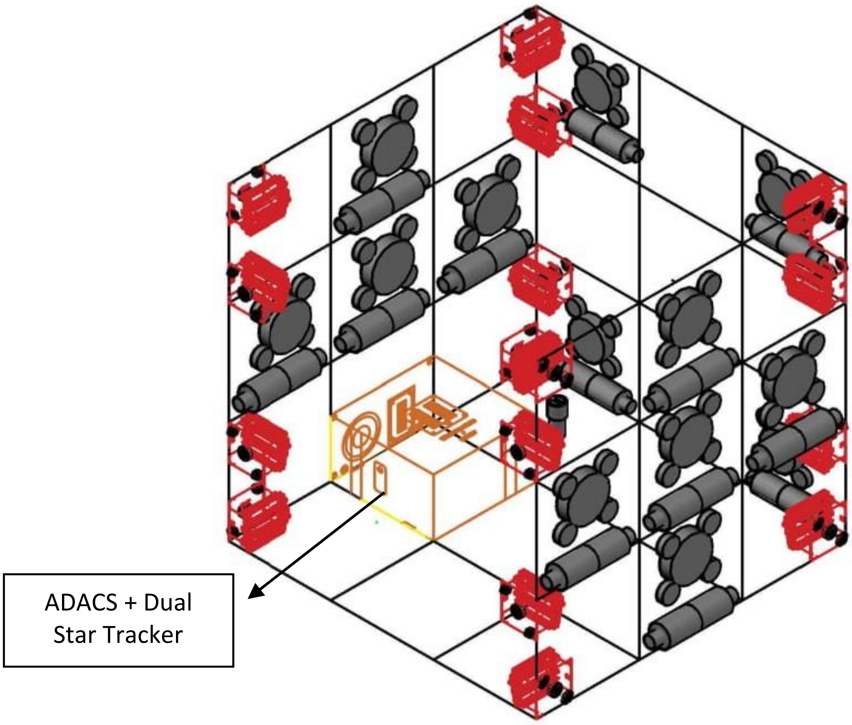


FIGURE 13. 48 ADACS + DUAL STAR TRACKER CONFIGURATION OF THE WIDESAT-3

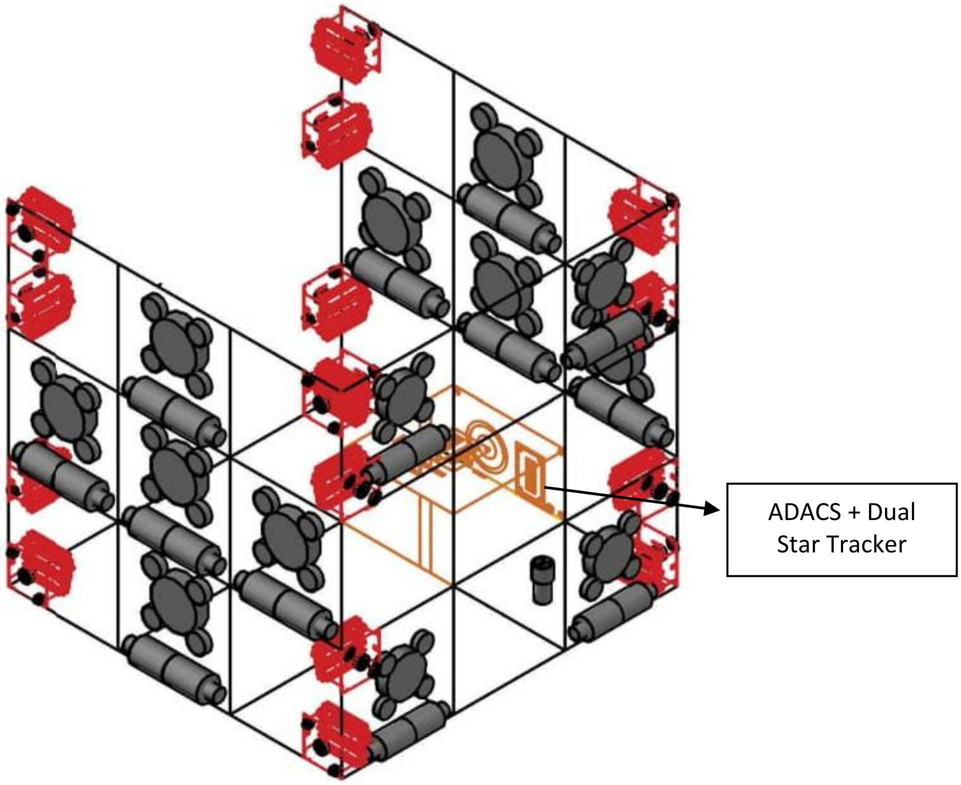


FIGURE 13. 49 ADACS + DUAL STAR TRACKER CONFIGURATION OF THE WIDESAT-4

Air temperature sensor, air pressure sensor, humidity sensor, GPS sensor and XBEE series S2C pro configurations of the WIDESAT is,

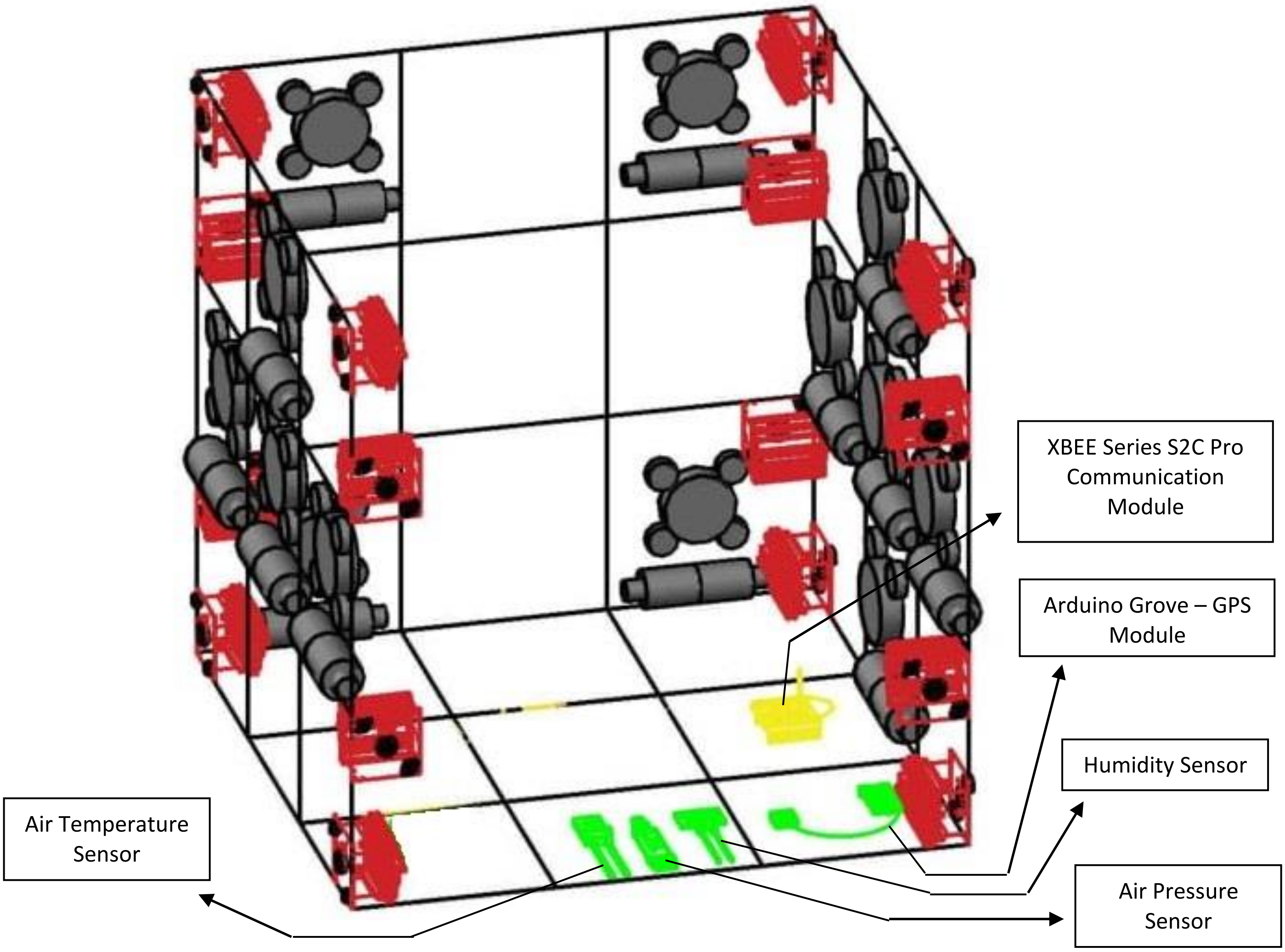


FIGURE 13. 50 AIR TEMPERATURE SENSOR, AIR PRESSURE SENSOR, HUMIDITY SENSOR, ARDUINO GROVE – GPS MODULE AND XBEE SERIES S2C PRO COMMUNICATION MODULE CONFIGURATION OF THE WIDESAT

GOZ CAMERA configuration of the WIDESAT is,

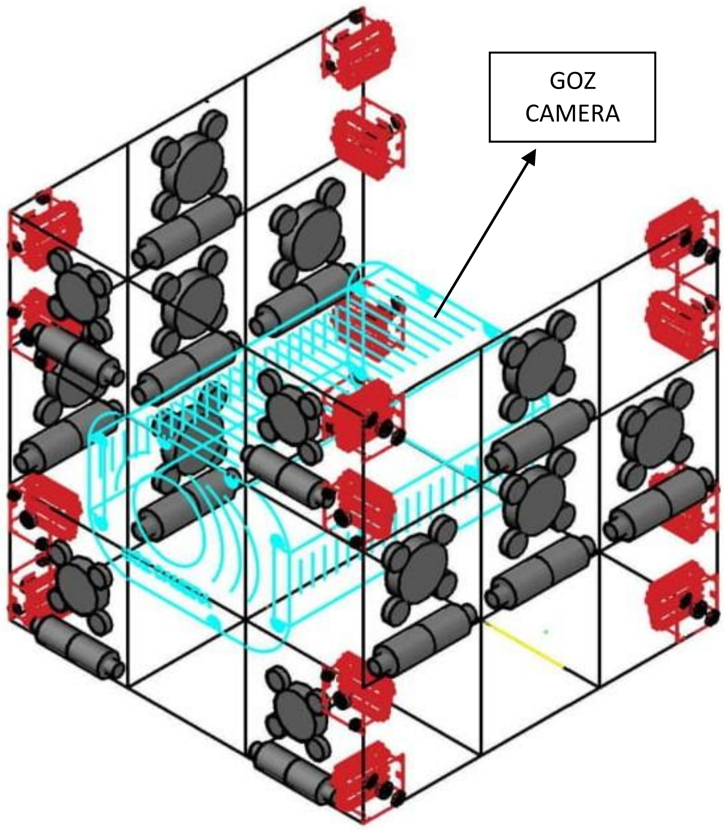


FIGURE 13. 51 GOZ CAMERA CONFIGURATION OF THE WIDESAT-1

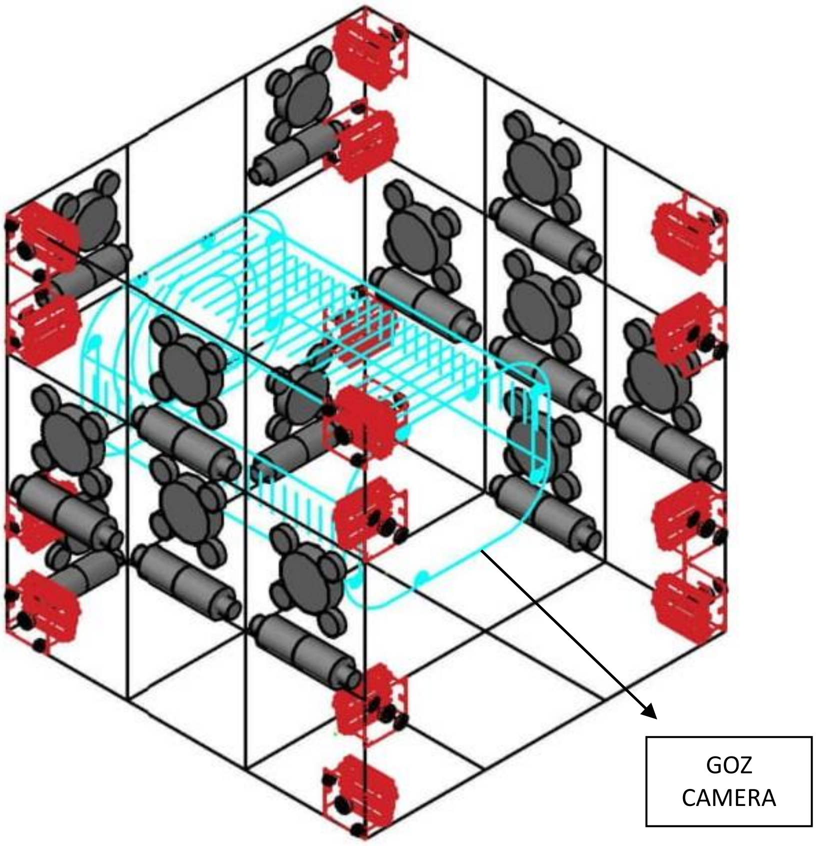


FIGURE 13. 52 GOZ CAMERA CONFIGURATION OF THE WIDESAT-2

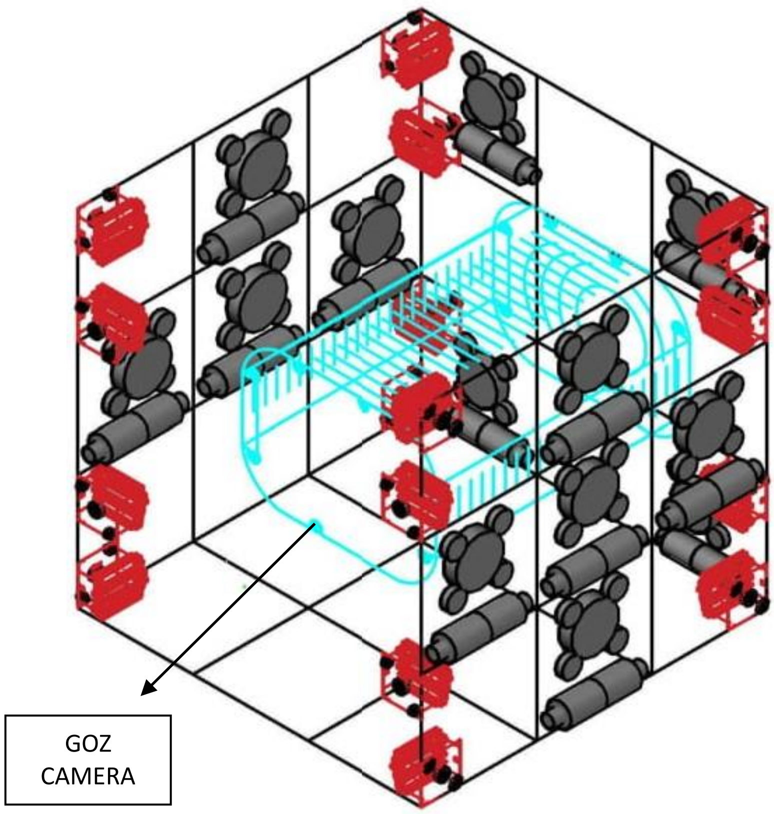


FIGURE 13. 53 GOZ CAMERA CONFIGURATION OF THE WIDESAT-3

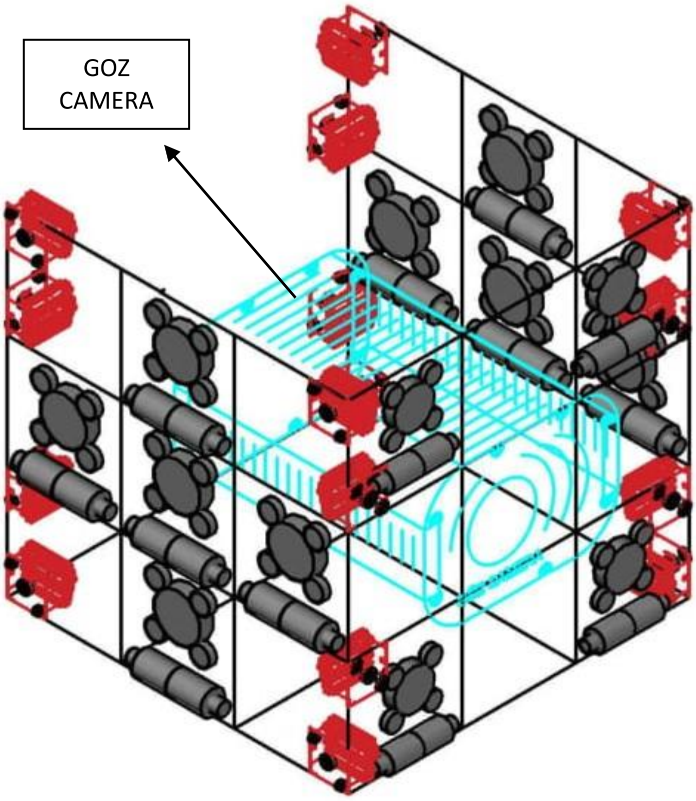


FIGURE 13. 54 GOZ CAMERA CONFIGURATION OF THE WIDESAT-4

Li-Ion battery called iEPS configuration of the WIDESAT is,

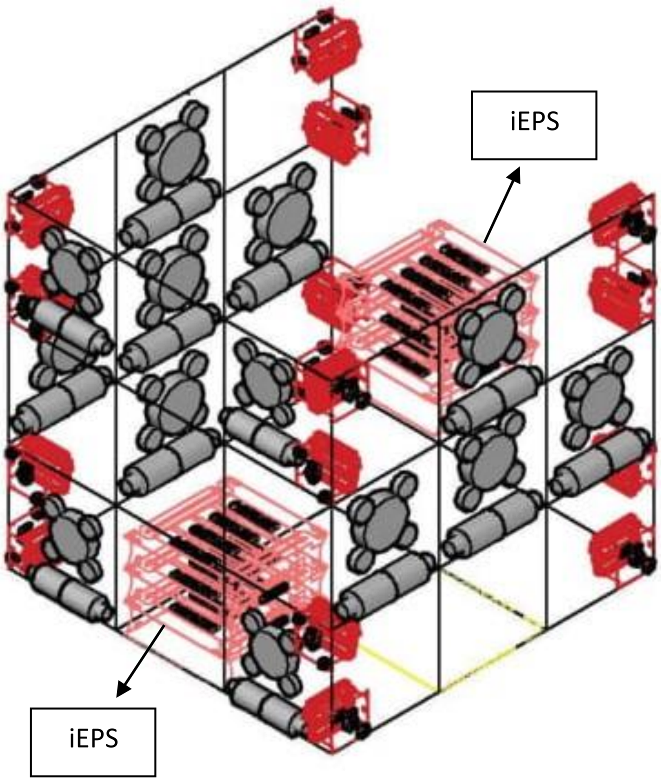


FIGURE 13. 55 iEPS CONFIGURATION OF THE WIDESAT-1

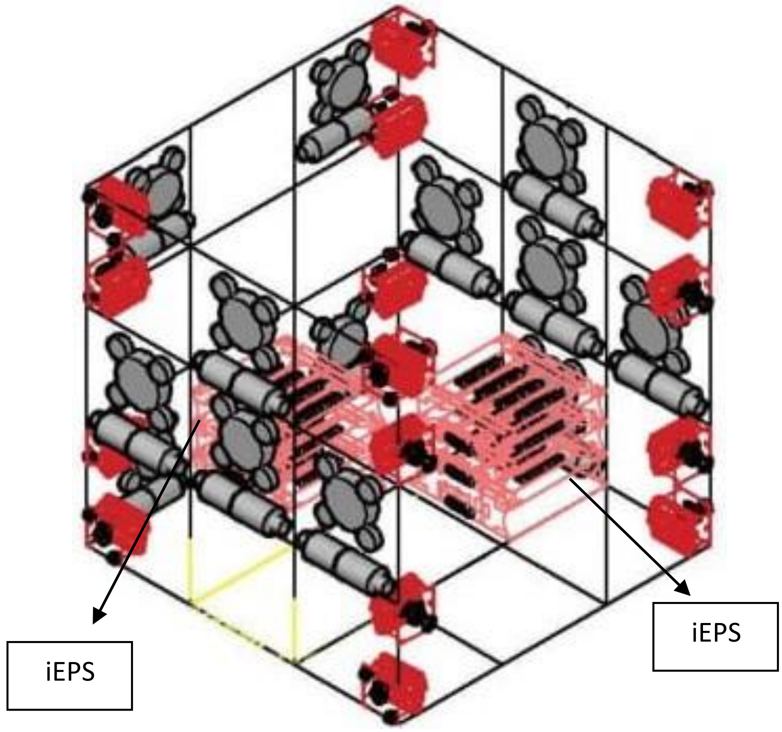


FIGURE 13. 56 iEPS CONFIGURATION OF THE WIDESAT-2

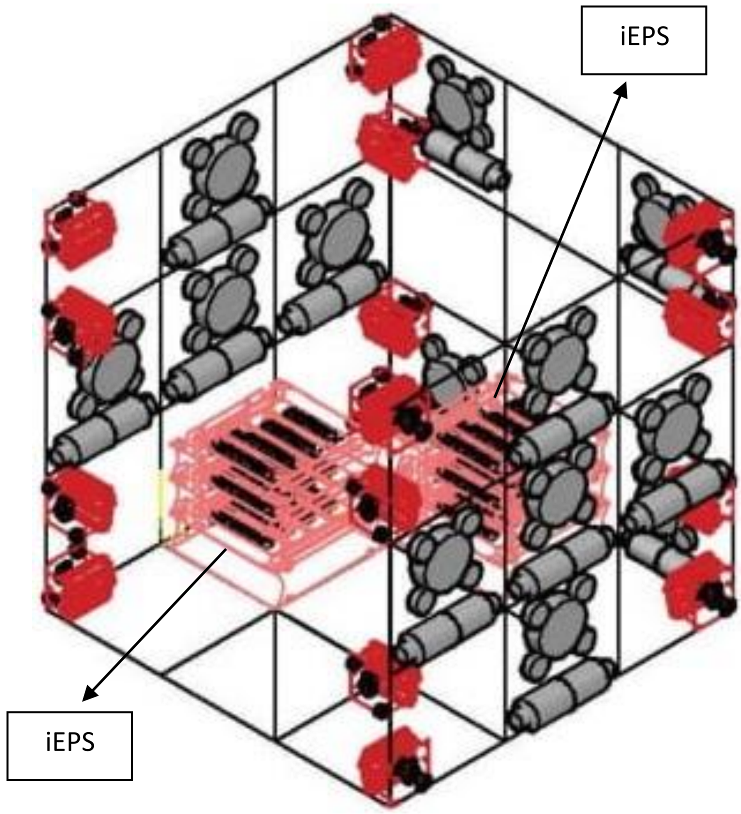


FIGURE 13. 57 iEPS CONFIGURATION OF THE WIDESAT-3

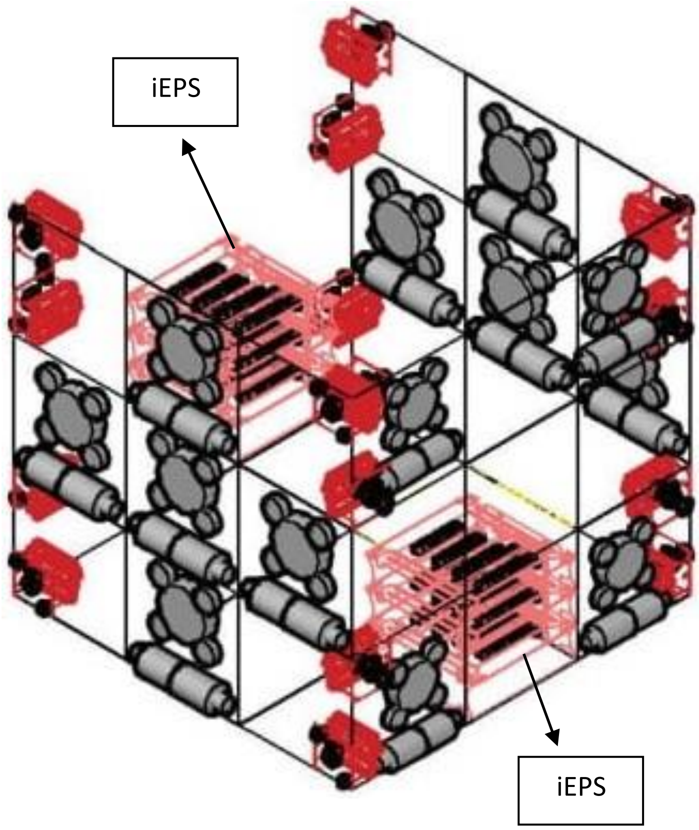


FIGURE 13. 58 iEPS CONFIGURATION OF THE WIDESAT-4

Magnetorquers and reaction wheels configuration of the WIDESAT is,

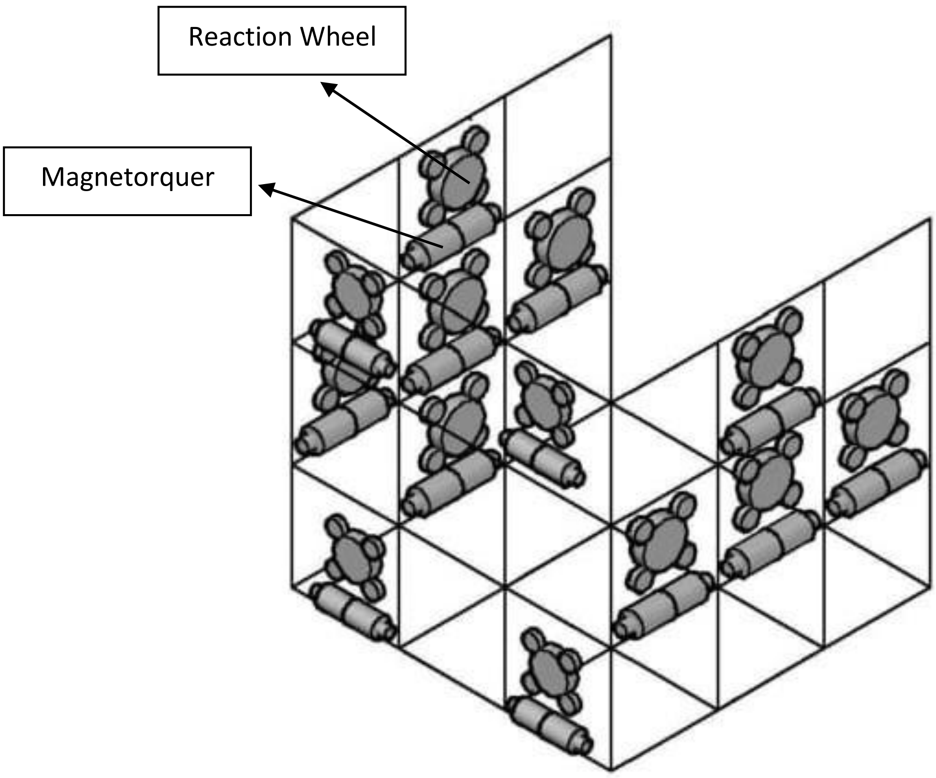


FIGURE 13. 59 MAGNETORQUERS AND REACTION WHEELS CONFIGURATION OF THE WIDESAT-1

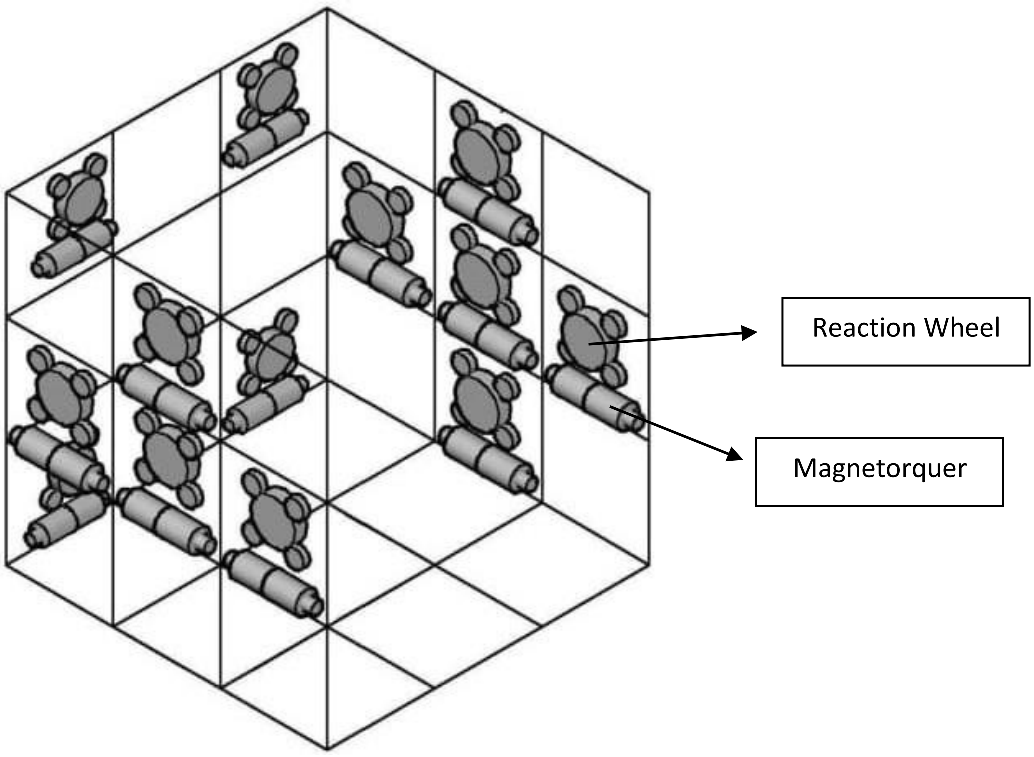


FIGURE 13. 60 MAGNETORQUERS AND REACTION WHEELS CONFIGURATION OF THE WIDESAT-2

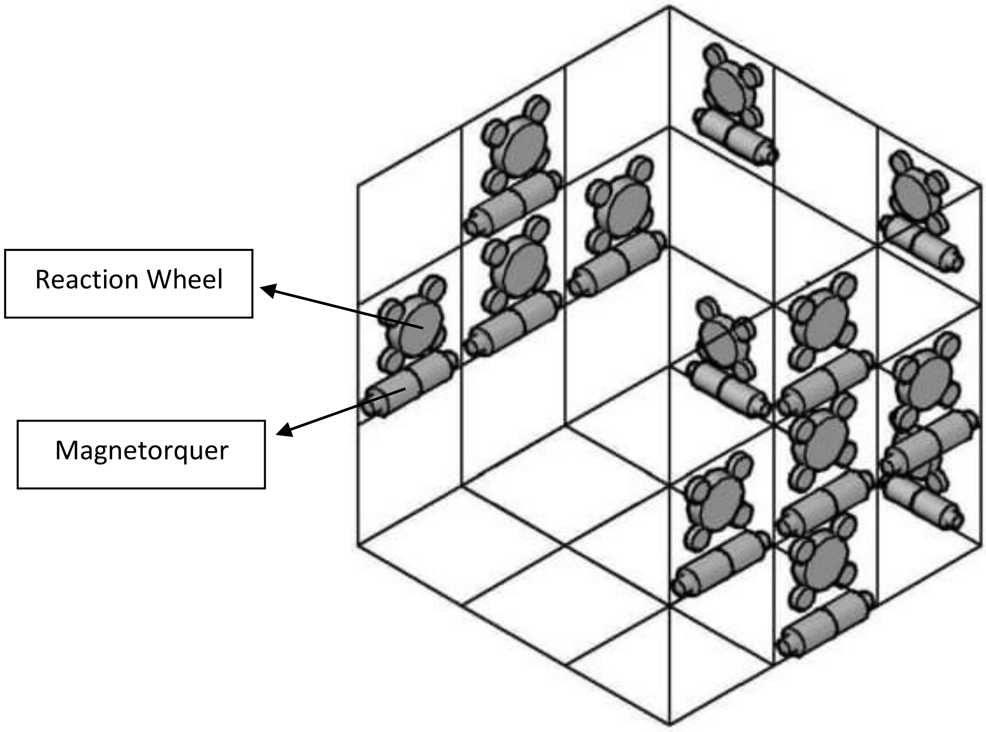


FIGURE 13. 60 MAGNETORQUERS AND REACTION WHEELS CONFIGURATION OF THE WIDESAT-3

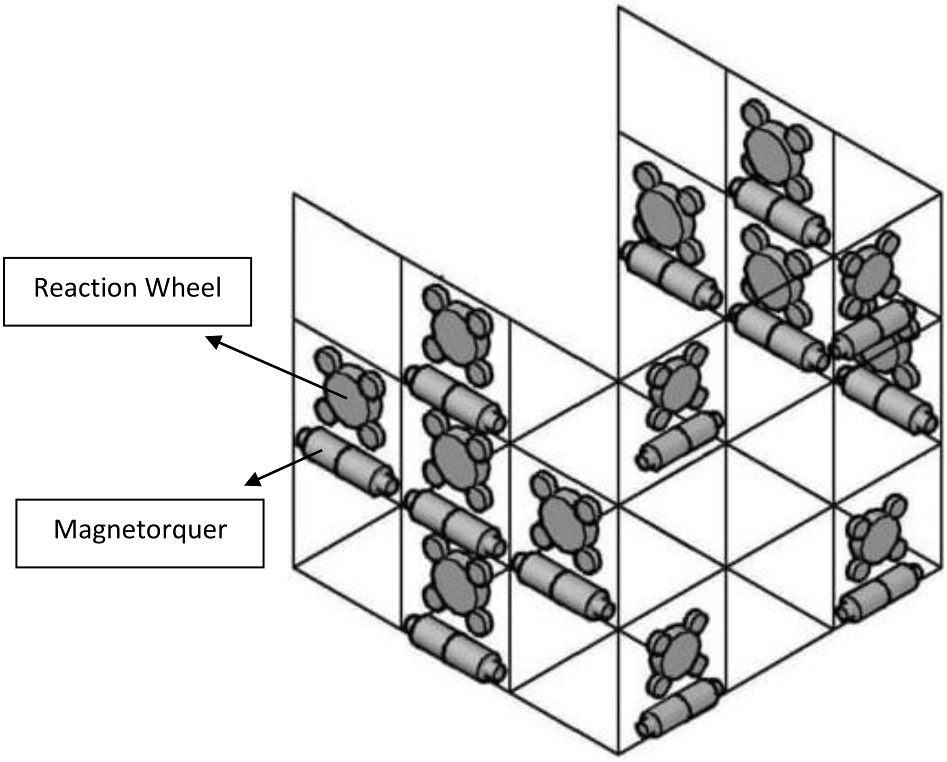


FIGURE 13. 61 MAGNETORQUERS AND REACTION WHEELS CONFIGURATION OF THE WIDESAT-4

ATmega 2560, DS3231 Real-Time Clock (RTC), XBEE Stock Wire Antenna, Sandisk Ultra 16 GB and 5.8 GHz TRUERC SNIPER Antenna configuration of the WIDESAT is,

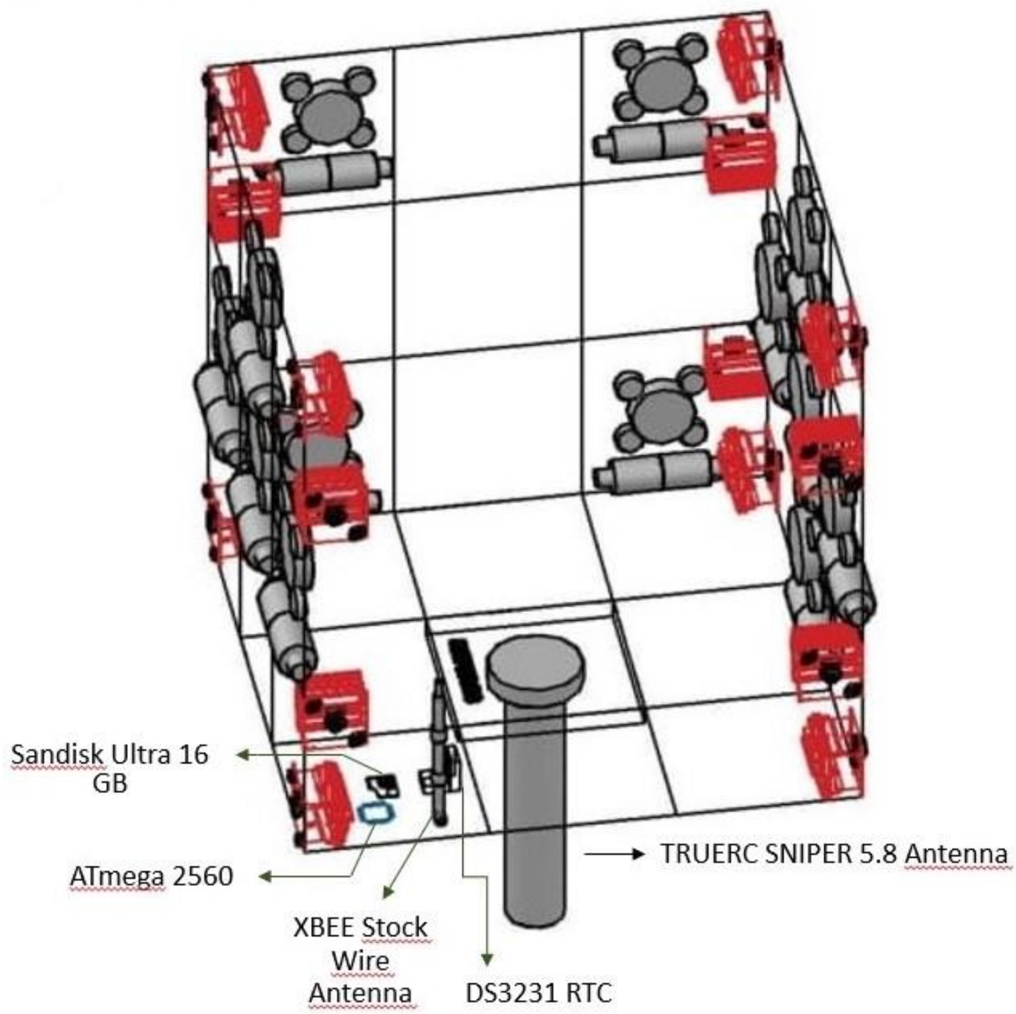


FIGURE 13. 62 ATMEGA 2560, DS3231 RTC, XBEE STOCK WIRE ANTENNA, SANDISK ULTRA 16 GB AND 5.8 GHz TRUERC SNIPER ANTENNA CONFIGURATION OF THE WIDESAT

On-Board Computer (OBC) called Arduino MEGA 2560 configuration of the WIDESAT is,

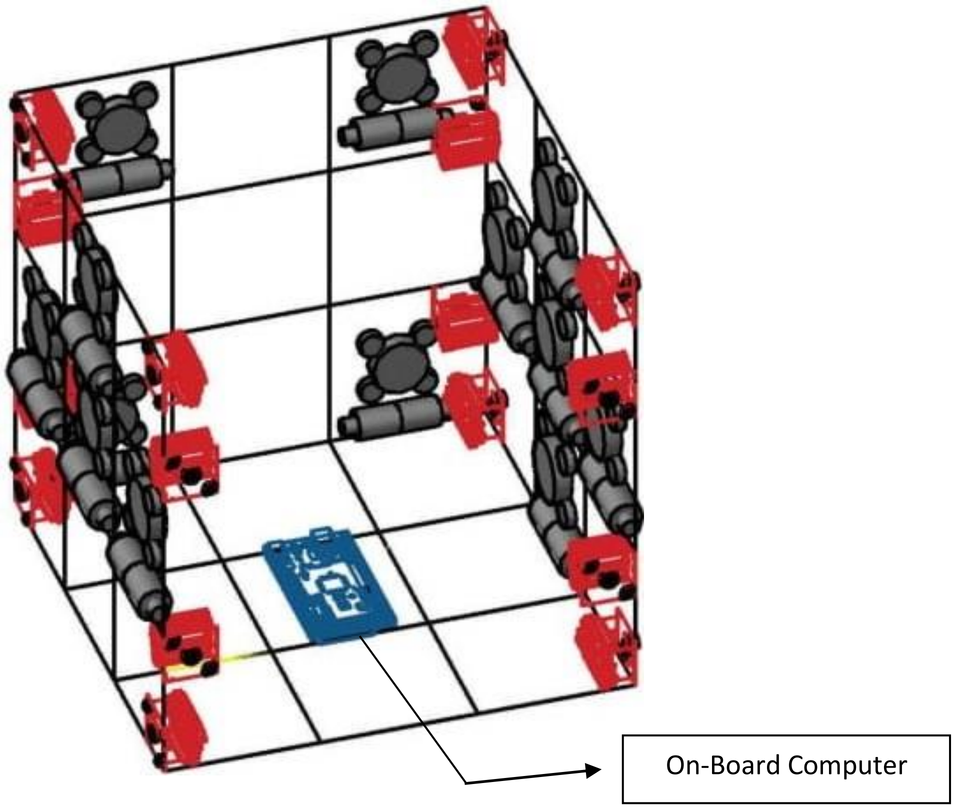


FIGURE 13. 63 ON-BOARD COMPUTER (OBC) CONFIGURATION OF THE WIDESAT

Power Voltage Sensor configuration of the WIDESAT is,

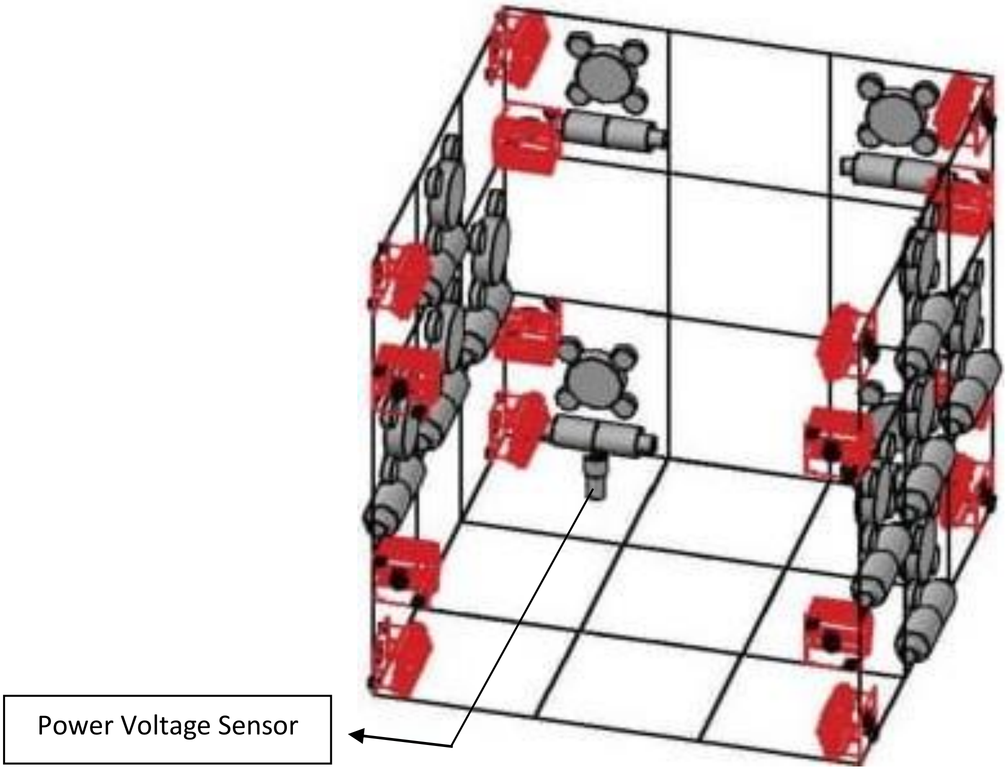


FIGURE 13. 64 POWER VOLTAGE SENSOR CONFIGURATION OF THE WIDESAT

Printed Circuit Board (PCB) configuration of the WIDESAT is,

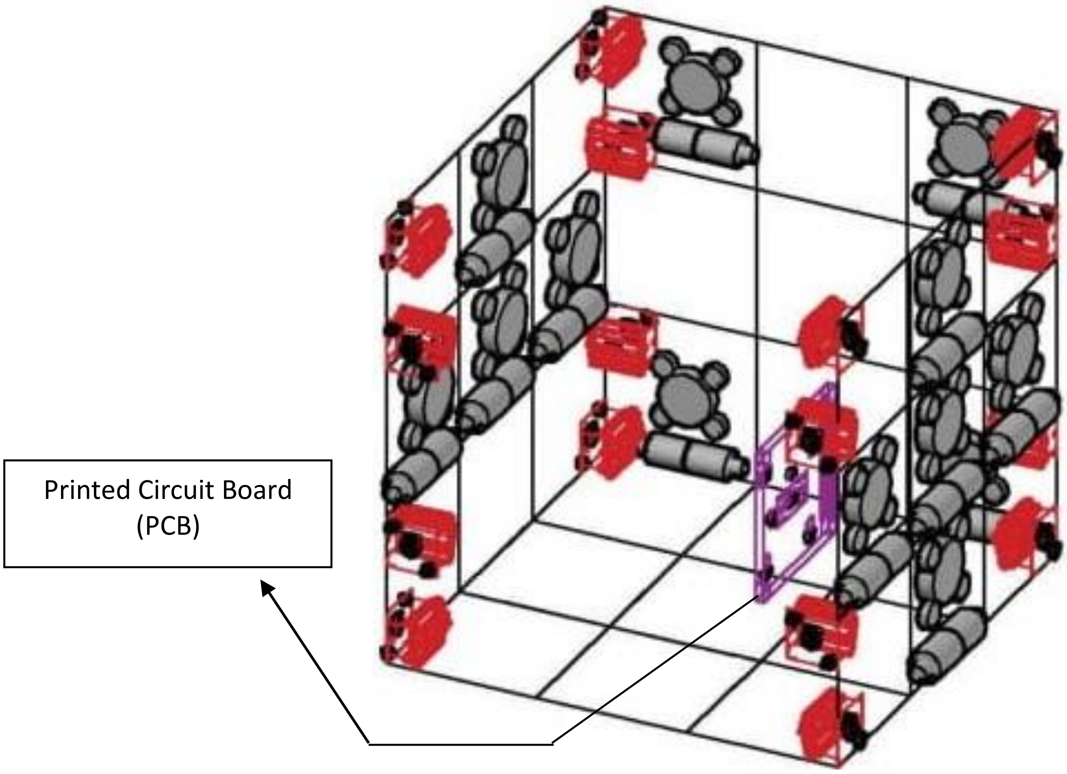


FIGURE 13. 65 PRINTED CIRCUIT BOARD (PCB) CONFIGURATION OF THE WIDESAT

Thrusters configuration of the WIDESAT is,

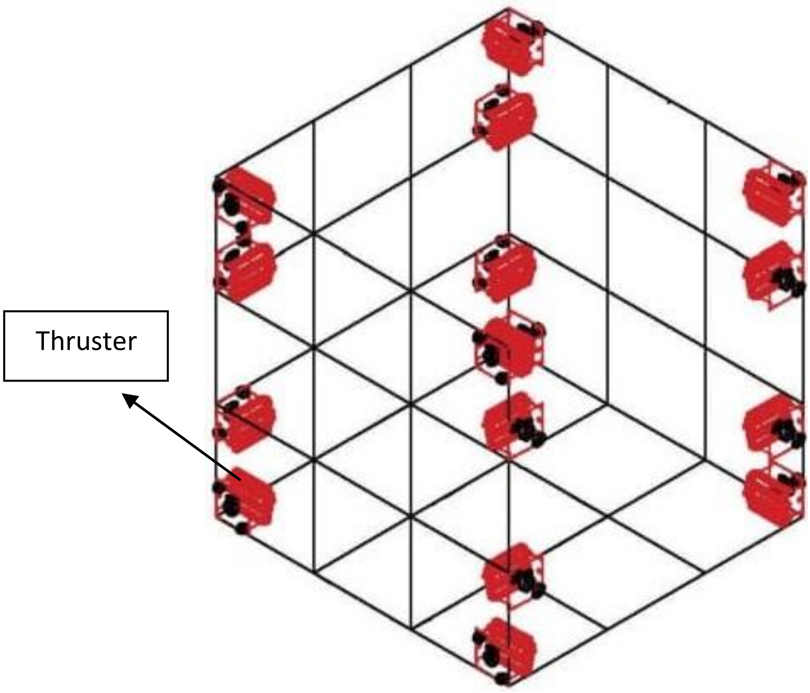


FIGURE 13. 66 THRUSTERS CONFIGURATION OF THE WIDESAT-1

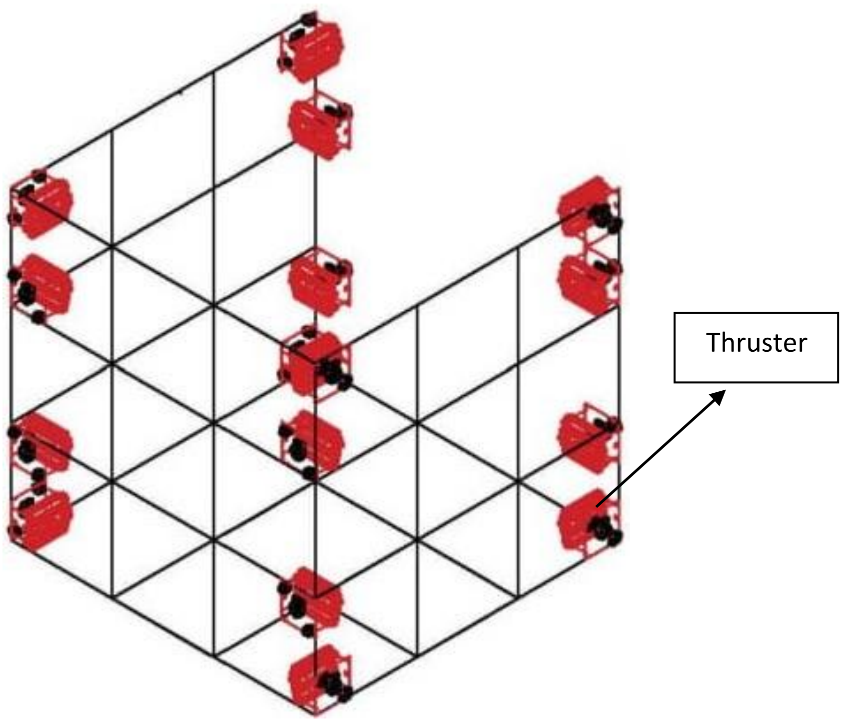


FIGURE 13. 67 THRUSTERS CONFIGURATION OF THE WIDESAT-2

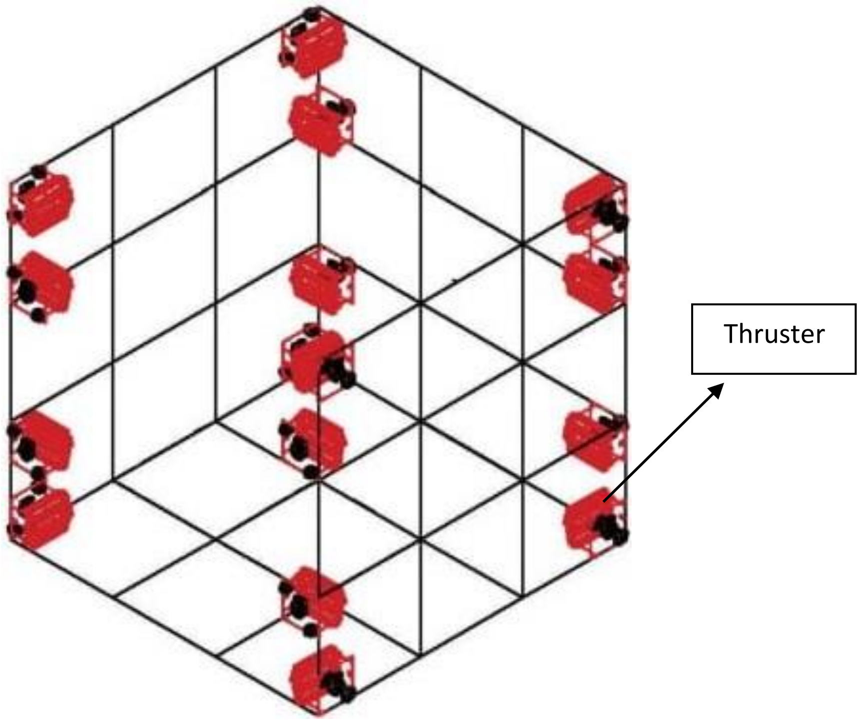


FIGURE 13. 68 THRUSTERS CONFIGURATION OF THE WIDESAT-3

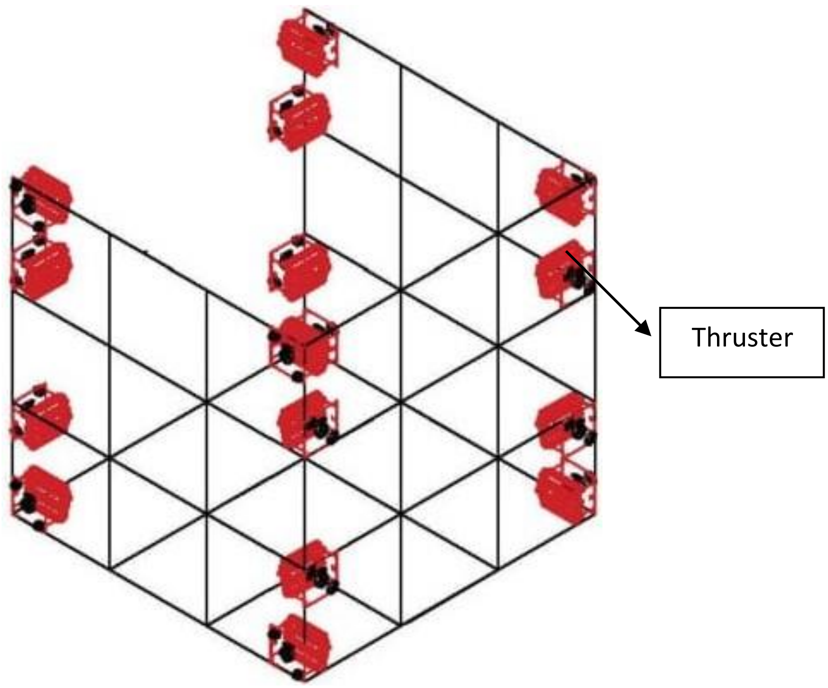


FIGURE 13. 69 THRUSTERS CONFIGURATION OF THE WIDESAT-4

Heat Pipe Structure configuration of the WIDESAT is,

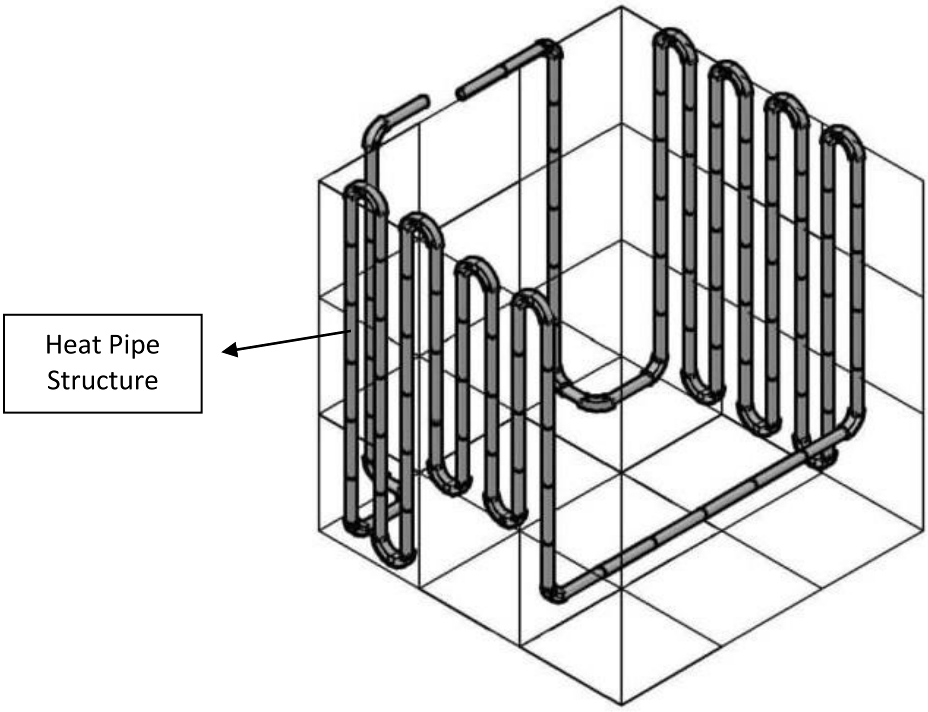


FIGURE 13. 70 HEAT PIPE STRUCTURE CONFIGURATION OF THE WIDESAT-1

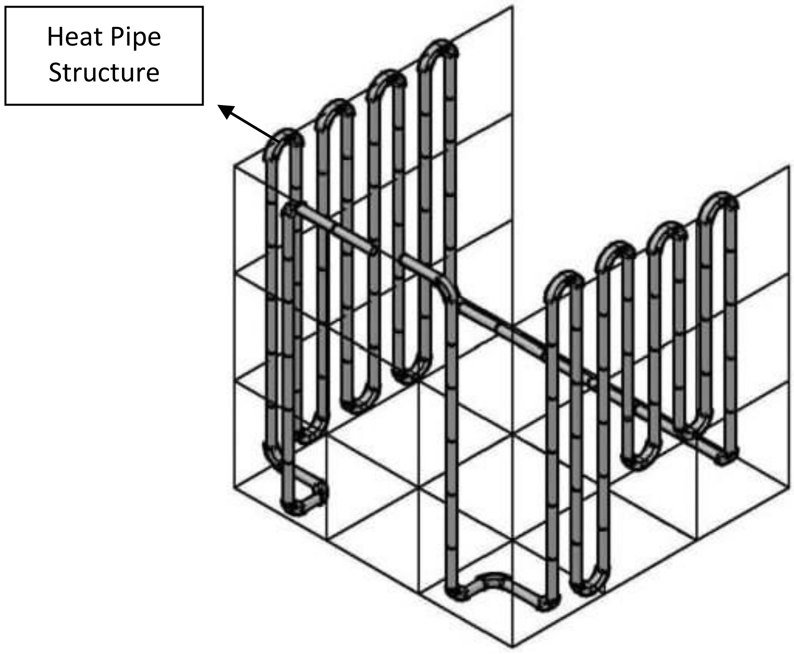


FIGURE 13. 71 HEAT PIPE STRUCTURE CONFIGURATION OF THE WIDESAT-2

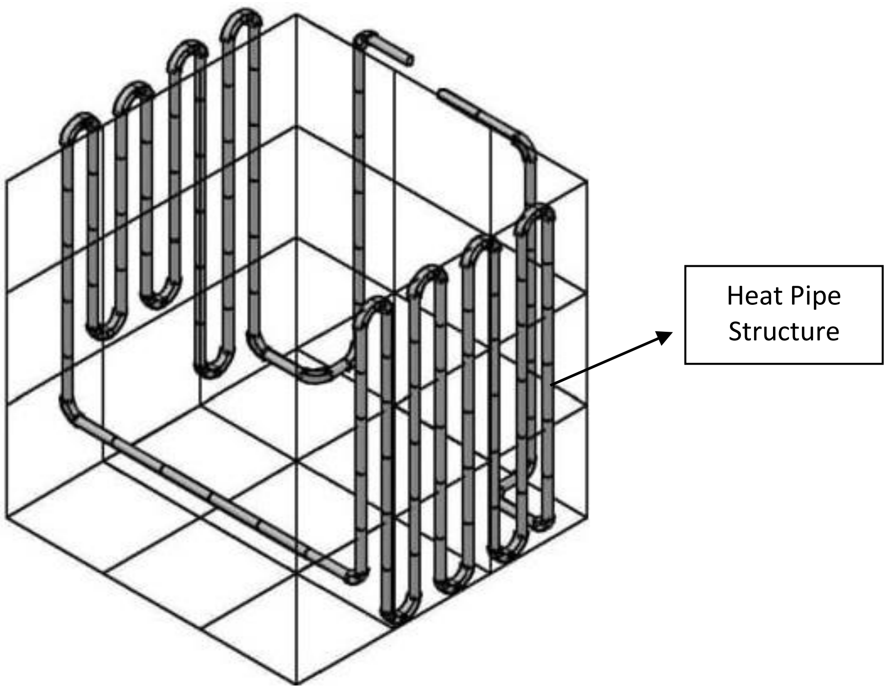


FIGURE 13. 72 HEAT PIPE STRUCTURE CONFIGURATION OF THE WIDESAT-3

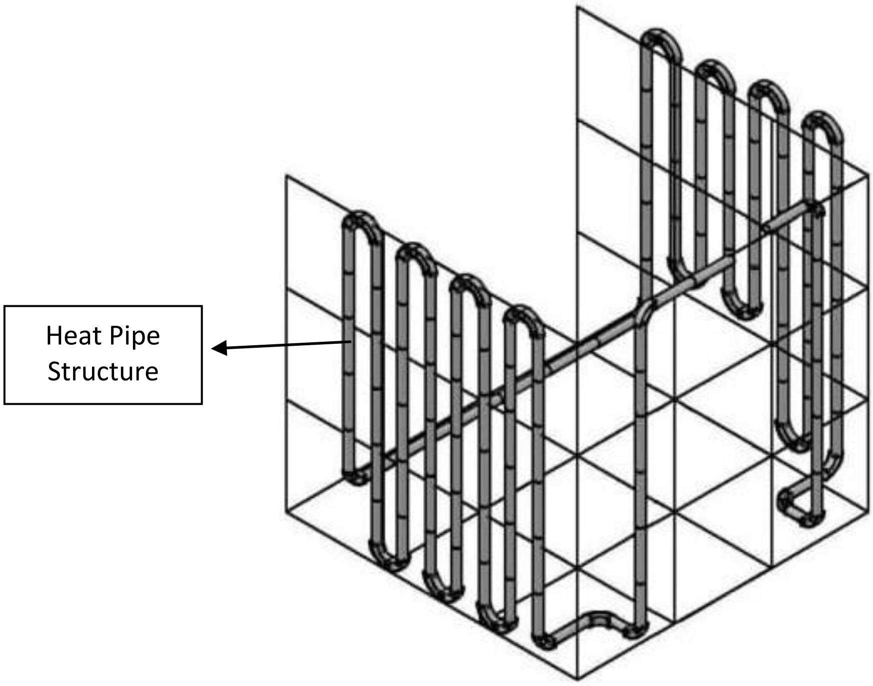


FIGURE 13. 73 HEAT PIPE STRUCTURE CONFIGURATION OF THE WIDESAT-4

Payload release mechanism is the mechanism that provides force to separating processes between container and payload. This mechanism consists of servo motor and basic springs. While the WIDESAT orbits at the designated point, servo motor and springs starts to application of releasing. So that, servo motor has high value due to releasing processes. Selected servo motor for the releasing mechanism is Power HD Hd-1370a. Reasons of this selection are, [19]

- Light weight
- High torque
- Lower power consumption
- High output

NOTE THAT, QUANTITY OF THE SERVO MOTORS IS 16.

Some properties of the Power HD Hd-1370a servo motor are, [19]

DESCRIPTION	SPECIFICATION
VOLTAGE	4.8 V to 6.0 V
MOVEMENT RANGE	From 0° to 180°
TYPE	Analog
WORKING TEMPERATURE	- 20° C to 60° C
FREQUENCY OF THE CONTROL SIGNAL	50 Hz
NEUTRAL POSITION	1500 µs
ROTATE CLOCKWISE	1500 µs -> 2000 µs
MAXIMUM RANGE OF PULSES	800 - 2200 µs
CONNECTOR TYPE	JR Connector
WIRE LENGTH	Approximately 100 mm
DIMENSIONS	20.2 x 8.5 x 17.6 mm
WEIGHT	3.7 g

TABLE 13. 26 PROPERTIES OF THE POWER HD HD-1370a SERVO MOTOR

Parameters of different voltage values are so important on servo motor types. This servo motor has two voltage values that includes different parameters. These are 4.8 V and 6.0 V. [19]

4.8 V parameters of the Power HD Hd-1370a servo motor are, [19]

PARAMETER	SPECIFICATION
TORQUE	0.4 kg*cm (0.39 Nm)
SPEED	0.12 s/60°
POWER CONSUMPTION IN STAND-BY MODE	4 mA
POWER CONSUMPTION WITHOUT LOAD	110 mA
MAXIMUM CURRENT CONSUMPTION	260 mA

TABLE 13. 27 4.8 V PARAMETERS OF THE POWER HD HD-1370a SERVO MOTOR

6.0 V parameters of the Power HD Hd-1370a servo motor are, [19]

PARAMETER	SPECIFICATION
TORQUE	0.6 kg*cm (0.59 Nm)

SPEED	0.10 s/60°
POWER CONSUMPTION IN STAND-BY MODE	5 mA
POWER CONSUMPTION WITHOUT LOAD	120 mA
MAXIMUM CURRENT CONSUMPTION	320 mA

TABLE 13. 28 6.0 V PARAMETERS OF THE POWER HD HD-1370a SERVO MOTOR

Processes of the payload releasing mechanism are,

- Servo motors which located at the corners of connection points between payload and container will have been started to turn remotely.
- Resistant conditions can be exist, while servo motors start to turn.
- These resistant conditions will have been protected by container.
- Open section will have been finished perfectly, while 6 parts of the container will have been released.

Mass budget calculation is the last point of this design. Each subsystems and total WIDESAT structure has mass. This mass should less than 100 kg.

PART	VALUE
SENSOR SUBSYSTEM DESIGN	3,2603 kg
ORBITAL CONTROL DESIGN	9,999 kg
MECHANICAL SUBSYSTEM DESIGN	14,18332 kg
COMMUNICATION AND DATA HANDLING DESIGN	0,561784 kg
THERMAL CONTROL SUBSYSTEM DESIGN	-
ELECTRICAL POWER SUBSYSTEM	4,890 kg

GENERAL	VALUE
TOTAL WEIGHT	33,098524 kg

OTHERS	VALUE
MAIN COMPARTMENT, CONTAINER AND COVER	0,20412 kg

FIGURE 13. 74 MASS BUDGET

13.8 Communication and Data Handling (CDH) Subsystem Design

The Communication and Data Handling (CDH) Subsystem Design creates communication of the WIDESAT. It includes valuable structure and components. Synopsis of the Communication and Data Handling (CDH) Subsystem Design is,

COMPONENT	TYPE	QUANTITY	PURPOSE
Arduino MEGA 2560	On-Board Computer (OBC)	1	Controlling the WIDESAT Effectively
ATmega 2560	Microcontroller	1	Collect and Processes Sensors Data
ARDUINO GROVE –	GPS Location	1	Gets Locations From the WIDESAT

GPS MODULE			
XBee S2C Pro	Communication Module	1	Sends and Receives Telemetry Data
DS3231	Real-Time Clock	1	Measures Operation Time
XBEE Stock Wire Antenna	2.4 GHz 3dBi Outdoor Antenna	1	Emittes or Radiates Electromagnetic Waves
SanDisk Ultra 16 GB	Micro SD Card	1	Stores the Telemetry Data
GOZ CAMERA	Camera with 5.8 GHz Transmitter and SD Card Recorder	1	Recordes Video with Internal Camera, Writes Video to SD Card and Sends Analog Video Output with Internal 5.8 GHz Controllable RF Power Transmitter
5.8 GHz TRUERC SNIPER ANTENNA	5.8 GHz 13.5dBi Outdoor Antenna	1	Emits or radiates electromagnetic waves

TABLE 13. 29 OVERVIEW OF THE CDH SYSTEM DESIGN

Somre requirements of this design are,

- This design will have been allowed the satellite for functioning by carrying TT&C (tracking, telemetry and command data) and data of the mission between its' components.
- The system complexity will have been heavily driven from the TT&C amount between the satellite and the GS called ground station.

- Part of this design has not got any alternatives due to their mechanisms.
- The payload shall transmit all sensor data in the telemetry.
- Telemetry shall be updated once per second.
- XBEE radio should be performed for telemetry.
- XBEE radio should have their NETID/PANID set to their team number.

- XBEE radio should not use broadcast mode.

13.8.1 On-board computer (obc)

The On-Board Computer called OBC will have been allowed to control measures of the communication and data handling subsystem on the WIDESAT. The Arduino MEGA 2560 for the On-Board Computer (OBC) will have been branded by ARDUINO Co. We will have been planned to use space qualified version of the Arduino MEGA 2560. [19]

FIGURE 13. 75 ARDUINO MEGA 2560-1

The On-Board Computer (OBC) called Arduino MEGA 2560 is a microcontroller board based on the ATmega2560. Some properties of the ATmega2560 are, [19]

- 54 digital input/output pins (of which 15 can be used as PWM outputs)
- 16 analog inputs
- 4 UARTs (hardware serial ports)
- 16 MHz crystal oscillator
- USB connection
- Power jack
- ICSP header
- Reset button

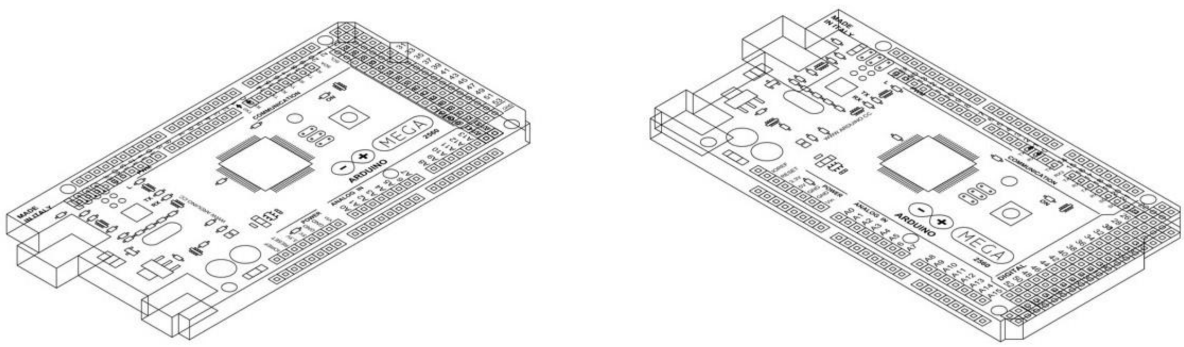


FIGURE 13. 76 ARDUINO MEGA 2560-2

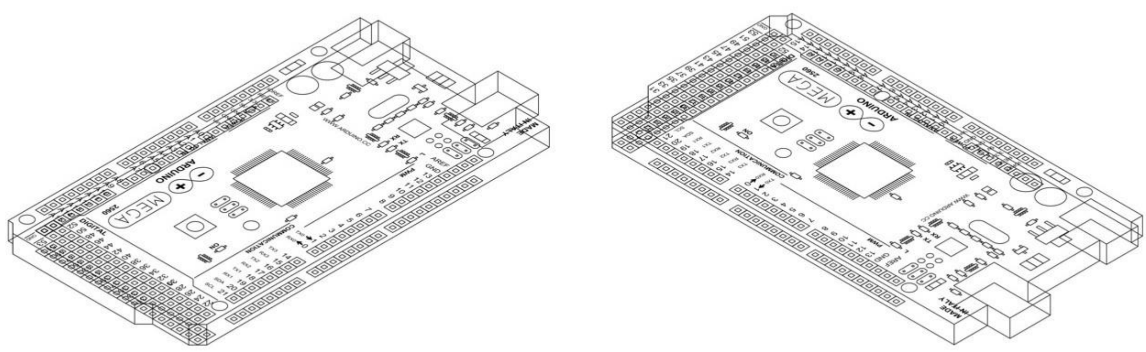


FIGURE 13. 77 ARDUINO MEGA 2560-3

It contains everything that has been required to support the microcontroller; easily connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get beginned. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila. The Mega 2560 is an update to the Arduino Mega, which it take places. Technical specifications of the Arduino MEGA 2560 are, [19]

NAME	TECHNICAL SPECIFICATION
MICROCONTROLLER	ATmega2560
OPERATING VOLTAGE	5V
INPUT VOLTAGE (RECOMMENDED)	7-12V
INPUT VOLTAGE (LIMIT)	6-20V
DIGITAL I/O PINS	54 (of which 15 provide PWM output)
ANALOG INPUT PINS	16
DC CURRENT per I/O PIN	20 mA
DC CURRENT for 3.3V PIN	50 mA
FLASH MEMORY	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
CLOCK SPEED	16 MHz
LED_BUILTIN	13
LENGTH	101.52 mm
WIDTH	53.3 mm
WEIGHT	37 g

TABLE 13. 30 TECHNCAL SPECIFICATIONS OF THE ARDUINO MEGA 2560

13.8.2 Atmega2560

ATmega 2560 is the component that in main role. Also, the Arduino MEGA 2560 has ATmega 2560. It controls whole functions and coordinate them with sufficiently. Comparison and features between ATmega 2560 and some other components are, [19]

FEATURES	18F4550	STM32F103C8T6	ATmega 2560
CPU SPEED	12 MIPS	1.25 MIPS	16 MIPS
BOOT TIME	20.1 sn	1 sn	2.6 sn
COMMUNICATION INTERFACE	UART,SPI,I2C	UART,SPI,I2C	UART,SPI,I2C
NUMBER OF COMMUNICATION INTERFACE	1 UART, 1 SPI,1 I2C	3 UART, 2 SPI, 2 I2C	4 UART, 5 SPI, 1 I2C
VOLTAGE AND CURRENT	25mA @2-5V	12.5mA @2-5.5V	20mA @1.8-5.5V
MEMORY UNIT AND SIZE	256 byte EEPROM 32Kbyte Program Memory	64Kbyte Program Memory	4Kbyte EEPROM 256Kbyte Program Memory
PHYSICAL DIMENSIONS	Weight 6 g Length 52.26	Weight 6 g Length 7mm	Weight 657 mg Length 14 mm

	mm Width 13.84 mm	Width 7 mm	Width 14 mm

TABLE 13. 31 COMPARISON AND FEATURES BETWEEN ATMEGA 2560 AND SOME OTHER COMPONENTS

After comparison as shown above, reasons of selected ATmega 2560 are, [19]

- Low power consumption
- High performance
- Can be used as special Arduino board by using Bootloader

FIGURE 13. 78 ATmega2560

13.8.3 Micro sd card

This component is one of the smallest and most valuable component of the Communication and Data Handling (CDH) Subsystem design. It stores received data smoothly. So that, it should has efficient read / write speed. Comparison and features between Sandisk Ultra 16 GB and some other components is, [19]

FEATURE	SANDISK ULTRA	SAMSUNG EVO	LEXAR 633X
CAPACITY (GB)	16	32	16
TRANSFER SPEED	98 MB/s	95 MB/s	100 MB/s

TABLE 13. 32 COMPARISON AND FEATURES BETWEEN ATMEGA2560 AND SOME OTHER COMPONENTS

After comparison as shown above, reasons of the selected Sandisk Ultra 16 GB SD card are, [19]

- Low cost
- High data read / write speed

FIGURE 13. 79 SANDISK ULTRA 16 GB

13.8.4 Real-time clock

The real-time clock provides necessary continuous timing externally. So that, this is one of most requiered component of the Communication and Data Handling (CDH) subsystem design. Comparison and features between DS3231 and some other components is, [19]

FEATURE	DS1307	DS3231
VOLTAGE	3.3V	3.3V
POWER CONSUMPTION	300 nA	300 uA
ACCURACY	20 ppm	2 ppm
RESET TOLERANCE	In reset condition external clock will continue measurement	In reset condition external clock will continue measurement
HARDWARE/SOFTWARE	Hardware	Hardware

TABLE 13. 33 COMPARISON AND FEATURES BETWEEN DS3231 AND SOME OTHER COMPONENTS

After comparison as shown above, reasons of the selected DS3231 are, [19]

- Provide battery backup for continuous timing
- Smaller volume
- Better accuracy than DS1307

FIGURE 13.80 DS3231

13.8.5 Antenna and antenna module

13.8.5.1 Antenna

Antenna of the Communication and Data Handling (CDH) subsystem helps to provide communication processes. It has some main features. Comparison and features between XBEE Stock Wire Antenna and some other components is, [19]

FEATURE	XBEE STOCK WIRE ANTENNA	TL-ANT2409A	A24-HASM-450
OPERATING FREQUENCY	2.4 GHz	2.4 GHz	2.4 GHz
GAIN	3 dBi	9 dBi	2.14 dBi
TYPE	Omni-Directional	Directional	Non-Directional
Range	1.2 km	1.77 km	1.75km

TABLE 13. 34 COMPARISON AND FEATURES BETWEEN XBEE STOCK WIRE ANTENNA AND SOME OTHER COMPONENTS

After comparison as shown above, reasons of the selected XBEE Stock Wire Antenna are, [19]

- Low size
- Low cost
- Meets the requirements

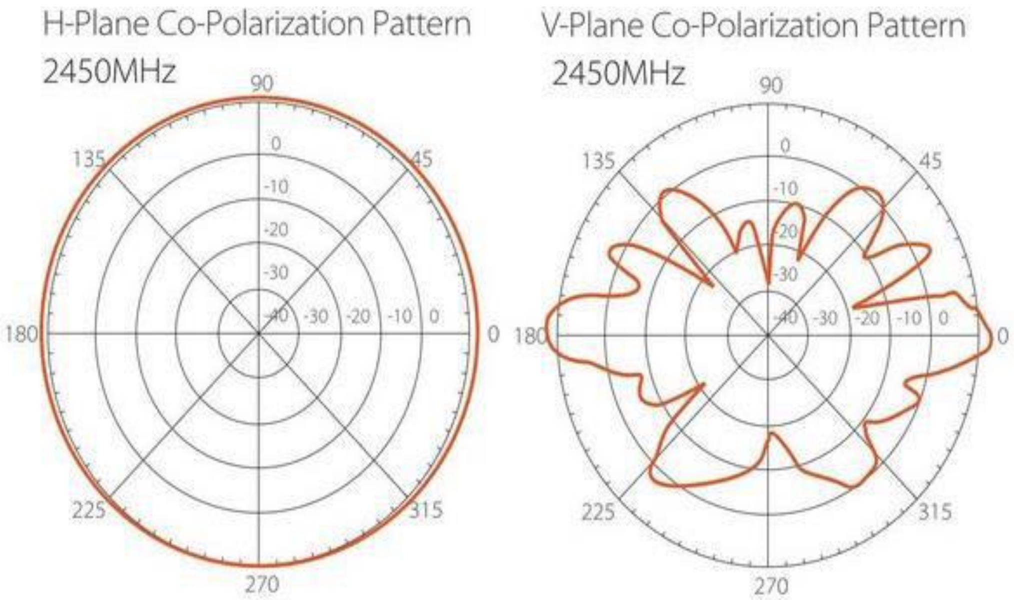


FIGURE 13. 81 RADIATION PATTERN OF THE XBEE STOCK WIRE ANTENNA

13.8.5.2 Antenna module

Antenna module is in an assistant about positioning for the antenna. It creates transceiving processes. So that, XBEE Series S2C Pro module can used as transceiver for ground station and payload. Some properties of the XBEE Series S2C Pro module are, [19]

- Design of radio settings for Xbee is constructed with X-CTU software.
- ID number of the XBees is 7221.
- 1Hz is set as transmission rate of XBee in payload.
- Radio as coordinator which takes the telemetry data from the endpoint and communication between payload and ground station is ensured with 2 XBees.
- Xbee module on the payload is set as an end point and Xbee module in ground station is set as coordinator.
- We need to register Xbee modules' serial numbers on their destination address sections to avoid broadband communication and interference.
- Xbee in the payload is set as an endpoint which posts the telemetry data to coordinator Xbee.
- Both Xbee modules can be used as transceiver.
- Communication channel between modules is Full-Duplex.

FIGURE 13. 82 XBEE SERIES S2C PRO MODULE

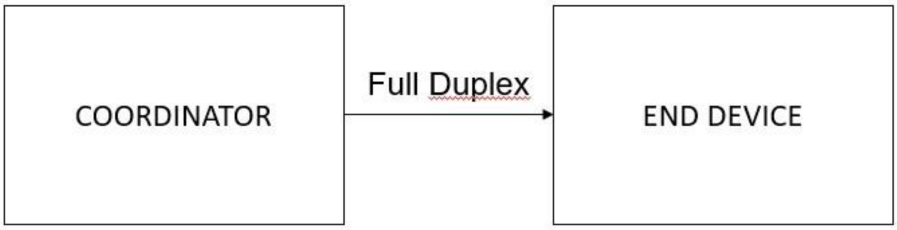


FIGURE 13. 83 COORDINATION DIAGRAM OF THE XBEE SERIES S2C PRO MODULE

Telemetry is the way that includes all received datas from components. Format of telemetry should intelligible, simple and basic. So that, each values can understands and handles easily. Planned telemetry format of the WIDESAT is, [19]

DATA FORMAT	DESCRIPTION
<ID>	Identification Number
<Mission Time>	Mission time value in seconds
<Packet Count>	Time sum up of sended packets, which is to be continued through processor reset
<Altitude>	Altitude sensed with resolution
<Pressure>	Measurement of atmospheric pressure
<Temp>	Sensed temperature in degrees °C with resolution
<Voltage>	Voltage of WIDESAT power bus
<Thermal>	Thermal statues of WIDESAT
<Humidity>	Humidity conditions of WIDESAT
<GPS Time>	Time from GPS Satellite
<GPS Latitude>	The latitude produced by the GPS receiver

<GPS Longitude> **<GPS Altitude>**	**The longitude produced by the GPS receiver** **The altitude produced by the GPS receiver**
<GPS Sats>	**The number of GPS satellites being tracked by the GPS receiver. This must be an integer number**
<Software State>	**Performing state of the software (boot, idle, launch detect, deploy, etc.)**

TABLE 13. 35 PLANNED TELEMETRY FORMAT-1

<ID> , <MISSION TIME> , <PACKET COUNT> , <ALTITUDE> , <PRESSURE> , <TEMP> , <VOLTAGE> , <THERMAL> , <HUMIDITY> , <GPS TIME> , <GPS LATITUDE> , <GPS LONGITUDE>, <GPS ALTITUDE> , <GPS SATS> , <SOFTWARE STATE>

Ex:
7221 , 21:26:38 , 0226 , 367.4 , 968 , 35.6 , 8 .54 , 12.63 , 25.67 , 23:26:48 , 43.3456 , 56.6785 , 802.4, 6 , deploy

FIGURE 13. 84 PLANNED TELEMETRY FORMAT-2

13.9 Thermal Control Subsystem Design

This design will have been maintained the temperature level for spacecraft components within operational ranges during all mission phases. Design of this subsystem guarantees the cubesat reliability in its' performance in space missions. Requirements of the Thermal Control Subsystem design are,

- The cubesat encounters in space like heat transfer, convection, conduction, radiation and Earth albedo.
- So that, the approach to thermal control of the cubesat uses passive techniques. These techniques consist of space radiators, coatings/paints, multilayer insulation (MLI) and heat pipes.

- We have been discussed that the heat pipes are the best solution for the WIDESAT.

Heat pipes are the main issue of this design. They work with their own theoretical processes. So that, heat pipe working theory steps are, [20]

- Performance is achieved through a passive liquid-vapor cycle which depends on the capillary pressure force.
- While point of the ends of the heat pipe is dependent to heat input called evaporator, the present liquid in the wick will vaporize.
- This lead to a depression and decrese in pressure of the remaining liquid.
- The local vapor pressure will increase with evaporation.
- This effectively leads to the movement of the vapor towards the condenser section.
- Detecting proper wick structure and material capillary forces will transport liquid from the condenser section towards the evaporator section.

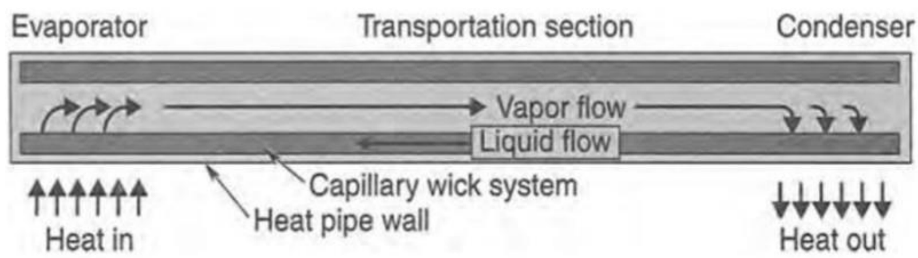


FIGURE 13. 85 HEAT PIPE-1

Testing commercial heat pipes are so important before the selection. In this testing, performance values of heat pipes are main points. [20]

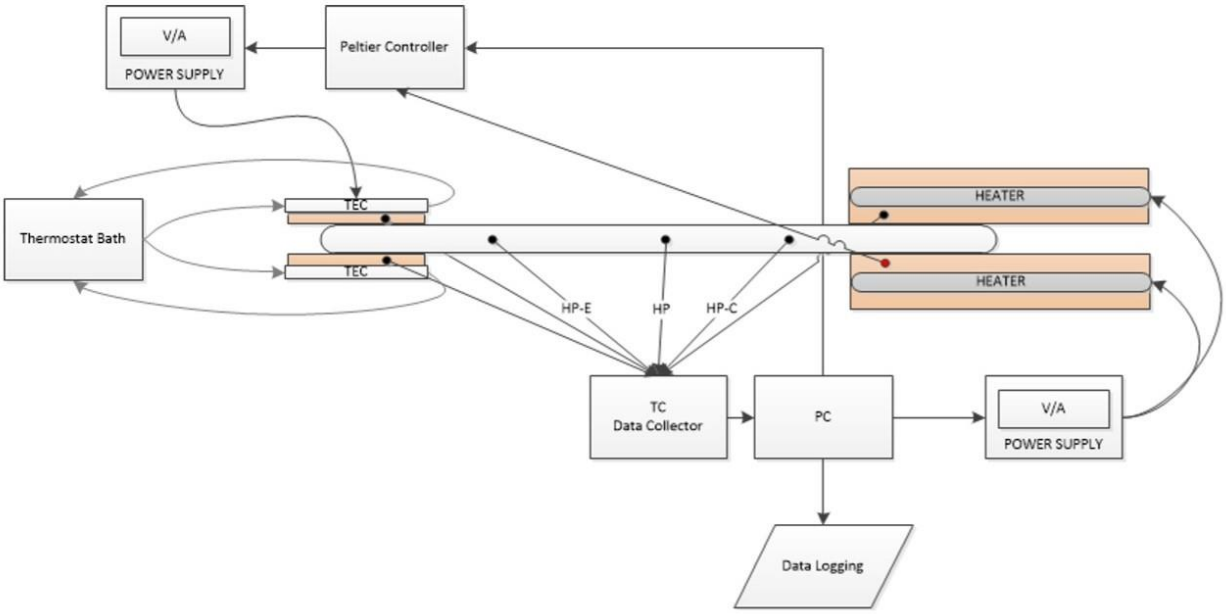


FIGURE 13. 86 PERFORMANCE TESTING DIAGRAM FOR THE HEAT PIPE

Testing steps are,

- The energy value which stored by the solar panels in the batteries is adjusted on the computer and transmitted to the power supply as a signal.
- At the same time, this value is transmitted to the part known as the "Peltier Controller", which enables the transfer of the heat in the heat pipe from one place to another along the direction of electric current.
- Each data on the computer is recorded in real time in the "Data Logging" section.
- The energy value which is transmitted to the power source is applied to the heat pipe through heaters.
- From starting of the application, the part known as "Thermal Electrical Controller" that follows the liquid flow in the heat pipe acquires the necessary measurement values.
- While obtaining the measurement values, in order to maintain the functionality of the heat pipe, the second power supply and the "Thermostat Bath" part, which has the energy values transferred by the "Peltier Controller", help the "Thermal Electrical Controller" part. The task of the "Thermostat Bath" part is to provide the optimal liquid temperature value.

- All measurements performed in the heat pipe are obtained from different points of the whole heat pipe through the "Thermal Controller Data Collector" section and transferred to the computer.
- In order to optimize the changes in both energy change and liquid temperature values, the last value sent to the computer is checked and after the necessary corrections are made, all operations are repeated in the same way and the heat pipe structure performance test is continued.

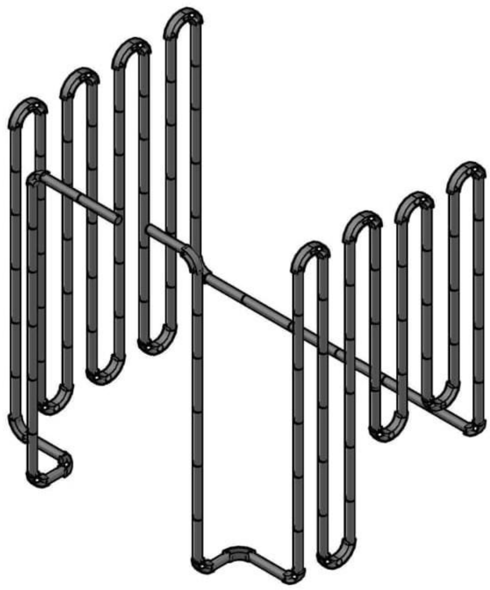


FIGURE 13. 87 HEAT PIPE-2

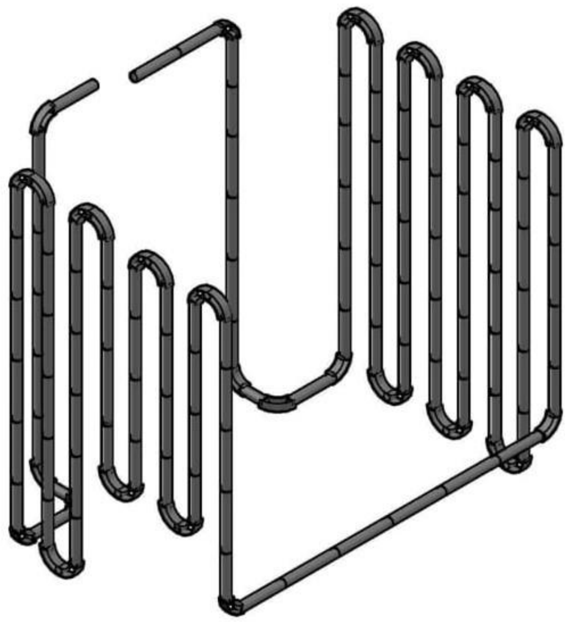


FIGURE 13. 88 HEAT PIPE-3

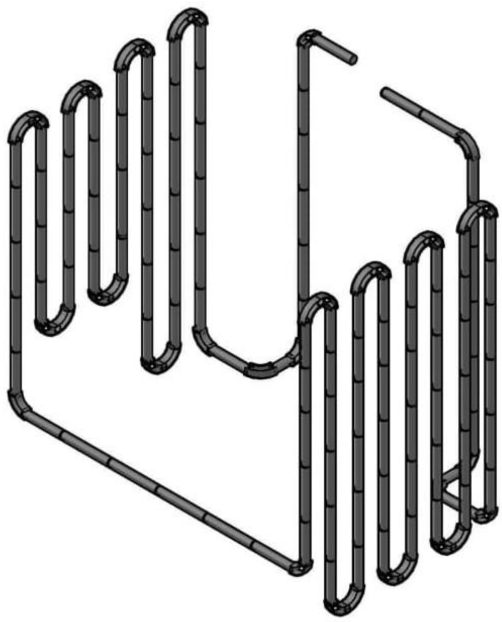


FIGURE 13. 89 HEAT PIPE-4

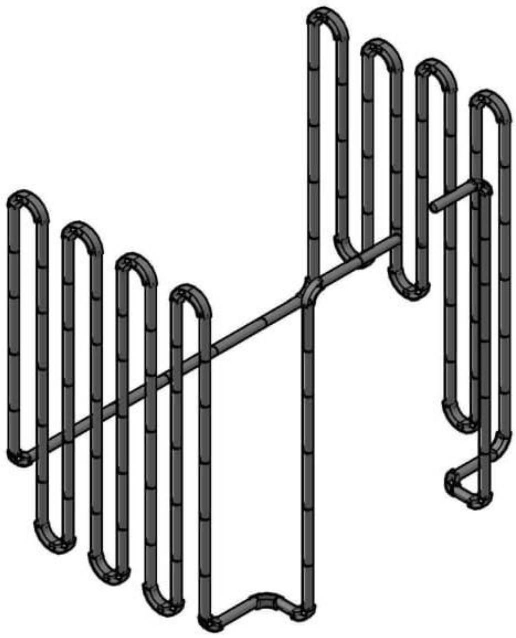


FIGURE 13. 90 HEAT PIPE-5

13.10 Electrical Power (EPS) Subsystem Design

This design will have been provided the required energy of the WIDESAT. Total energy usage of the WIDESAT will have been detected by the Power Voltage Sensor. After this detection, results will have been transmitted for determining total quantities of the Power System and Solar Panels. Overview of the Electrical Power (EPS) Subsystem design is,

COMPONENT	QUANTITY	PURPOSE
Solar Panel	54	Absorbing the solar rays from the Sun
Li-Ion Battery	6	Storing solar energy and supplying this to the whole system

Voltage Regulator	2	Step down the suitable voltage for the system
Voltage Divider	1	Control battery voltage
MOSFET	1	Switching component for the GOZ CAMERA
Power Switch	1	Switching the whole electronic system remotely

TABLE 13. 36 OVERVIEW OF THE ELECTRICAL POWER (EPS) SUBSYSTEM DESIGN

Electrical process diagram of the WIDESAT is,

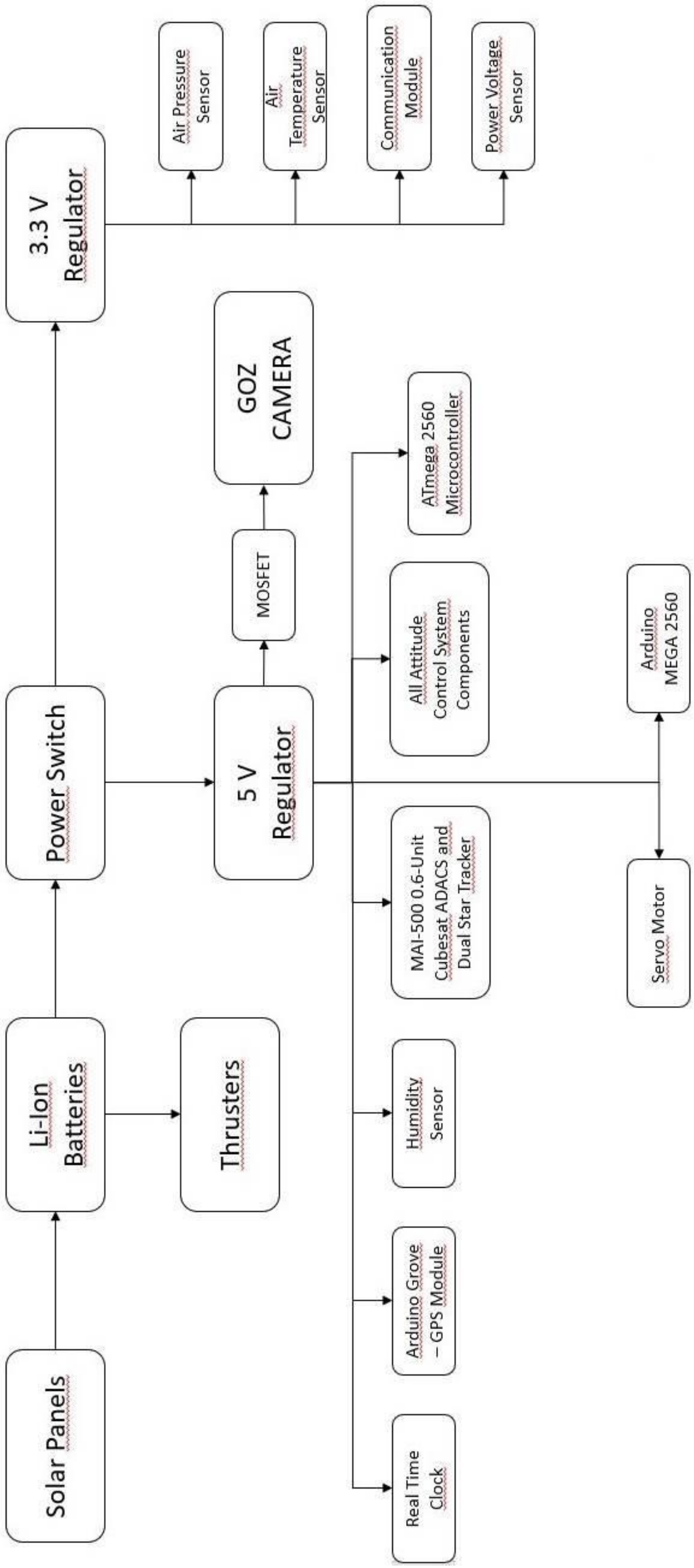
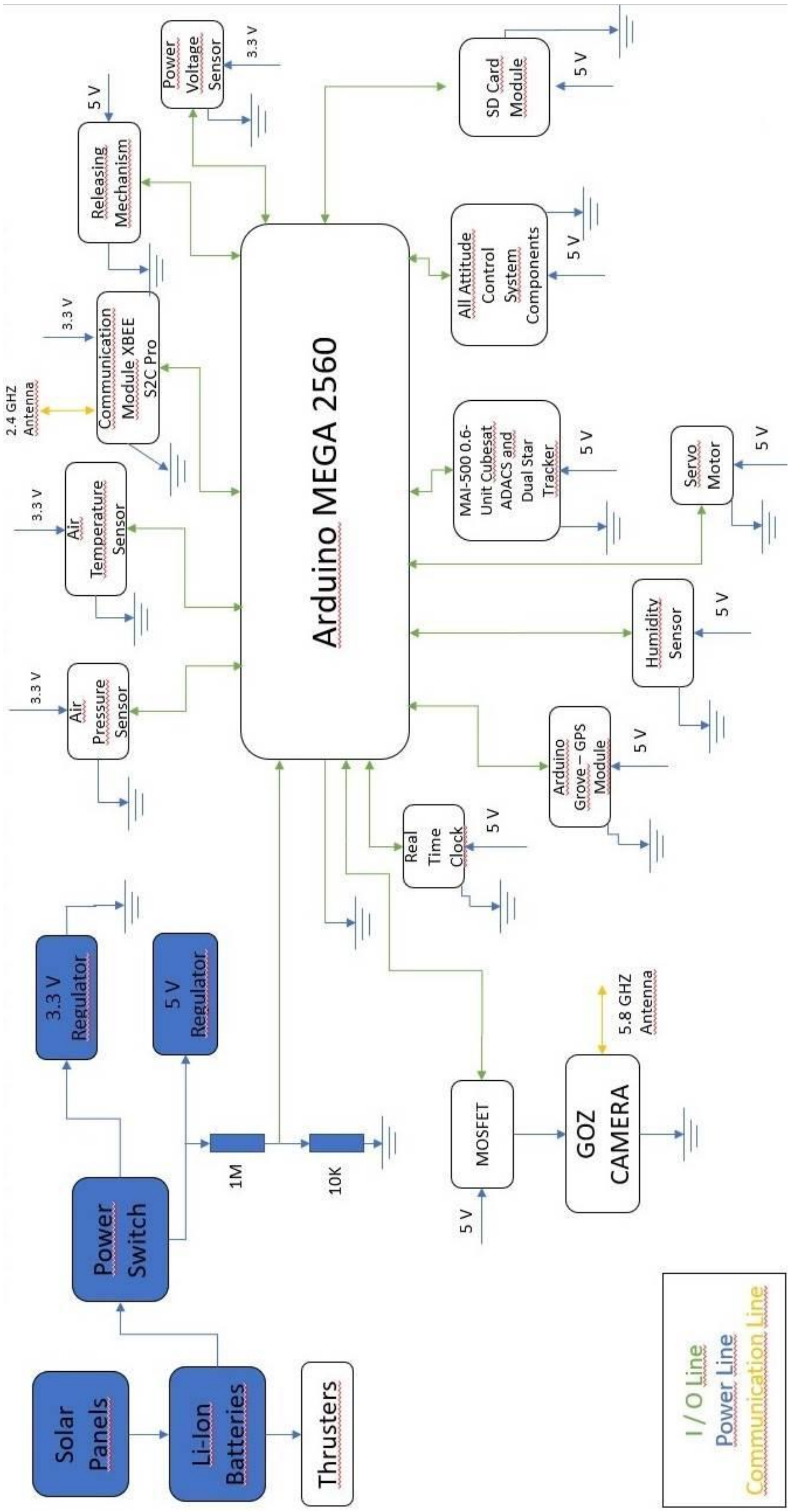


FIGURE 13. 91 ELECTRICAL PROCESS DIAGRAM OF THE WIDESAT

Requirements of the Electrical Power Subsystem (EPS) Design are,

- All electronic components shall enclose from the environment.
- All electronics shall well-mounted to use materials like standoffs, strong adhesives or screws.
- The probe should contain an fastly accessible power switch that can be accessed without disassembling the WIDESAT.
- The probe should contain a power indicator such as an LED or sound generating device that can be easily seen without disassembling the WIDESAT.
- Battery source shall Li-ION batteries.
- Power battery compartment shall include allowing the batteries.
- Spring contacts shall not use to make an electrical connections to batteries. If this occurs, momentary disconnection exists by shock forces.
- Payload/Container shall operate for a minimum of two hours when integrated into rocket.

Payload electrical block diagram of the WIDESAT is,



Arduino MEGA 2560
Solar Panels
Li-Ion Batteries
Thrusters
Power Switch
3.3 V Regulator
5 V Regulator
1M
10K
Air Pressure Sensor
3.3 V
Air Temperature Sensor
3.3 V
Communication Module XBEE S2C Pro
2.4 GHZ Antenna
3.3 V
Releasing Mechanism
5 V
Power Voltage Sensor
3.3 V
SD Card Module
5 V
All Attitude Control System Components
5 V
MAI-500 0.6-Unit Cubesat ADACS and Dual Star Tracker
5 V
Servo Motor
5 V
Humidity Sensor
5 V
Arduino Grove – GPS Module
5 V
Real Time Clock
5 V
MOSFET
5 V
GOZ CAMERA
5.8 GHZ Antenna
I / O Line
Power Line
Communication Line

FIGURE 13. 92 PAYLOAD ELECTRICAL BLOCK DIAGRAM OF THE WIDESAT

13.10.1 Solar panel

Solar panel is the first process component of Electrical Power Subsystem (EPS) design. Solar rays receives to surface of solar panel. After that, these solar rays emits and ready for storage in Li-Ion batteries. Solar panel selection is so important due to space qualifications. The selected solar panel is DHV-CS-10. Planned total quantity of the DHV-CS-10 is 54. [21]

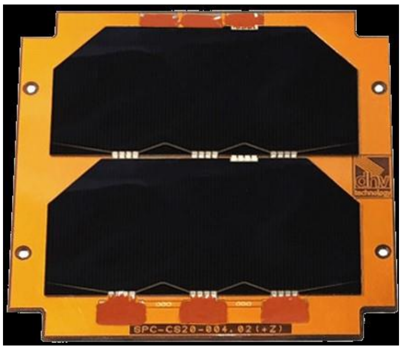


FIGURE 13. 93 DHV-CS-10 SOLAR PANEL-1

Main points of this solar panel are, [21]

- Available for top, bottom and side versions
- Qualified on space applications include 30% efficiency with using junction technics called triple-junction
- Two solar cells can connect in series to obtain voltage value like 4.8 V
- Wires, connectors, magnetometer and temperature sensor are included
- Body mounted Aluminium and Carbon panel structure included

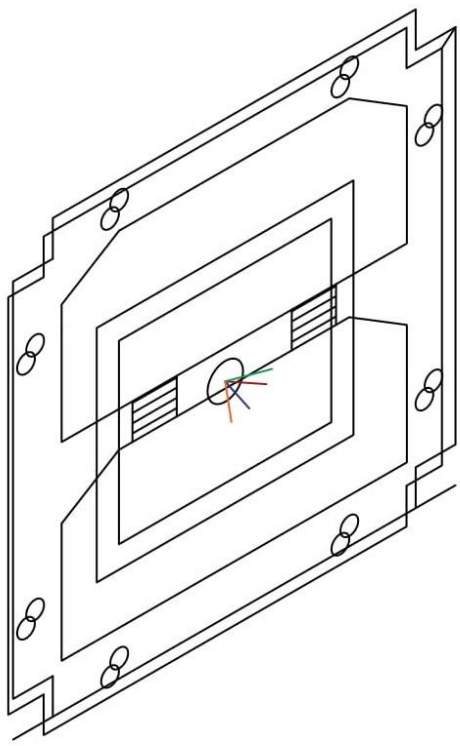


FIGURE 13. 94 DHV-CS-10 SOLAR PANEL-2

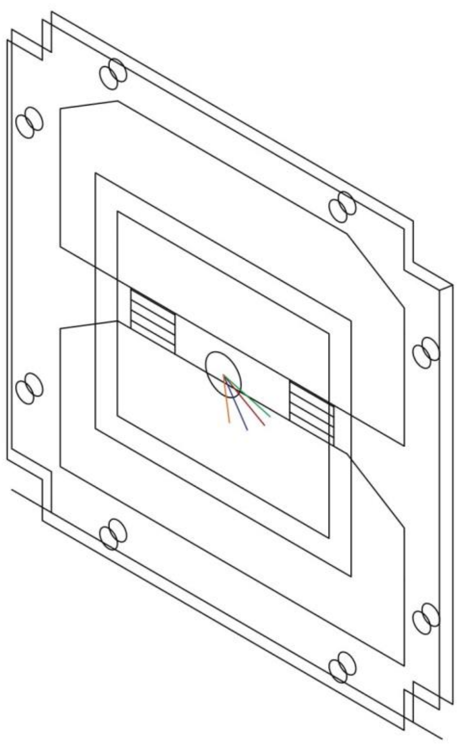


FIGURE 13. 95 DHV-CS-10 SOLAR PANEL-3

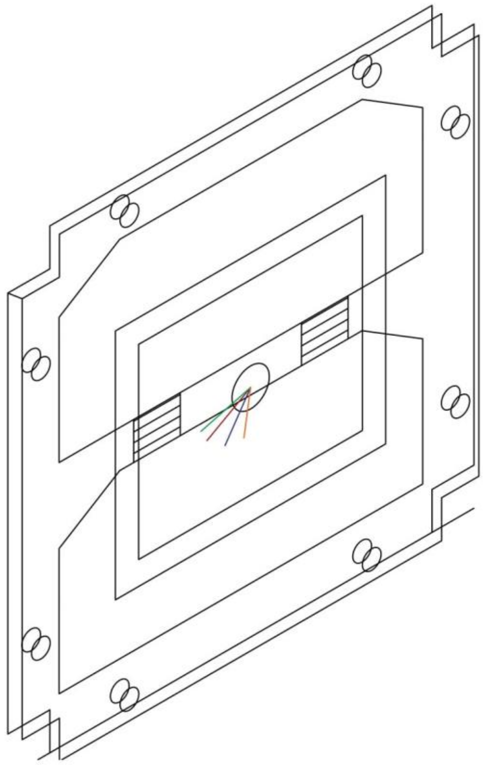


FIGURE 13. 96 DHV-CS-10 SOLAR PANEL-4

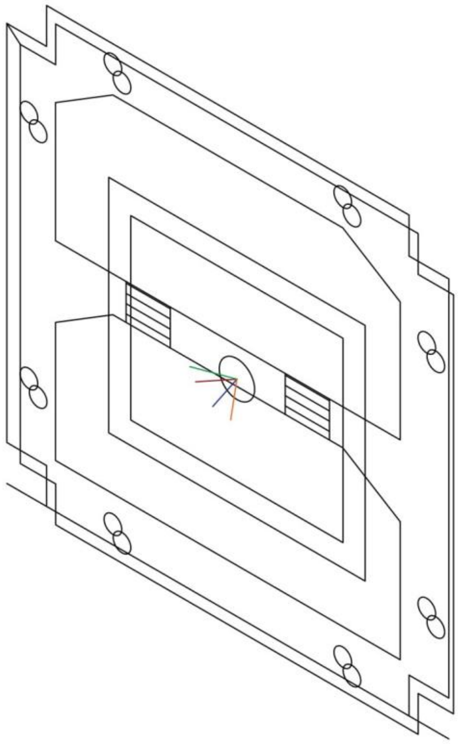


FIGURE 13. 97 DHV-CS-10 SOLAR PANEL-5

Working mechanism steps of the DHV-CS-10 solar panel are, [21]

- Mounted solar panels on each 1U surface of outside of the cubesat has deployable system
- This system structured on burn wire triggering holding and release mechanism
- This mechanism will have been organised on nichrome burn wire cutting method which is extensively used for CubeSat applications
- It supplies a high loading capability, reliable wire cutting, multiplane constraints and handling simplicity during the tightening process of wire
- The structural safety of the solar panel united with the mechanism in a launch vibration environment will have been verified through sine and random vibration test at qualification level

Some properties of this solar panel are, [21]

PROPERTY	VALUE
SUBSTRATE MATERIAL	Polyımıde double sıde copper lamınate wıth KAPTON cover lay
NOMINAL THICKNESS	1.6 mm ± 10 %
OPERATIONAL TEMPERATURE	-120°C to +150°C
MASS	50 g
DIMENSIONS (PCB + SOLAR CELLS)	82.5 x 98 x 2.4 mm

TABLE 13. 37 PROPERTIES OF THE DHV-CS-10 SOLAR PANEL

Space qualification certificating is so important. That's why Qualification and Acceptance Tests of this solar panel are, [21]

TEST	QT	AT
FUNCTIONAL	✔	✔
VIBRATION	✔	✕
THERMAL CYCLING	✔	✕
CONTINUITY/ISOLATION	✔	✔
FLASH TESTER	✔	✔

SOLAR CELL CRACKS	✔	✔

TABLE 13. 38 QUALIFICATION AND ACCEPTANCE TESTS OF THE DHV-CS-10 SOLAR PANEL

Note that,
QT is made on the design/qualification model
AT is conducted on the unit to be transferred

13.10.2 Li-ion battery system

Li-Ion battery system is the second process component of Electrical Power Subsystem (EPS) design. Solar rays which received by solar panels store inside of Li-Ion battery system. After that, this battery system get ready total power for components. Li-Ion battery system selection is so important due to space qualifications. The selected Li-Ion battery system is iEPS called the ISIS Electrical Power System. Planned total quantity of the iEPS Type B/C is 6. [22]

FIGURE 13. 98 LI-ION BATTERY SYSTEM-1

Some main points of the iEPS are, [22]

- Cutting-Edge structure included
- The system implements GaN-FETs to progress solar power conversion efficacy and production
- It is donated with an integrated heater, hardware-based Maximum Power Point Tracking called MPPT and hardware voltage and over-current protection
- Suitable daughterboard type included which can allow different configurations

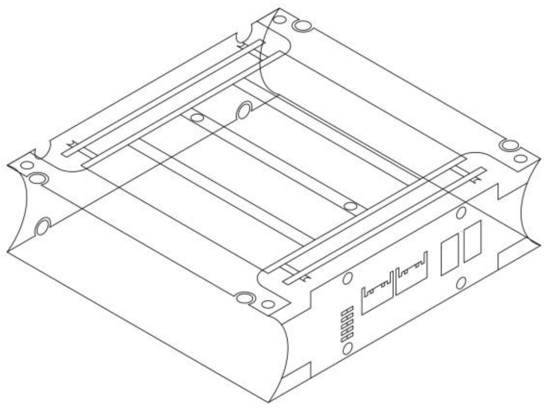


FIGURE 13. 99 LI-ION BATTERY SYSTEM-2

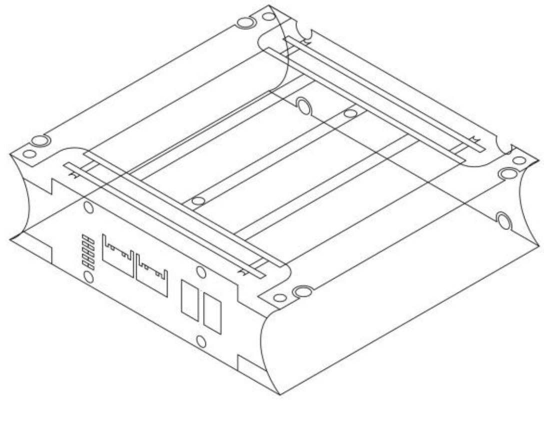


FIGURE 13. 100 LI-ION BATTERY SYSTEM-3

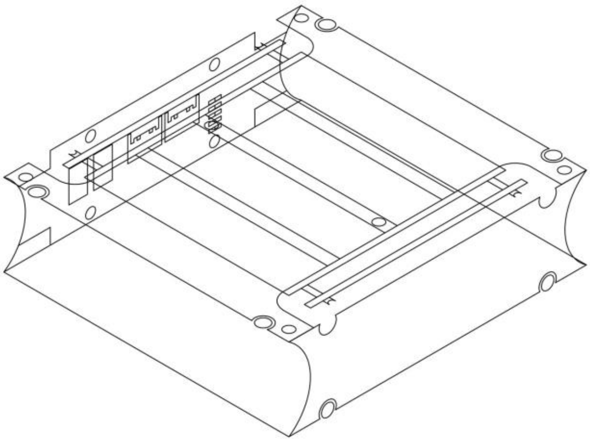


FIGURE 13. 101 LI-ION BATTERY SYSTEM-4

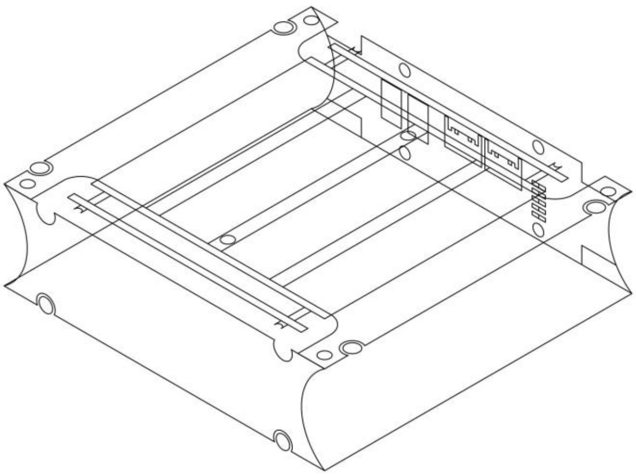


FIGURE 13. 102 LI-ION BATTERY SYSTEM-5

Properties of the iEPS are, [22]

PROPERTY	VALUE
MASS	Type A 184 ± 5 grams (2 cell battery pack) Type B 310 ± 5 grams (4 cell battery pack) Type C 360 ± 5 grams (4 cell battery pack + daughterboard)
VOLUME	Type A 96 mm x 92 mm x 26.45 mm (PCB and top battery) Type B 96 mm x 92 mm x 11.34 mm (PCB B) Type C 96 mm x 92 mm x 15.95 mm (PCB C) Type B/C 94.4 x 89.3 x 21 mm (4-Cell Battery Pack)
OPERATING TEMPERATURE RANGE	-20°C to +70°C
ENERGY STORAGE	22.5Wh (Type A), 45Wh (Type B/C)
OUTPUT VOLTAGE	3.3 V and 5 V
COMMUNICATION INTERFACE	I^2C

TABLE 13. 39 PROPERTIES OF THE iEPS

Space qualification certificating is so important. So that, Qualification and Acceptance Tests of the iEPS are, [22]

TEST	QT	AT
FUNCTIONAL	✔	✔
VIBRATION	✔	-
MECHANICAL SHOCK	✔	-
THERMAL CYCLING	✔	✔
THERMAL VACUUM	✔	-

TABLE 13. 40 QUALIFICATION AND ACCEPTANCE TESTS OF THE iEPS

Note that,

QT is made on the design/qualification model

AT is donated on the unit to be shipped

Power budget of each design of the WIDESAT, payload power budget and total consumption are,

PART	VALUE
SENSOR SUBSYSTEM DESIGN	$10{,}120 \times 10^{-6}$ W
ORBITAL CONTROL DESIGN	$16{,}25$ W + $251{,}4 \times 10^{-6}$ W
MECHANICAL SUBSYSTEM DESIGN	128 W (without releasing components)

COMMUNICATION AND DATA HANDLING (CDH) DESIGN	92,72 W + 0,418x10⁻⁶
THERMAL CONTROL SUBSYSTEM DESIGN	10 W

TABLE 13. 41 POWER BUDGET OF EACH DESIGN

SATELLITE	VALUE
TOTAL CONSUMPTION	236,97 W + 261,938x10⁻⁶ W

TABLE 13. 42 TOTAL CONSUMPTION

Payload power budget that includes each component which used in the Wind Detection Satellite (WIDESAT) are,

COMPONENT	QUANTITY	CURRENT	VOLTAGE	POWER	SOURCE
Air Pressure Sensor	1	-	3.3 V	-	Datasheet
Air Temperature Sensor	1	1 mA	3.3 V	10x10^-6 W	Datasheet/ Calculation
Humidity Sensor	1	-	5 V	-	Datasheet
Power Voltage Sensor	1	-	3.3 V	-	Datasheet
GOZ CAMERA	1	-	13 – 33 Vdc	-	Will Design for New Specfications
ADACS + Star Tracker	1	-	5 V	3.05 W	Datasheet / Calculation
All Attitude System Component	33 (Reaction Wheel and Magnetorquer) 1 Printed Circuit Board (Including Three-Axis Magnetormeter, Gyroscope, Microcontroller, Torque Rod Driver, Coarse Sun Sensor)	-	5 V	13.2 W + 251,4x10^-6 W	Uncertainty / Calculation
Thruster	16	-	3.3 and 5 V	8 W (each)	Product Manual / Calculation
Arduino MEGA 2560	1	50 mA	5 V	1.52 W	Datasheet / Calculation
Xbee S2C Pro	1	120 mA	3.3 V	0,418x10^-6 W	Datasheet / Calculation
Xbee Stock Wire Antenna	1	-	5 V	7.2 W	Product Manual / Calculation
ATmega2560	1	20 mA	5.5 V	-	Datasheet
DS3231	1	300 uA	3.3 V	-	Datasheet
TRUERC SNIPER 5.8 GHz	1	-	-	-	Datasheet
Heat Pipe System	1	-	-	10 W	Reference Documents

TABLE 13. 43 PAYLOAD POWER BUDGET

13.11 Flight Software (FSW) Design

Software of the WIDESAT should detailed and intelligible. It can create lots of responses for any kind of emergency situations. Requirements of the Flight Software (FSW) design are, [19]

- The releasing process shall start.
- After that moment, the payload shall release effectively from the container.
- Telemetry should be updated once per second.
- The ground system will command the WIDESAT to start transmitting telemetry prior to launch.
- Telemetry shall include mission time values. This values contains resolution like one second or better.
- Mission time will maintain processor reset action during launch and mission sections.
- Configuration states, if commanded to transmit telemetry, shall maintain processor reset action during launch and mission sections.
- The flight software shall maintain the counted packets that transmitted. This shall improve with transmission section for each packet throughout mission.
- The value should maintain through reset parts of processor.
- An audio beacon which required shall power continuously after operation starts.
- Imaging shall be in color with a minimum resolution of 640x512 pixels.

We will have been used Arduino IDE to program Atmega2560 microcontroller. Programming language will have been C or C++. All these conditions depends on flight software tasks structure. Contents of this structure are, [19]

- Reading real time clock, air pressure, altitude, temperature, air speed, particulates in the air and transmitting packets every second witch XBee
- WIDESAT status control

- Activating release mechanism
- In case of autonomous release fails, triggering manual releasing by the command from ground station
- Recording telemetry packets, status and packet number
- Packet Recovery System controls packet’s transmission status. If packet is not received by ground station, transmition section for that packet re-activates until the receiving that packet by the ground station

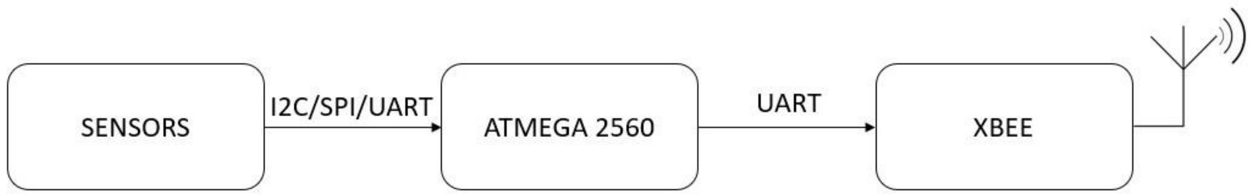


FIGURE 13. 103 BASIC WORKING DIAGRAM OF THE FLIGHT SOFTWARE (FSW) DESIGN

Protoyping and Prototyping Plan of the Flight Software (FSW) Design are, [19]

- 2-way communication will have been tested with Xbee module
- Each sensor will have been tested on breadboard
- Whole electronic system will have been tested
- Designing and printing sections of the PCB will have been existed
- All sensors and microcontroller will have been tested

Development and Development Plan of the Flight Software (FSW) Design are, [19]

- Each sensor will have been tested separately
- Each sensors’ C / C++ codes will have been combined
- Each sensors’ libraries will have been simplified
- Communication system will have been programmed and combined

- Ensuring all the sensors work properly together
- Scheduling to perform necessary calibrations
- Improvements will have been made

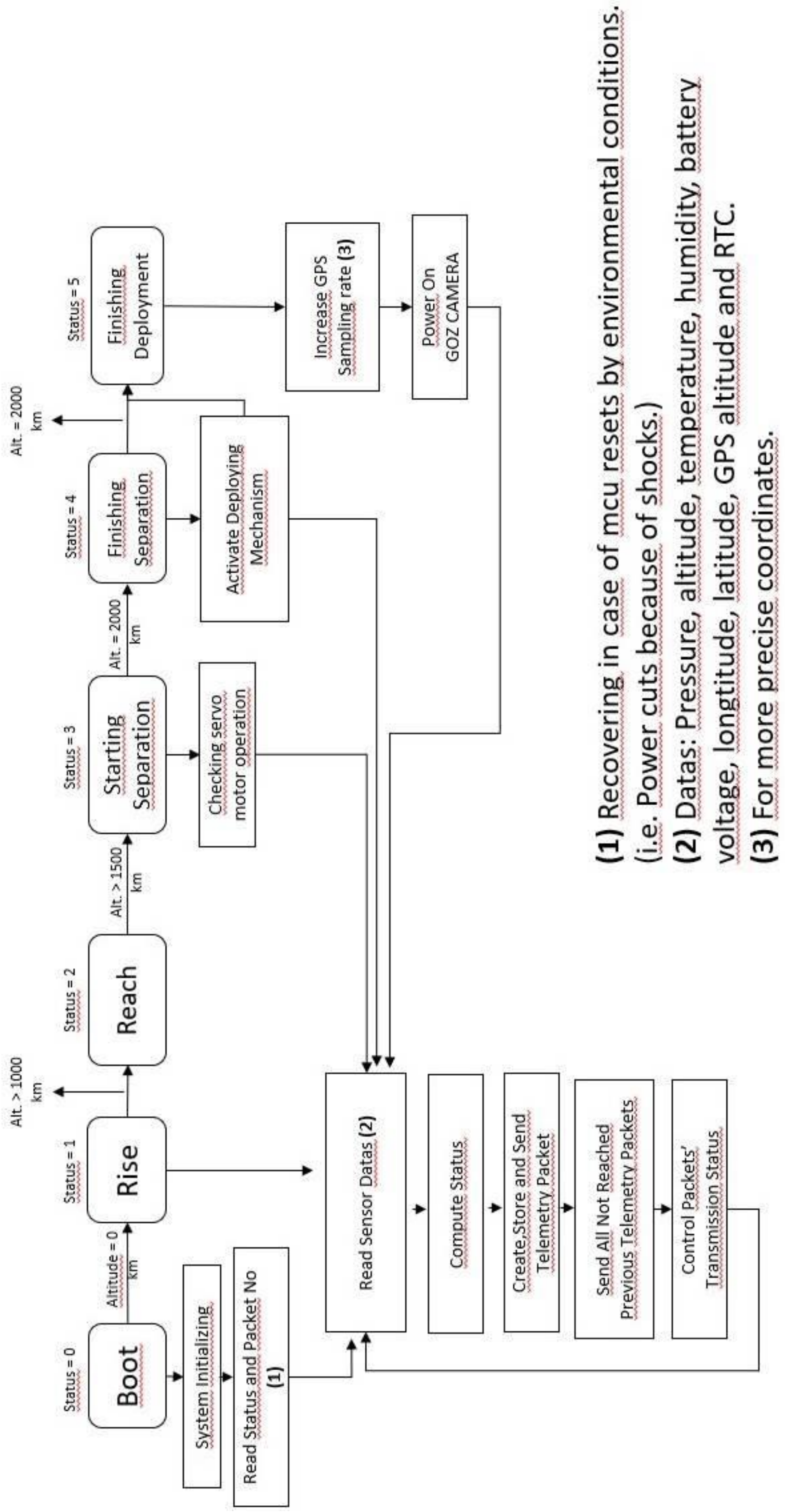


FIGURE 13. 104 FLIGHT SOFTWARE (FSW) STATE DIAGRAM OF THE PAYLOAD

13.12 Ground Control Subsystem (GCS) Design

Ground control subsystem (GCS) design is an order base subsystem of the WIDESAT. This design provides mainly controlling, commanding and managing processes. So that, it shoud have high capable components and well-designed structure. [19]

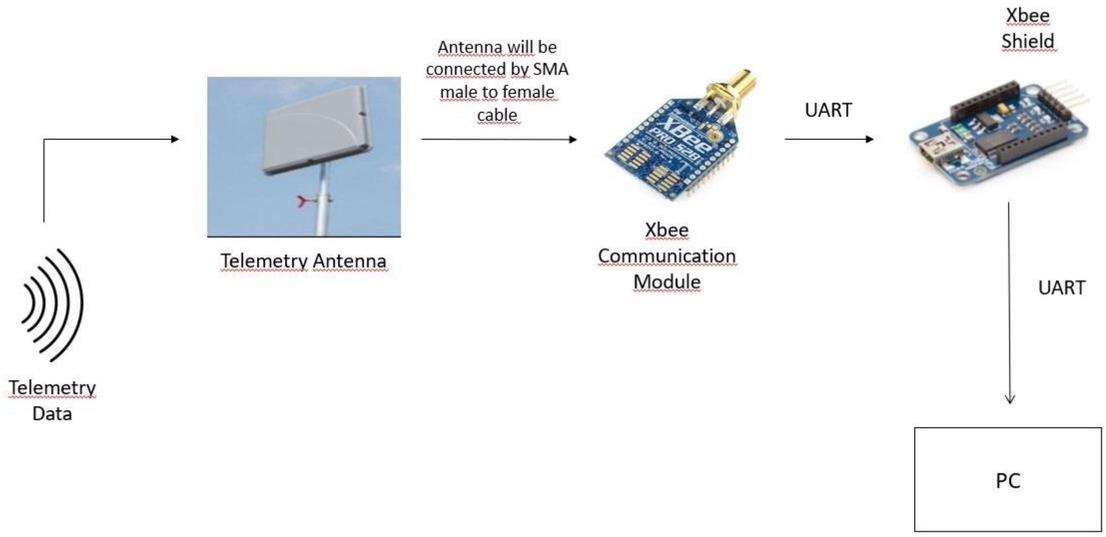


FIGURE 13. 105 GROUND CONTROL SUBSYSTEM (GCS) DESIGN

In case of these situations, requirements of this design are,

- This design will have been the main location for the WIDESAT on land.
- Measurements of this design will have been obtained instant location values of the WIDESAT.
- The selected kit for this design called the Full Ground Station Kit for S-Band has not got alternative.
- This kit is a turnkey solution to prioritize, automatically tracking and receiving data from earth-orbiting satellites which are performing on S-band frequency.
- It contains of an antenna-rotor unit and an indoor tracking and communications system that work together to generate a fully-functional satellite tracking suite.

- The ground system shall command the science vehicle to start transmitting telemetry prior to launch.
- The ground station should generate the CSV file of all sensor data as specified in the telemetry section.
- All telemetry shall display in real time.
- All telemetry shall display with engineering units.
- WIDESAT Ground Control Crew will plot each telemetry data in real time during space flight.
- The ground satellite station should contain computer with two hours battery for operation, XBEEs and antenna called hand-held antenna.
- The ground satellite station shall portable. WIDESAT Ground Control Crew shall position along the flight time. AC power shall not available.
- An audio beacon which required shall power after landing or operating continuously.

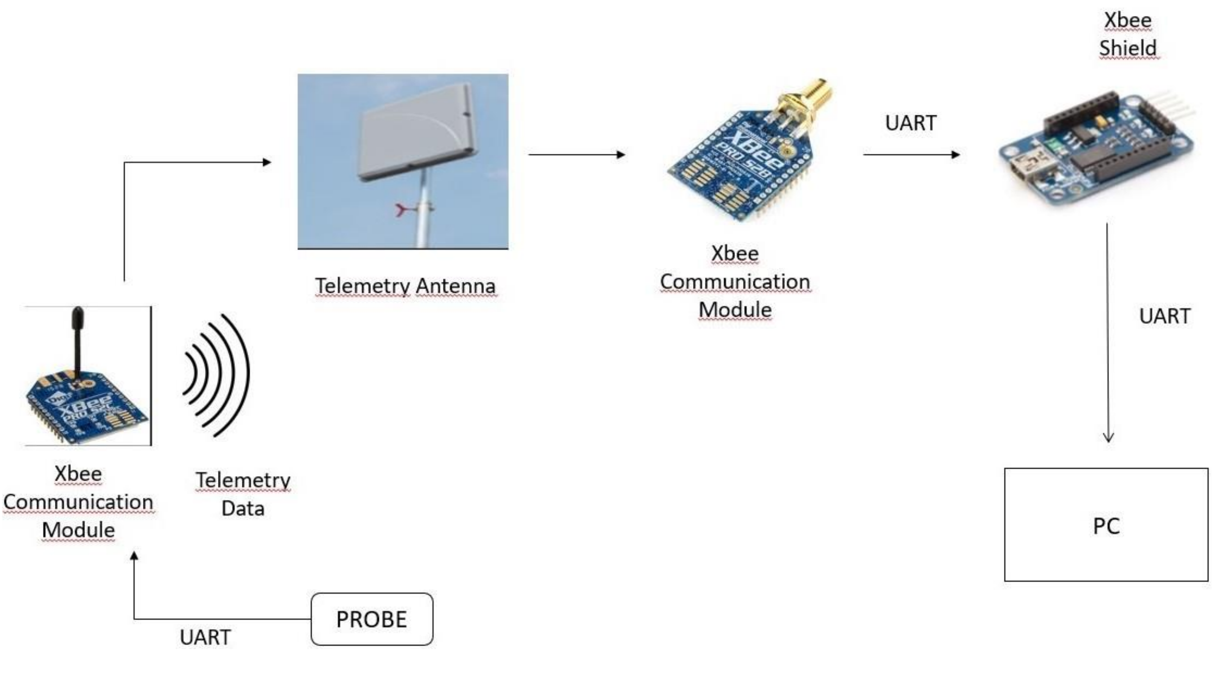


FIGURE 13. 106 TELEMETRY TRANSFER PROCESS

13.12.1 Antenna

Antenna is the first phase of the Ground Control Subsystem (GCS) design. Data packages receives here to decode. After that, data packages transmit to personnel computer (PC) that Mission Control Officer uses via communication module and shield. Antenna should has omni-directional structure. Comparison and features of some antenna types are, [19]

MODEL	TYPE	ANTENNA GAIN (dBi)	OPERATING FREQUENCY	BEAMWIDTH
TP-Link TL-ANT2415D	Omni-Directional	15 dBi	2.4 GHz	360 degree
TP-Link TL-ANT2409A	Directional	9 dBi	2.4 GHz	60 degree
TP-Link TL-ANT2424B	Directional	24 dBi	2.4 GHz	3 degree

TABLE 13. 44 COMPARISON AND FEATURES OF SOME ANTENNA TYPES

We choose TL-2415D due to gain values. The gain value is 15 dBi. This minimizes some effects on our communication telemetry connection such as interference, polarization mismatch and multiple paths. Also, 360-degree beamwidth provides convenience. If we use a narrow beamwidth antenna due to wind or sunlight, we may lose the line of sight (LoS). [19]

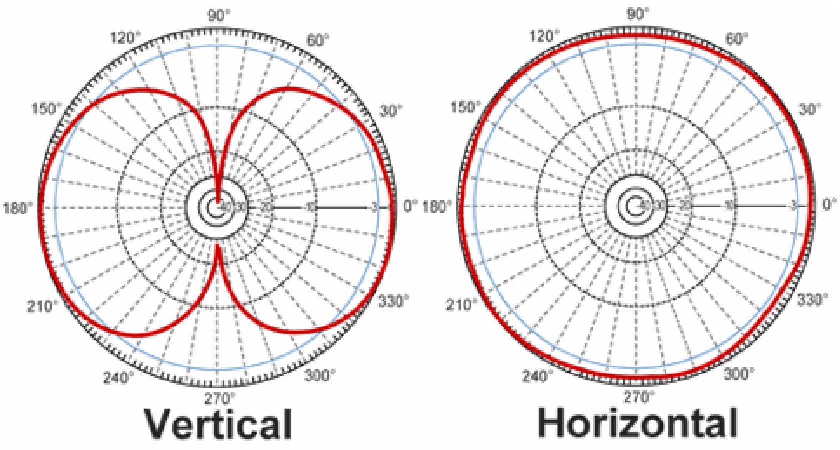


FIGURE 13. 107 OMNI-DIRECTIONAL ANTENNA PATTERN

Telemetry display properties of this antenna are, [19]

- Commercial off the shelf (COTS) software packages will have been Visual Studio, X-CTU and Putty (SSH and Telnet Program).
- In real-time plotting software design that we will have been used is ZedGraph library commands. Temperature, altitude, pressure, humidity and battery voltage datas posted in real-time graphics.

Command Software and Interface properties of this antenna are, [19]

- Data will have been recorded in CVS format separated by semicolons.
- Recorded datas will have been transfered with flash memory stick to judge for inspection.

13.12.2 Full ground station kit

The Full Ground Station Kit will have been tracked the WIDESAT. Also, it ensures imaging processes for New Design GOZ CAMERA. The Full Ground Station Kit will have been branded by ISIS Co. [23]

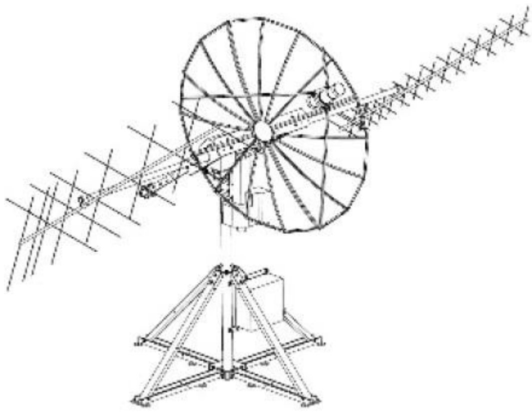


FIGURE 13. 108 FULL GROUND STATION KIT-1

Parts of the Full Ground Station Kit are, [23]

- Instrumentation Rack
- Standard Software
- Steerable Antenna System
- Remote Operations
- Educational Value

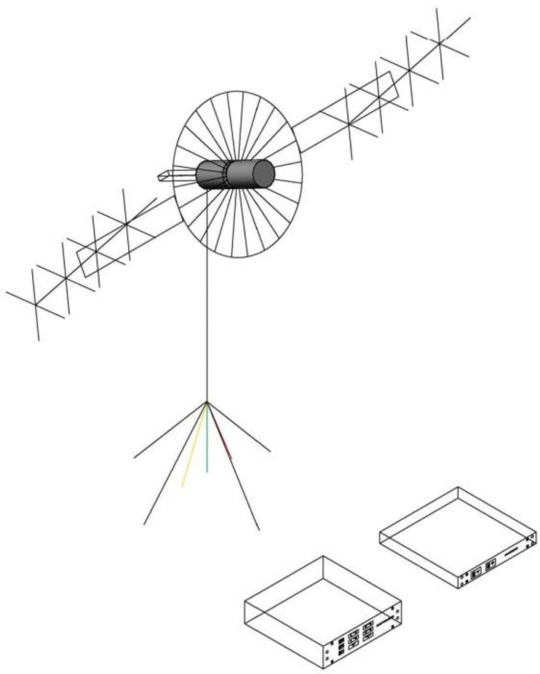


FIGURE 13. 109 FULL GROUND STATION KIT-2

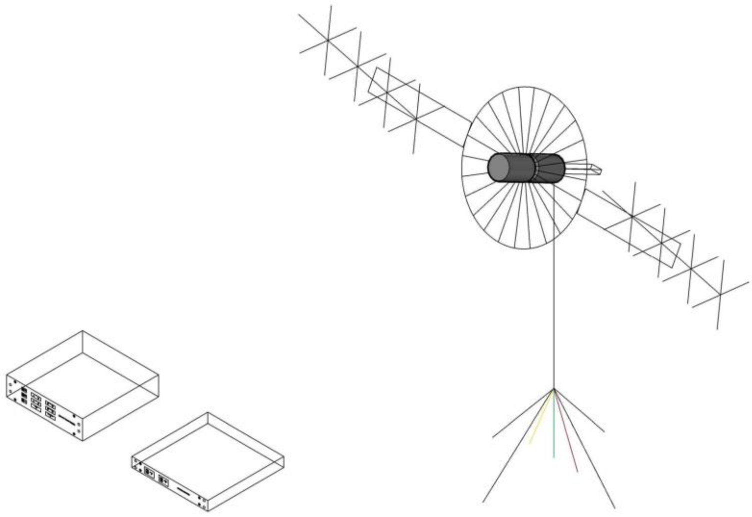


FIGURE 13. 110 FULL GROUND STATION KIT-3

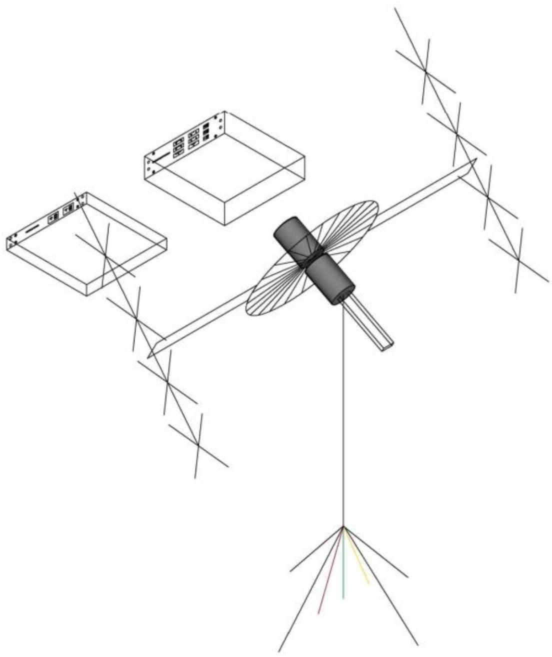


FIGURE 13. 111 FULL GROUND STATION KIT-4

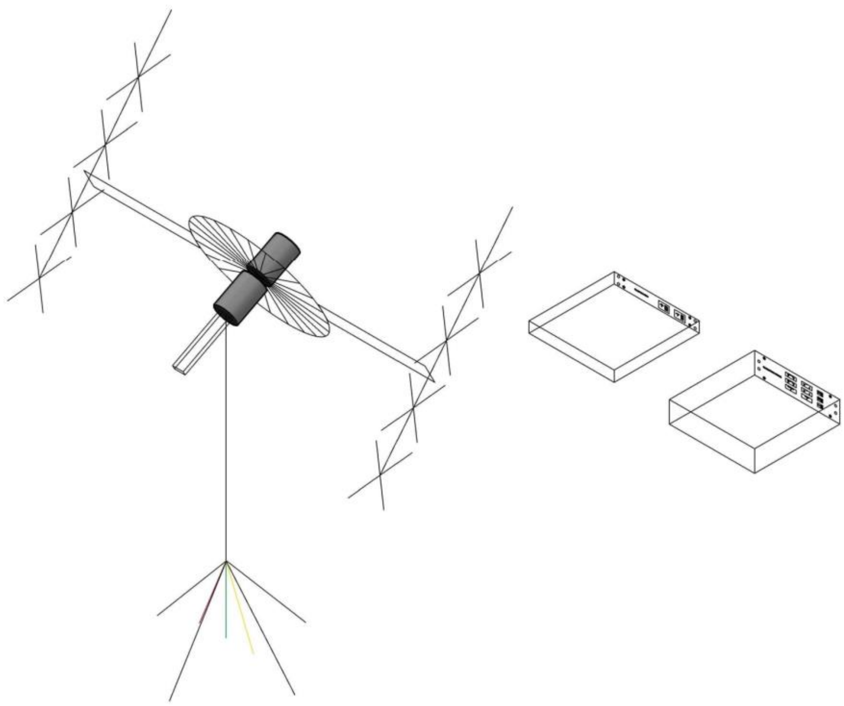


FIGURE 13. 112 FULL GROUND STATION KIT-5

Properties of the instrument rack structure are, [23]

- ISIS S-Band ground satellite station receiver
- Rack mount PC with Local Ground Station (LGS) software
- Rotator Control systems
- Cavity filters to repress UMTS interferences

Properties of the standard software structure are, [23]

- Satellite tracking software pre-installed
- Autonomous tracking with scheduler
- Debian/GNU LINUX operating system pre-installed

Properties of the steerable antenna system structure are, [23]

- Azimuth and elevation rotators with speed up to 6° /sec.
- Hot-dip galvanized steel mounting mast

- 3m mesh dish with helix feed, LNA and cavity filters for S-band (2200 – 2290 MHz or 2400 – 2450 MHz)
- Lightning protection system
- 20m of cable between 19″rack and antenna included in price

Properties of the remote operations structure are, [23]

- It is manageable to configure and check the ground station remotely through the internet
- Software compatible to be used as Data Distribution Center (DDC) in ground station networks.
-

Radio characteristics of the Full Ground Station Kit are, [23]

Low Rate S-Band Receiver		
Frequency Ranges	RX	Amateur: 2400 – 2450 MHz Commercial: 2200 – 2290 MHz
Frequency Stability		±2 ppm at 25°C
Modulation Schemes	RX	BPSK, BPSK-G3RUH, AFSK, FSK, FSK-G3RUH
Data rates	RX	9.6, 14.4, 28.8, 57.6, 115.2 kbps
Data link layer protocol		AX.25
Data Interfaces		IQ data output, Raw bytes output, KISS output, Binary output
High Rate S-Band Receiver		
Frequency Ranges	RX	Amateur: 2400 – 2450 MHz Commercial: 2200 – 2290 MHz
Frequency Stability		±0.01 ppm at 25°C
Modulation Schemes	RX	BPSK, OQPSK
Data rates	RX	625 – 5000 ksymbols/s
Data link layer protocol	RX	CCSDS
Data Interfaces		Binary output

TABLE 13. 45 RADIO CHARACTERISTICS OF THE FULL GROUND STATION KIT

Rotor characteristics of the Full Ground Station Kit are, [23]

Description		
Rotational Range	Azimuth	360°
	Elevation	180°
Rotational Speed		0 – 6 °/sec
Rotor Pointing Accuracy		≤ 0.2°

TABLE 13. 46 ROTOR CHARACTERISTICS OF THE FULL GROUND STATION KIT

Antenna characteristics of the Full Ground Station Kit are, [23]

Description		
Gain	Ø1.9 m	31.4 dBic
	Ø3.0 m	35.4 dBic
Beamwidth	Ø1.9 m	5.1°
	Ø3.0 m	3.2°
Polarization		Either LHCP or RHCP

TABLE 13. 47 ANTENNA CHARACTERISTICS OF THE FULL GROUND STATION KIT

Mechanical and Environmental characteristics of the Full Ground Station Kit are, [23]

Outdoor System		
Height (from ground to cross-boom)		2.3 m
Clearance Radius	Ø1.9 m	1.5 m
	Ø3.0 m	2.5 m
Weight	Ø1.9 m	230 kg
	Ø3.0 m	250 kg
Operating Temperature		-10 °C to 50 °C
Humidity		95%, non-condensing
Lightning Protection		< 10kA
Survival Wind Speed		120 km/h
Indoor System		
Size (w x h x d)		9U 19" rack: 56x46x60 cm
Weight		< 46 kg
Operating Temperature		10 °C to 35°C
Humidity		95%, non-condensing
Supply Voltage		100 to 240 VAC, 50 to 60 Hz
Supply Current		max 3.5 A @220V, max 7.0 A @110V

TABLE 13. 48 MECHANICAL AND ENVIRONMENTAL CHARACTERISTICS OF THE FULL GROUND STATION KIT

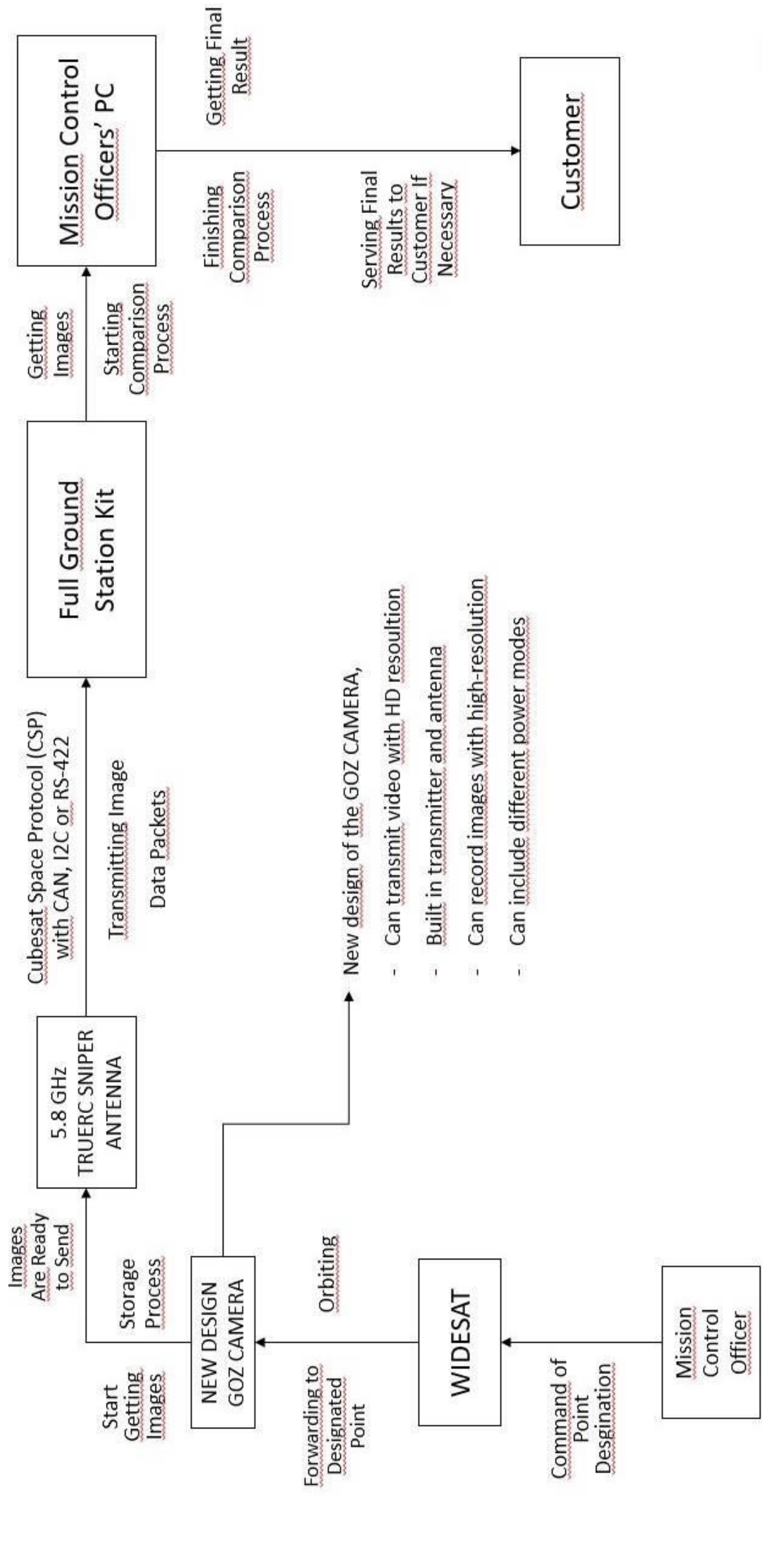


FIGURE 13. 113 INFRARED (IR) CAMERA COMMUNICATION DIAGRAM

Value impressions of the data packages should intelligible. Each value can read fairly. Some sample graphs about this is as shown below.

Values of the BME 280 sensor at 9600 baud rate,

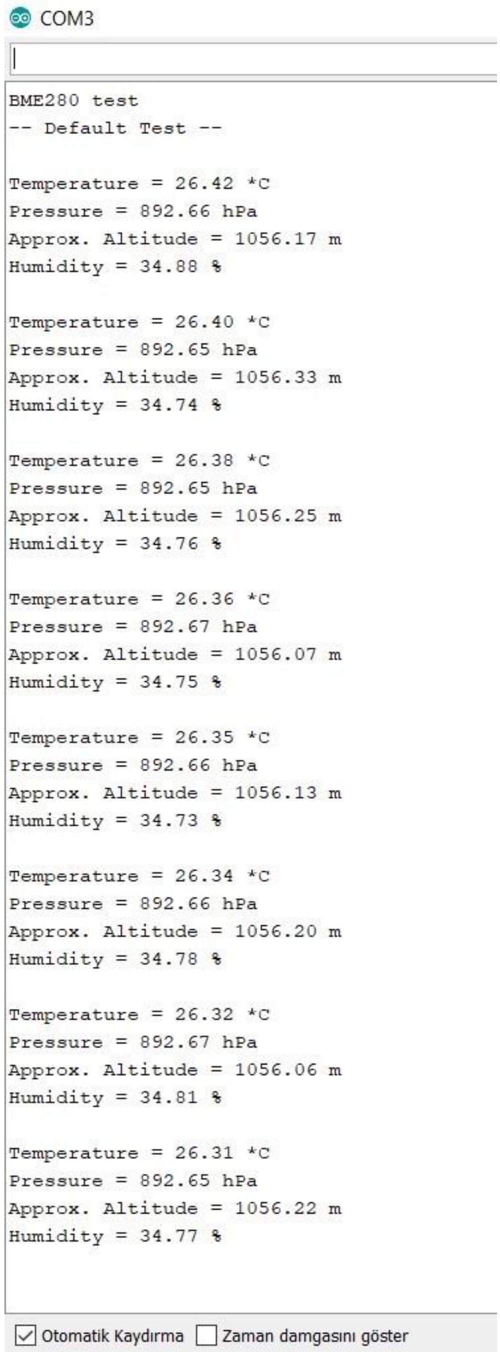


FIGURE 13. 114 VALUES OF THE BME 280 SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

Graph of the BME 280 sensor at 9600 baud rate,

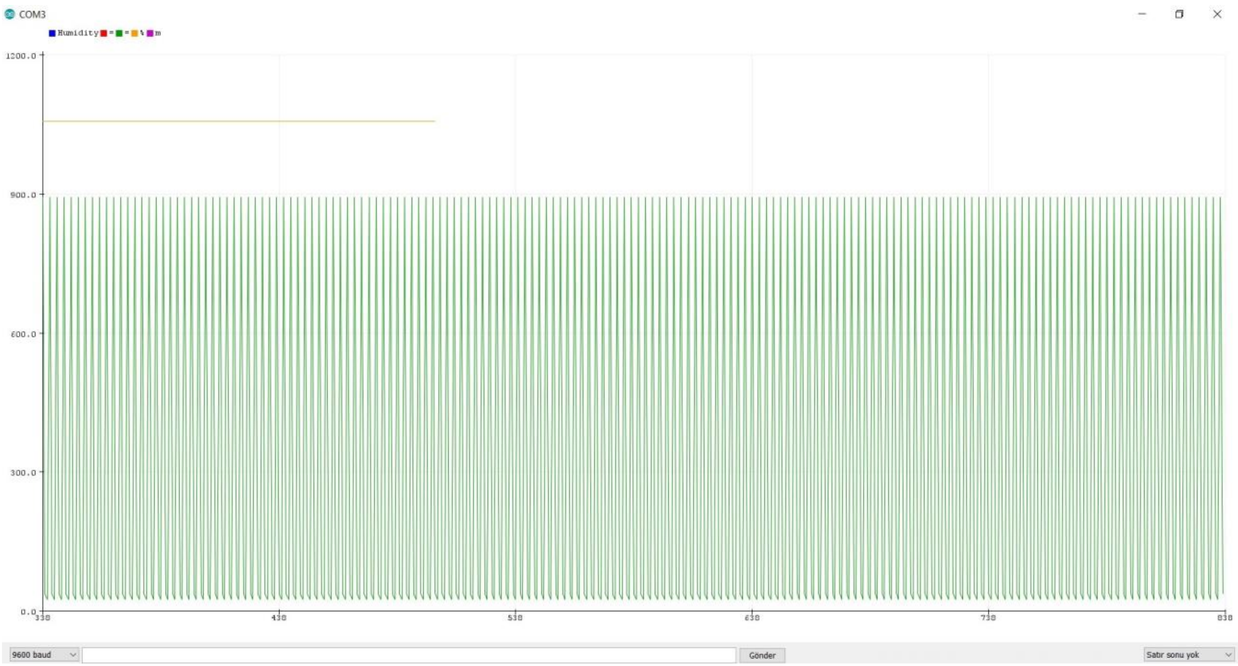


FIGURE 13. 115 GRAPH OF THE BME 280 SENSOR

NOTE THAT, THIS IS SAMPLE REPRESENTATIVE GRAPH FOR THE WIDESAT

Values of the ADAFRUIT MPL3115A2 sensor at 9600 baud rate,

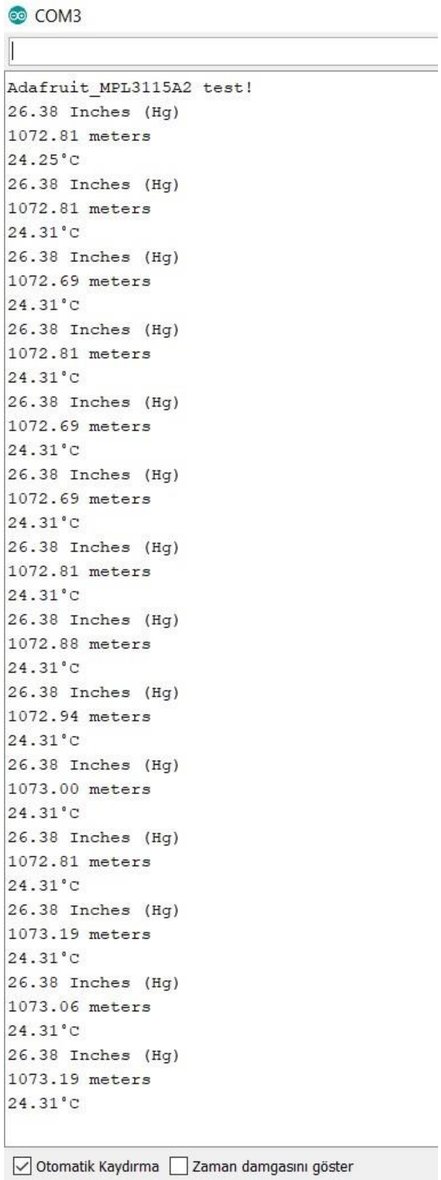


FIGURE 13. 116 VALUES OF THE ADAFRUIT MPL3115A2 SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

Graph of the ADAFRUIT MPL3115A2 sensor at 9600 baud rate,

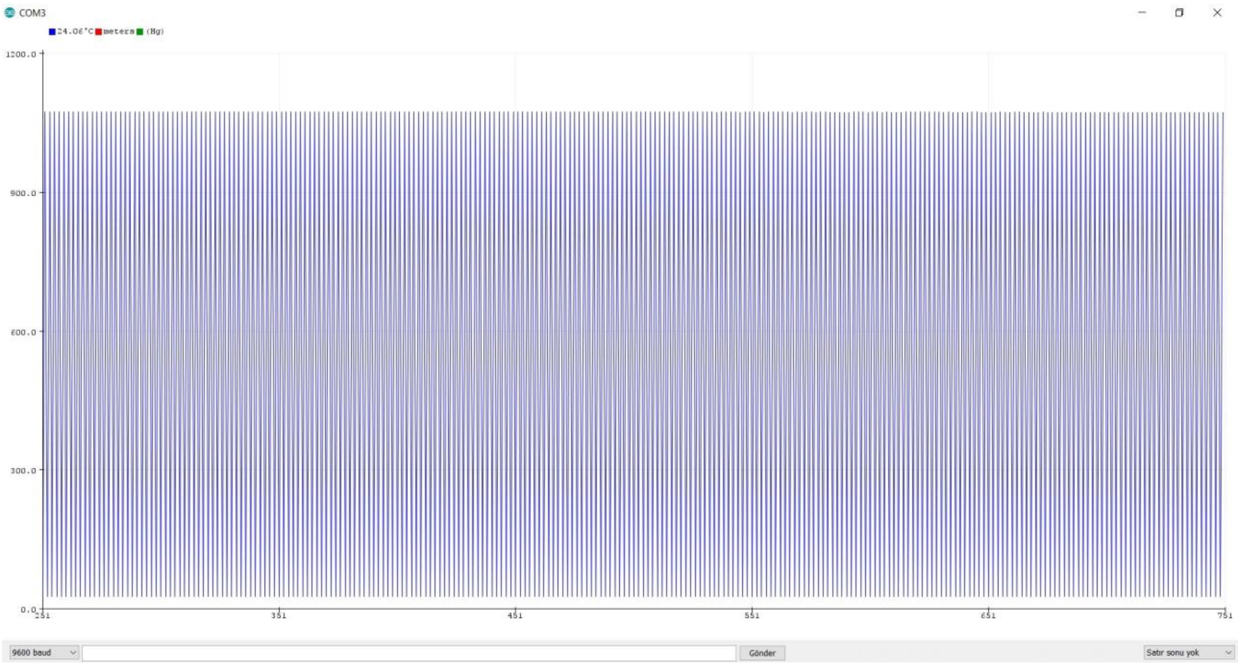


FIGURE 13. 117 GRAPH OF THE ADAFRUIT MPL3115A2 SENSOR

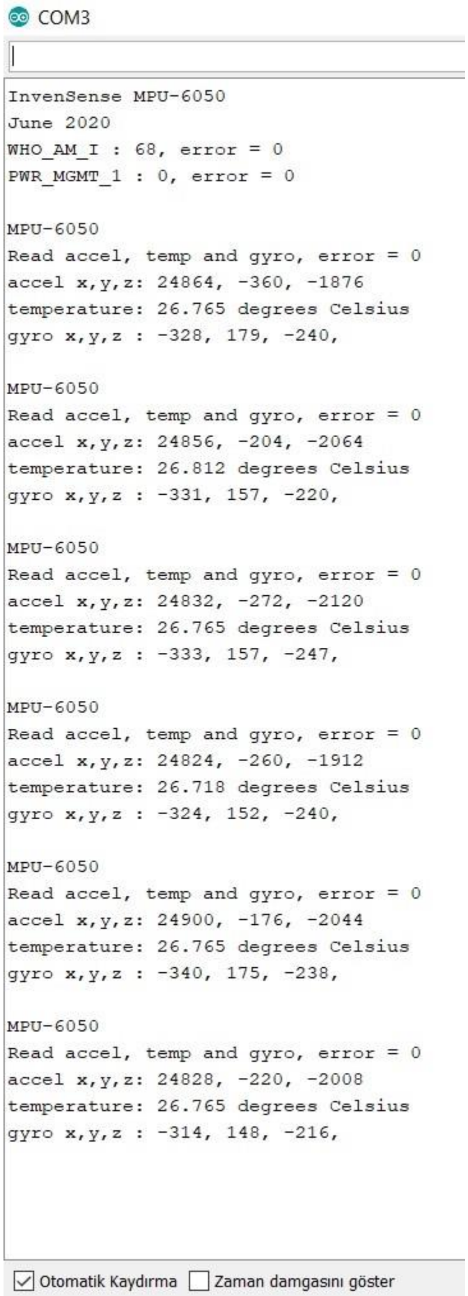
NOTE THAT, THIS IS SAMPLE REPRESENTATIVE GRAPH FOR THE WIDESAT

Checking values of the MPU-6050 sensor at 9600 baud rate,

FIGURE 13. 118 CHECKING VALUES OF THE MPU-6050 SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

Values of the MPU-6050 sensor at 9600 baud rate,




```
InvenSense MPU-6050
June 2020
WHO_AM_I : 68, error = 0
PWR_MGMT_1 : 0, error = 0

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24864, -360, -1876
temperature: 26.765 degrees Celsius
gyro x,y,z : -328, 179, -240,

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24856, -204, -2064
temperature: 26.812 degrees Celsius
gyro x,y,z : -331, 157, -220,

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24832, -272, -2120
temperature: 26.765 degrees Celsius
gyro x,y,z : -333, 157, -247,

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24824, -260, -1912
temperature: 26.718 degrees Celsius
gyro x,y,z : -324, 152, -240,

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24900, -176, -2044
temperature: 26.765 degrees Celsius
gyro x,y,z : -340, 175, -238,

MPU-6050
Read accel, temp and gyro, error = 0
accel x,y,z: 24828, -220, -2008
temperature: 26.765 degrees Celsius
gyro x,y,z : -314, 148, -216,
```

FIGURE 13. 119 VALUES OF THE MPU-6050 SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

Graph of the MPU-6050 sensor at 9600 baud rate,

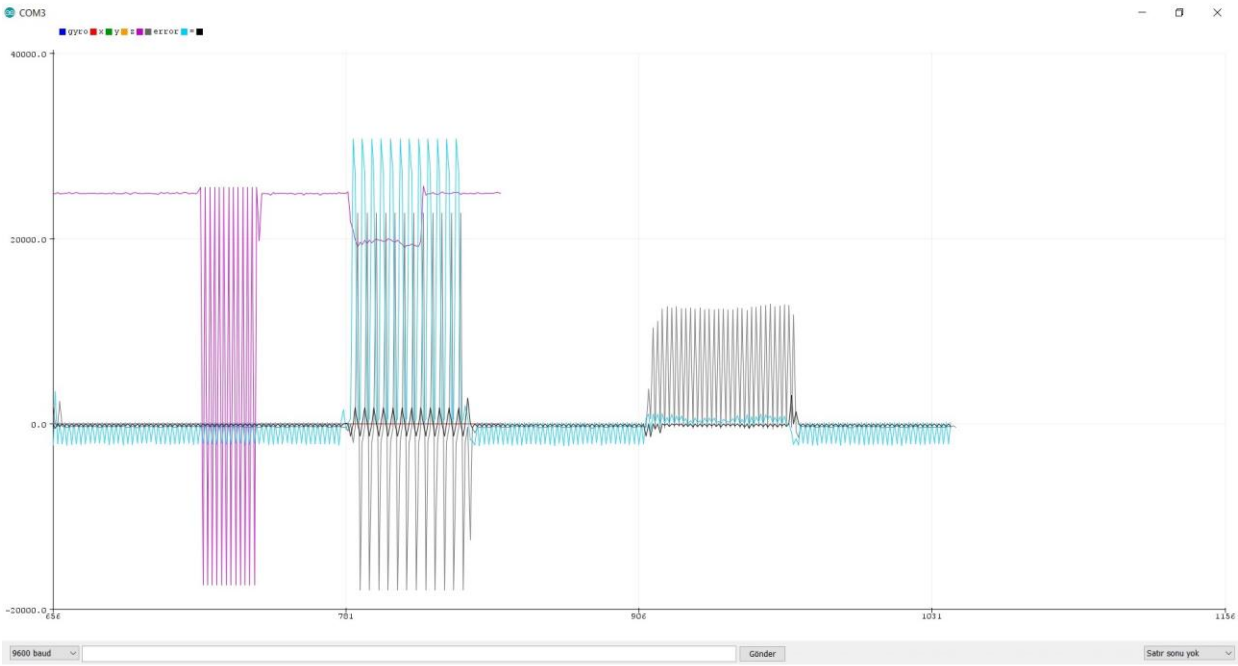


FIGURE 13. 120 GRAPH OF THE MPU-6050 SENSOR

Peak points are the points that determines changing location of the sensor

NOTE THAT, THIS IS SAMPLE REPRESENTATIVE GRAPH FOR THE WIDESAT

Checking values of the ADAFRUIT ULTIMATE GPS BREAKOUT sensor at 115200 baud rate,

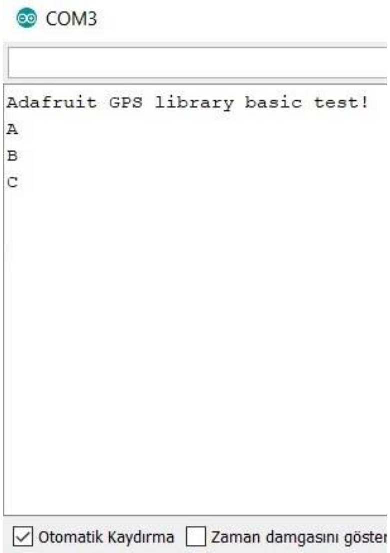


FIGURE 13. 121 CHECKING VALUES OF THE ADAFRUIT ULTIMATE GPS BREAKOUT SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

Zero Values of the ADAFRUIT ULTIMATE GPS BREAKOUT sensor at 115200 baud rate,

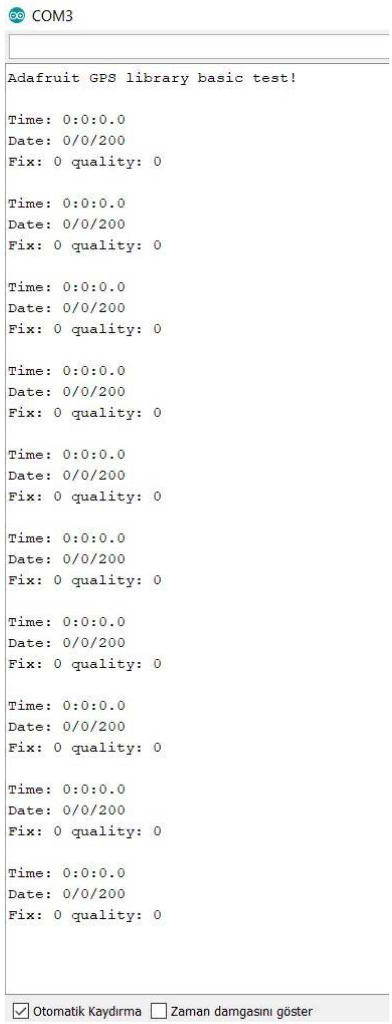


FIGURE 13. 122 ZERO VALUES OF THE ADAFRUIT ULTIMATE GPS BREAKOUT SENSOR

NOTE THAT, THESE ARE SAMPLE REPRESENTATIVE VALUES FOR THE WIDESAT

14. WIDESAT INTEGRATION AND TEST

Integration and test processes of the WIDESAT are the inspection part. When these two processes occur fluently, all subsystems of the WIDESAT work forever. So that, there are different types of tests. [19]

Mechanical subsystem tests are, [19]

- Thermal Test
- Vibration Test
- Pressure Test
- Mass Test
- Releasing System Test

Communication and Data Handling (CDH) subsystem tests are, [19]

- Serial Communication Test
- Real-Time Clock (RTC) Time Keeping Test

Electrical Power (EPS) subsystem tests are, [19]

- Battery Voltage Test
- Power Consumption Test

Flight Software (FSW) subsystem tests are, [19]

- Status Perception Test
- Releasing Algorithm Test
- Packet Recovery System Test

Sensor subsystem test is, [19]

- Data Accuracy Test

Communication tests are, [19]

- Xbee Range & Configuration Test
- Video Transmition Test

- Range test will have been done for probe's Xbee and ground station's Antenna. Signal quality will have been observed.

Main tests is, [19]

- After each electrical and mechanical components integrated on chasis, flight and releasing tests will have been done.

Mechanism test is, [19]

- Payload and container will have been integrated. Then releasing tests will have been done.

Environment conditions test is, [19]

- Some places where are properly will have been selected. (oftenly university's lab and football field)

Each subsystem has its own testing plan. These test plans can ease the controlling of the WIDESAT. [19]

Testing plan of the Sensor Subsystem is, [19]

NO	SENSOR SUBSYSTEM
1	Testing pressure sensor and humidity sensor with different altitudes
2	Heating up to temperature sensor and observing the output datas
3	Testing GPS sensor with different locations and comparing the exact location
4	Using power voltage sensor for measuring voltage with different batteries
5	GOZ CAMERA system

TABLE 14. 1 TESTING PLAN OF THE SENSOR SUBSYSTEM

Testing plan of the Communication and Data Handling (CDH) Subsystem is, [19]

NO	COMMUNICATION AND DATA HANDLING (CDH) SUBSYSTEM
1	General system will have been tested on payload
2	Data storage testing
3	Testing Real Time Clock (RTC) for keeping exact time
4	Communication tests between microcontroller and each sensors
5	Transmission with XBees will have been tested
6	Xbee configuration and signal tests will have been actualized with software called X-CTU
7	Video transmition test
8	Communication between XBees will have been tested
9	Range between communication components will have been tested
10	Package recovery system test will have been done
11	Data package transmition test will have been done

TABLE 14. 2 TESTING PLAN OF THE COMMUNICATION AND DATA HANDLING (CDH) SUBSYSTEM

Testing plan of the Electrical Power (EPS) Subsystem is, [19]

NO	ELECTRICAL POWER (EPS) SUBSYSTEM
1	Measuring exact voltage and current values of each sensors
2	Ensured that batteries can supply power to whole system

TABLE 14. 3 TESTING PLAN OF THE ELECTRICAL POWER (EPS) SUBSYSTEM

Testing plan of the Flight Software (FSW) Subsystem is, [19]

NO	FLIGHT SOFTWARE (FSW) SUBSYSTEM
1	Checking status of the probe’s location
2	Testing releasing (from container) algorithm at required altitude
3	Testing releasing (from payload) algorithm at required altitude
4	Package recovery system will have been tested

TABLE 14. 4 TESTING PLAN OF THE FLIGHT SOFTWARE (FSW) SUBSYSTEM

Testing plan of the Mechanical Subsystem is, [19]

NO	MECHANICAL SUBSYSTEM
1	Testing the whole system whether it works correctly or not with different temperatures
2	Releasing system will have been tested with a weight
3	Testing the whole system whether it works correctly or not while shaking
4	Ensured that whole WIDESAT’s mass will have been required value
5	Testing releasing mechanism whether it works correctly or not.
6	Testing the payload will not have been harmed when the probe landed on the ground

TABLE 14. 5 TESTING PLAN OF THE MECHANICAL SUBSYSTEM

Testing plan of the Ground Control (GCS) Subsystem is, [19]

NO	GROUND CONTROL (GCS) SUBSYSTEM
1	Testing the whole system whether it works correctly or not
2	Testing the whole parts of the Full Ground Station Kit
3	Checking telemetry transfer processes
4	Checking command software and interface

TABLE 14. 6 TESTING PLAN OF THE GROUND CONTROL (GCS) SUBSYSTEM

Testing plan of the Orbital Control Design is, [19]

NO	ORBITAL CONTROL DESIGN
1	Testing the orbital control system whether it works correctly or not
2	Testing the attitude control system whether it works correctly or not
3	Checking orbital control system component
4	Checking attitude control system components

TABLE 14. 7 TESTING PLAN OF THE ORBITAL CONTROL DESIGN

Testing plan of the Thermal Control (TCS) Subsystem is, [19]

NO	THERMAL CONTROL (TCS) SUBSYSTEM
1	Testing the thermal control subsystem whether it works correctly or not
2	Testing the heat pipe working theory whether it works correctly or not
3	Checking each heat pipe structure

TABLE 14. 8 TESTING PLAN OF THE THERMAL CONTROL (TCS) SUBSYSTEM

Integrated level functional test plan consists of two issues. These are Mechanism and Deployment tests. [19]

Mechanism tests are, [19]

NO	MECHANISM TESTS
1	Payload and container releasing mechanism will have been tested
2	Payload protection mechanism will have been tested

TABLE 14. 9 MECHANISM TESTS

Deployment tests are, [19]

NO	DEPLOYMENT TESTS
1	Each thruster will have been tested
2	Total thruster usage for deployment will have been tested

TABLE 14. 10 DEPLOYMENT TESTS

15.MISSION OPERATIONS AND ANALYSIS

In this thesis, each operation has responsible personnel. They are making coordination between events to manage the WIDESAT carefully. Pre-Launch Event, Deployment Event, Orbiting Event and Data Transferring Event are operations. Also, we planned Manuel Development Plan for emergency situations at space.

Pre-Launch Event steps and related responsible people are,

NO	PRE-LAUNCH EVENT	RESPONSIBILITY
1	Make the WIDESAT ready	WIDESAT Crew
2	Setting up the Ground Control Subsystem	Ground Station Crew
3	Make antennas ready	Ground Station Crew
4	The WIDESAT communication tests	Ground Station Crew
5	Data verifying	Ground Station Crew
6	Tests of the separation mechanism	WIDESAT Crew

TABLE 15. 1 PRE-LAUNCH EVENT STEPS AND RELATED RESPONSIBILITIES

Deployment Event steps and related responsible people are,

NO	DEPLOYMENT EVENT	RESPONSIBILITY
1	Power on the WIDESAT	Mission Control Officer
2	Integration of the WIDESAT into the rocket	Mission Control Officer
3	Confirmation of the received telemetry	Ground Station Crew

TABLE 15. 2 DEPLOYMENT EVENT STEPS AND RELATED RESPONSIBILITIES

Orbiting Event steps and related responsible people are,

NO	ORBITING EVENT	RESPONSIBILITY
1	Checking designated position of the WIDESAT in low earth orbit (LEO)	Mission Control Officer
2	Orbiting the WIDESAT successfully	Mission Control Officer
3	Positioning and stabilization controlling	Mission Control Officer

TABLE 15. 3 ORBITING EVENT STEPS AND RELATED RESPONSIBILITIES

Data Transferring Event steps and related responsible people are,

NO	DATA TRANSFERRING EVENT	RESPONSIBILITY
1	Controlling the camera and data transferring	Mission Control Officer
2	Posding the sample data from the camera and sensor	Mission Control Officer
3	Beginning real-time data sending after all controls done	Mission Control Officer

TABLE 15. 4 DATA TRANSFERRING EVENT STEPS AND RELATED RESPONSIBILITIES

Manuel Development plan for emergency situations at space is,

GROUND STATION CONFIGURATION	WIDESAT PREPARATION	LAUNCH	TRANSFERRING
Setting up the Ground Control Subsystem and antennas	Assembly	Launch procedures	Transferring the real-time data from the camera and sensors

Testing sensors, camera and communication	Heat shield mechanism test	-	-

TABLE 15. 5 MANUEL DEVELOPMENT PLAN

NOTE THAT, ALL REQUIREMENTS OF THE WIDESAT WILL HAVE BEEN COMPLY PERFECTLY

16.MANAGEMENT

Management of the WIDESAT has been divided to control and follow each step simply. We called it System Schedule to improve this thesis. [19]

SYSTEM SCHEDULE	LEVEL TASK
LITERATURE SURVEY	GATHERING KNOWLEDGE ABOUT SYSTEM REQUIREMENTS
STUDIES	GATHERING KNOWLEDGE ABOUT SYSTEM REQUIREMENTS
SATELLITE DESIGN	PRELIMINARY SYSTEM DESIGN
ANALYSIS	PRELIMINARY SYSTEM DESIGN
DISCUSSION GENERAL	PRELIMINARY SYSTEM DESIGN

PREPARING PRELIMINARY DESIGN REVIEW	PREPARING PRELIMINARY DESIGN REVIEW
PRELIMINARY DESIGN REVIEW DISCUSSION	PREPARING PRELIMINARY DESIGN REVIEW
PRELIMINARY DESIGN REVIEW LAST REVISION	PREPARING PRELIMINARY DESIGN REVIEW
MECHANISM SYSTEM MODIFICATION	SYSTEM MODIFICATION
ELECTRONIC SYSTEM MODIFICATION	SYSTEM MODIFICATION
COMMUNICATION SYSTEM MODIFICATION	SYSTEM MODIFICATION
MECHANIC SYSTEM TESTS	TEST AND SPECIFYING FINAL DESIGN
ELECTRONIC SYSTEM TESTS	TEST AND SPECIFYING FINAL DESIGN
COMMUNICATION SYSTEM TESTS	TEST AND SPECIFYING FINAL DESIGN
ANALYSING AND DISCUSSING TEST RESULTS	TEST AND SPECIFYING FINAL DESIGN
SPECIFYING FINAL DESIGN	TEST AND SPECIFYING FINAL DESIGN
CDR REVIEW	TEST AND SPECIFYING FINAL DESIGN
CDR DISCUSSION	TEST AND SPECIFYING FINAL DESIGN

CDR LAST REVISION	TEST AND SPECIFYING FINAL DESIGN
FINAL TESTS	FINALIZING THE SYSTEM
FINAL CHECKS	FINALIZING THE SYSTEM
FINAL ARRANGEMENTS	FINALIZING THE SYSTEM
DEMO FLIGHT	FINALIZING THE SYSTEM
PFR	FINALIZING THE SYSTEM

TABLE 16. 1 SYSTEM SCHEDULE

17. POSSIBLE AND GENERAL TOTAL COST CALCULATIONS

We calculated possible cost of the WIDESAT. Each subsystem and design were calculated with its own.

Possible and general total costs of the Sensor Subsystem are, [8], [9], [10], [11], [12], [13]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
Air Pressure Sensor	PCB Model 116B	1	2.000	2.000	Actual
Air Temperature Sensor	IST AG 300°C Pt	1	5,5	5,5	Actual

Humidity Sensor	IST P14-W	1	16,5	16,5	Actual
GPS Sensor	Arduino Grove – GPS Module	1	25	25	Approximate
Power Voltage Sensor	GWP T240K-0U	1	25	25	Approximate
GOZ CAMERA	N/A	1	N/A	N/A	N/A

TABLE 17. 1 POSSIBLE COST OF THE SENSOR SUBSYSTEM

GENERAL TOTAL [$]
2.072 (Without GOZ CAMERA)

TABLE 17. 2 GENERAL TOTAL COST OF THE SENSOR SUBSYSTEM

Possible and general total costs of the Orbital Control Design are, [15], [16], [17], [18]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
ADACS + Star Tracker	MAI-500 0.6-Unit	1	200.000	200.000	Approximate

	Cubesat ADACS and Dual Star Tracker				
Magnetorquer	-	33	2.000	66.000	Approximate
Reaction Wheel	-	33	7.500	247.500	Approximate
Printed Circuit Board (PCB) (Includes All Sensors)	-	1	10.000	10.000	Approximate

TABLE 17. 3 POSSIBLE COST OF THE ORBITAL CONTROL DESIGN

GENERAL TOTAL [$]
523.500

TABLE 17. 4 GENERAL TOTAL COST OF THE ORBITAL CONTROL DESIGN

Possible and general total costs of the Mechanical Subsystem are, [15], [19]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
Main Compertment, Container and Cover Material	Carbon Fiber	162	0,216	34,992	Actual
Thruster	IFM Nano Thruster	16	33.000	528.000	Actual
Servo Motor	Power HD Hd-1370a	16	8	128	Actual

TABLE 17. 5 POSSIBLE COST OF THE MECHANICAL SUBSYSTEM

GENERAL TOTAL [$]
528.162,992

TABLE 17. 6 GENERAL TOTAL COST OF THE MECHANICAL SUBSYSTEM

Possible and general total costs of the Communication and Data Handling (CDH) Subsystem are, [19]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
On-Board Computer	Arduino MEGA 2560	1	50	50	Actual
Microcontroller	ATmega	1	11	11	Actual
Memory	Sandisk Ultra	1	6	6	Actual
Real-Time Clock	DS3231	1	5	5	Actual
Omni-Directional Antenna	Xbee Stock Wire Antenna	1	60	60	Actual
Antenna	Xbee Series S2C Pro Module	1	60	60	Actual
Antenna	TRUERC SNIPER 5.8 GHz	1	55	55	Actual

TABLE 17. 7 POSSIBLE COST OF THE COMMUNICATION AND DATA HANDLING (CDH) SUBSYSTEM

GENERAL TOTAL [$]
247,00

TABLE 17. 8 GENERAL TOTAL COST OF THE COMMUNICATION AND DATA HANDLING (CDH) SUBSYSTEM

General total costs of the Thermal Control (TCS) Subsystem is, [20]

GENERAL TOTAL [$]
N/A

TABLE 17. 9 GENERAL TOTAL COST OF THE THERMAL CONTROL (TCS) SUBSYSTEM

Possible and general total costs of the Electrical Power (EPS) Subsystem are, [21], [22]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
Li-Ion Battery	iEPS	6	8.250	49.500	Actual
Solar Panel	DHV-CS-10	54	1.595	86.130	Actual

TABLE 17. 10 POSSIBLE COST OF THE ELECTRICAL POWER (EPS) SUBSYSTEM

GENERAL TOTAL [$]
135.630

TABLE 17. 11 GENERAL TOTAL COST OF THE ELECTRICAL POWER (EPS) SUBSYSTEM

General total costs of the Flight Software (FSW) Subsystem is, [19]

GENERAL TOTAL [$]
N/A

TABLE 17. 12 GENERAL TOTAL COST OF THE FLIGHT SOFTWARE (FSW) SUBSYSTEM

Possible and general total costs of the Ground Control (GCS) Subsystem are, [22]

COMPONENT	MODEL	QUANTITY	UNIT PRICE [$]	TOTAL PRICE [$]	PRICE
Ground Control System	Full Ground Station Kit	1	73.370	73.370	Actual

TABLE 17. 13 POSSIBLE COST OF THE GROUND CONTROL (GCS) SUBSYSTEM

General total costs of the Ground Control (GCS) Subsystem is, [22]

GENERAL TOTAL [$]
73.370

TABLE 17. 14 GENERAL TOTAL COST OF THE GROUND CONTROL (GCS) SUBSYSTEM

Possible and general total costs of the WIDESAT are,

SUBSYSTEM	TOTAL [$]
Sensor Subsystem	2.072,00 (Without GOZ CAMERA)
Orbital Control Design	523.500,00
Mechanical Subsystem	528.162,992
Communication and Data Handling (CDH) Subsystem	247,00
Thermal Control (TCS) Subsystem	N/A
Electrical Power (EPS) Subsystem	135.630,00

Fligth Software (FSW) Design	N/A
Ground Control (GCS) Subsystem	73.370,00

TABLE 17. 15 POSSIBLE COST OF THE WIDESAT

General total costs of the WIDESAT is,

WIDESAT TOTAL [$]
1.262.981,99 (Without GOZ CAMERA)

TABLE 17. 16 GENERAL TOTAL COST OF THE WIDESAT

18.CONCLUSION

After every process and situation of the Wind Detection Satellite (WIDESAT) was passed, we decided to conclude this thesis. Conclusion section exists step-by-step. So that, this section has points. These points are,

- Understanding objectives and mission requirements
- Effective material selection
- Designing whole subsystems and heat shield
- Completing the configuration parts for each subsystem
- Testing whole subsystems with their own test plans
- Finishing last processes of each subsystem
- Maintaining well-designed subsystems
- Whole system controlling
- Producing the Wind Detection Satellite (WIDESAT)

19.RECOMMENDATIONS

The Wind Detection Satellite called WIDESAT has lots of subsystems as I mentioned above. These subsystem are avaliable to develop with new researches and new components. Each of them can redesign and reconfigure for any meteorological space application requirements. That’s why these subsystems are compatible for every aspects of space qualifying issues.

Redesigning and reconfiguring these subsystems can give more opportunity for that satellite’s mission areas at space. These two actions help the satellite to get more datas wherever, whenever and whatever the space mission needs.

Do not forget that redesigning and reconfiguring this satellite can all about meteorological measuring. It never used for any other goals. The satellite design as shown above mainly about how to get meteorological values from the designated targets.

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