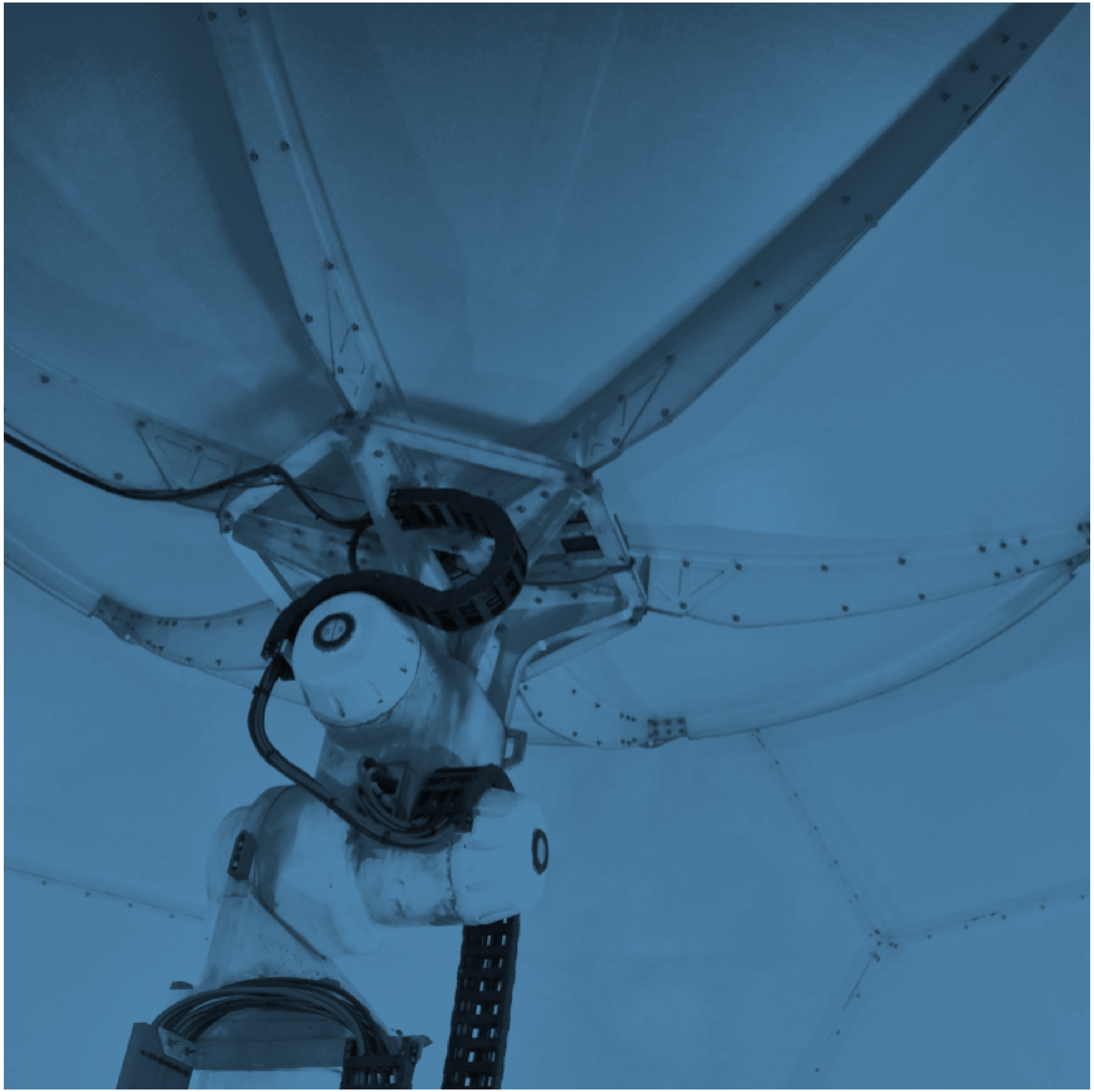
Our Place in Space

Space S&T and Applications in the Philippines

VOLUME 2

Space Technology

2016 to 2020



Philippine Space Agency

Foreword

Space is the expanse above us, which can bridge our islands, communities and wherever Filipinos may go on Earth. Space travel and rockets uplift us, figuratively, in mind and spirit (and literally). Being in space, building in space, with its high vantage point, empowers us.

The Philippines has taken significant steps in space science and technology applications (SSTA) over the period 2014-2020. A number of SSTA activities implemented as project-based initiatives have been initiated and continue to be pursued with the support of the Department of Science and Technology's (DOST) Grants-in-Aid (GIA). Projects such as the Philippine Scientific Earth Observation Microsatellite Program (PHL- Microsat) and its successor, the Space Technology and Applications Mastery, Innovation and Advancement Program (STAMINA4Space) have led to the development, launch, operation and utilization of the country's own small satellites for scientific Earth observation, DIWATA-1 launched in 2016, followed by DIWATA-2 in 2018 and MAYA-1, the country's first nanosatellite, also launched in 2018. DIWATA and MAYA provide a blueprint that enable the development of small satellites to be sustained, proliferated and localized in the country. These achievements have enabled the Philippines to join the ranks of countries that not only own and operate satellites, but have been able to build and develop them.

Thes satellite development activities are joined by complementary ground infrastructure and services, such as multi-mission satellite receiving stations, which we call the Philippine Earth Data Resource Observation (PEDRO) Center, as well as high performance computing (HPC) facilities for the processing, archiving and distribution of satellite images and other spaceborne data. There is also the Remote Sensing and Data Science Help Desk or DATOS, which have been developing a gamut of applications from the satellite image data. These investments have equipped the Philippines with a capacity to create and add value from space, specifically through the generation, processing, dissemination and utilization of data obtained by satellites and space infrastructure.

The success and value of these prior efforts confirmed that we need a dedicated and specialized agency to champion a national space program. On August 8, 2019, President Rodrigo Roa Duterte signed Republic Act No. 11363 or the "The Philippine Space Act". By virtue of this law, the Philippine Space Agency or PhilSA was established to serve as the primary policy, planning, coordinating, implementing, and administrative entity of the Executive Branch of the government that will plan, develop, and promote our national space program. The Philippine Space Act recognizes these prior efforts that have produced our emergent local technological capacity in space. With foundational elements in capabilities, infrastructure and people in place, the PhilSA is therefore building from the ground up and not starting from scratch. The PhilSA's succeeding programs shall grow, expand and nurture these resources so they can yield further socio-economic benefits and impact for Filipinos.

In Our Place in Space, we compile and select showcases from the prior initiatives in Space Science & Technology and Applications (SSTA) in the Philippines. These activities have been undertaken by different groups from the academe, research institutions and government agencies, which we acknowledge at the end of each of the three Volumes in the compilation. Each Volume highlights a different component of SSTA that contribute to the growth of the space ecosystem in the country. The simple and humble goal is to create better awareness of local SSTA capabilities and the benefits that they bring to Filipino society.

In coming up with the compilation, we considered the segmentation of the space economy and industry into two complementary sectors: the "Upstream" and the "Downstream". "Upstream space" activities consist of the design, assembly, integration and testing of satellites and other spacecraft and their payloads, systems, subsystems, and components. This also includes the infrastructure necessary to launch and operate them from Earth. In other words, the upstream segment is the sector of space that makes or manufactures, controls and launches objects such as satellites, rovers, space probes and other spacecraft into space orbit. "Downstream space" uses these spacecraft and systems to deliver products and services for scientific, experimental and commercial use on Earth, such as telecommunications, navigation, surveillance and Earth observation, among others.

Our country has been an active users in the downstream of satellites and space. That is, the utilization of and the applications arising from the data generated by satellites, such as images and other spaceborne data. That is valuable since the downstream is expected to largely account for the growth of the space sector and therefore its contributions to the economic growth of nations. Data and the resulting actionable information and intelligence is the currency of the knowledge economy. Current downstream activities in SSTA are discussed in Volume 1: Space Data Utilization.

A strong presence in the space upstream sector is important for our country as well. The upstream involves components of the space value chain that offer a strategic advantage to those who master and control such technologies. For example, the detailed knowledge and competence on the upstream engagement serves as the basis for the development of standards and operations that influence the downstream, such as end user applications and the needs of satellite operators. Building space satellite payloads and buses equip us with the wherewithal to adapt to and anticipate evolving downstream requirements, thus the ability to customize solutions for existing and new downstream verticals. Building satellites enables us to understand the source of the solutions – the source of the data. Current upstream activities in SSTA in the Philippines are addressed primarily in Volume 2: Space Technology.

By engaging in both the upstream and downstream of space, we can instantiate a "virtuous cycle" in this exponentially growing and exciting new area that our country should nurture and feed. The virtuous cycle will enable us to develop endogenous S&T capacity that will supplant the vicious cycle of technological dependence.

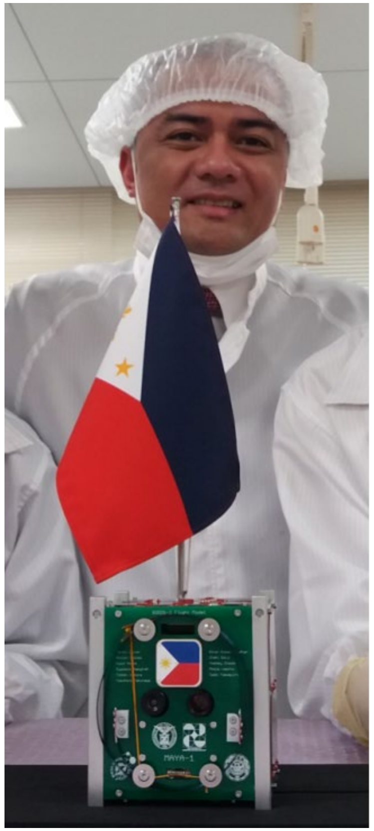
The downstream and upstream SSTA activities that have catapulted our country's capabilities in space need to be proliferated, disseminated and sustained. In Volume 3: Capacity-building, Outreach and Sustainability, we provide a window to the inward- and outward-facing initiatives aimed at developing people, institutions, linkages, partnerships and outreach activities. These activities are essential in cascading the gains and benefits obtained from our satellite development and space data mobilization efforts to society.

Finally, through this compilation, it is our aim to impart the PhilSA's vision – A Filipino nation bridged, uplifted and empowered through the peaceful uses of outer space; and our mission – To promote and sustain a robust Philippine space ecosystem that adds and creates value in space for and from Filipinos and for the world.

By capturing the best (so far) of our fledgling Philippine space ecosystem, we hope that you will find this compilation not only informative, but also inspiring. Through these pages, we find and truly affirm Our Place in Space.

Joel Joseph S. Marciano, Jr. PhD
Director General
Philippine Space Agency (PhilSA)

09 October 2020



Prologue

Volume 2: Space Technologies showcases the underlying technology components and infrastructure, i.e. the upstream space segment, that enable the generation, processing and utilization of space data. From satellites "buses", payloads, assembly/integration/test (AIT) to the calibration and validation of satellite instruments, these activities and capabilities facilitate the generation of data and the provision of services in the downstream. One of the cornerstones upon which the Philippine Space Agency (PhilSA) is built has been our prior work on building small satellites, Diwata-1, Diwata-2, Maya-1 and Maya-2. Since our engineers and scientists have been involved in the hands-on development of these space systems, we have gained access to underlying technologies and knowhow that we will use to our country's advantage in building many more useful and productive things.

If satellite imagery data is like water, then satellites are like the pipes and plumbing. Seldom do we care about the pipes and the plumbing, so long as we get the water flowing into our homes. However, one who knows the pipes and its intricacies can and does have the ability to determine the flow and the quality of the water. In that sense, obtaining knowhow in upstream space technologies and cascading them to local design and manufacturing services will help put us on a path of building stronger industries in aerospace, semiconductor, electronics, mechanical and materials, among others, that enhance our country's global market position and competitiveness. Investing in space science, technology and applications can help create more high value jobs.

In this volume, we also show the ground-based systems that enable us to communicate with and process the data from satellites. This infrastructure is part of the "plumbing" that works in the background and is largely invisible from an end user perspective, which we now shine a spotlight on and bring to the forefront.

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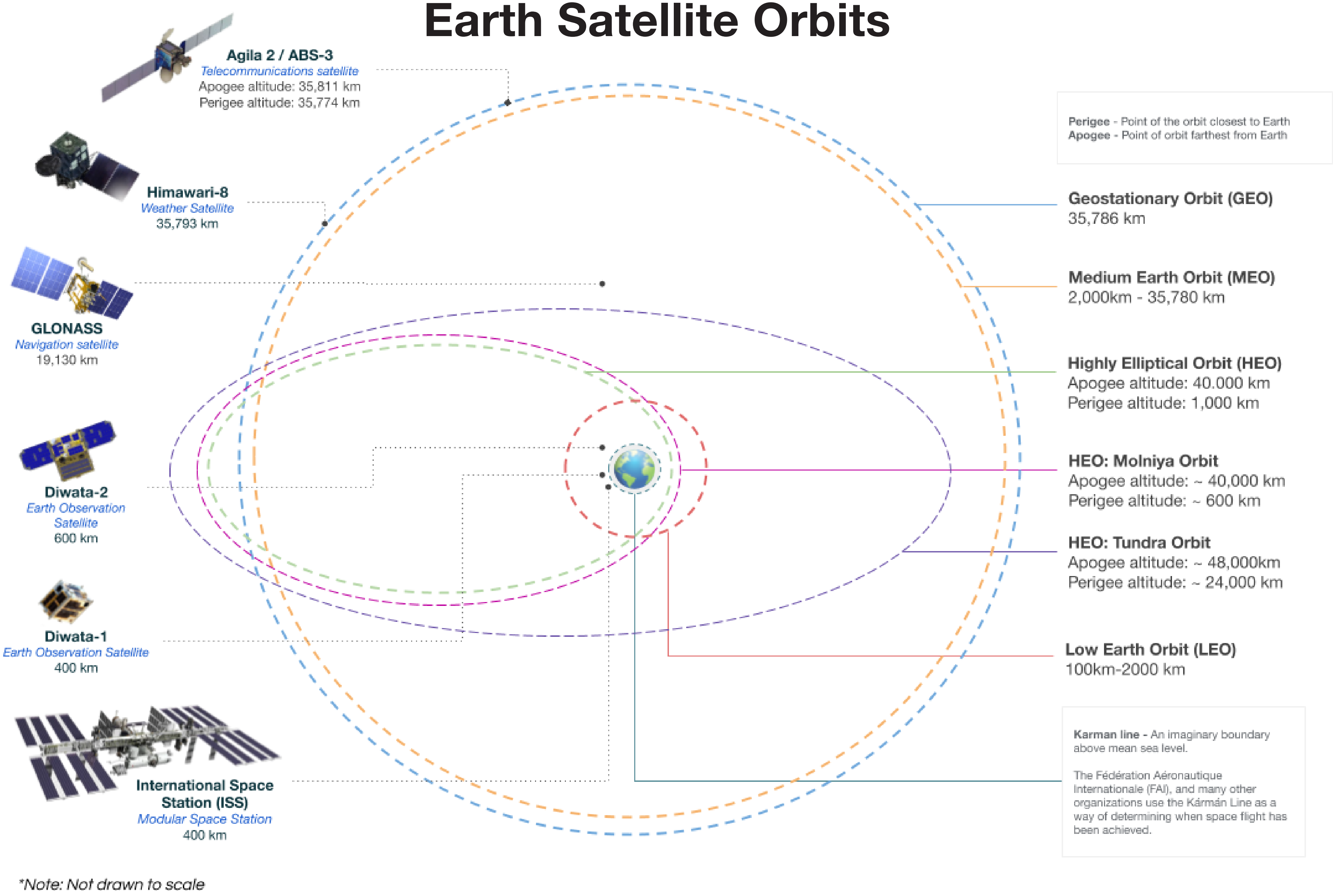
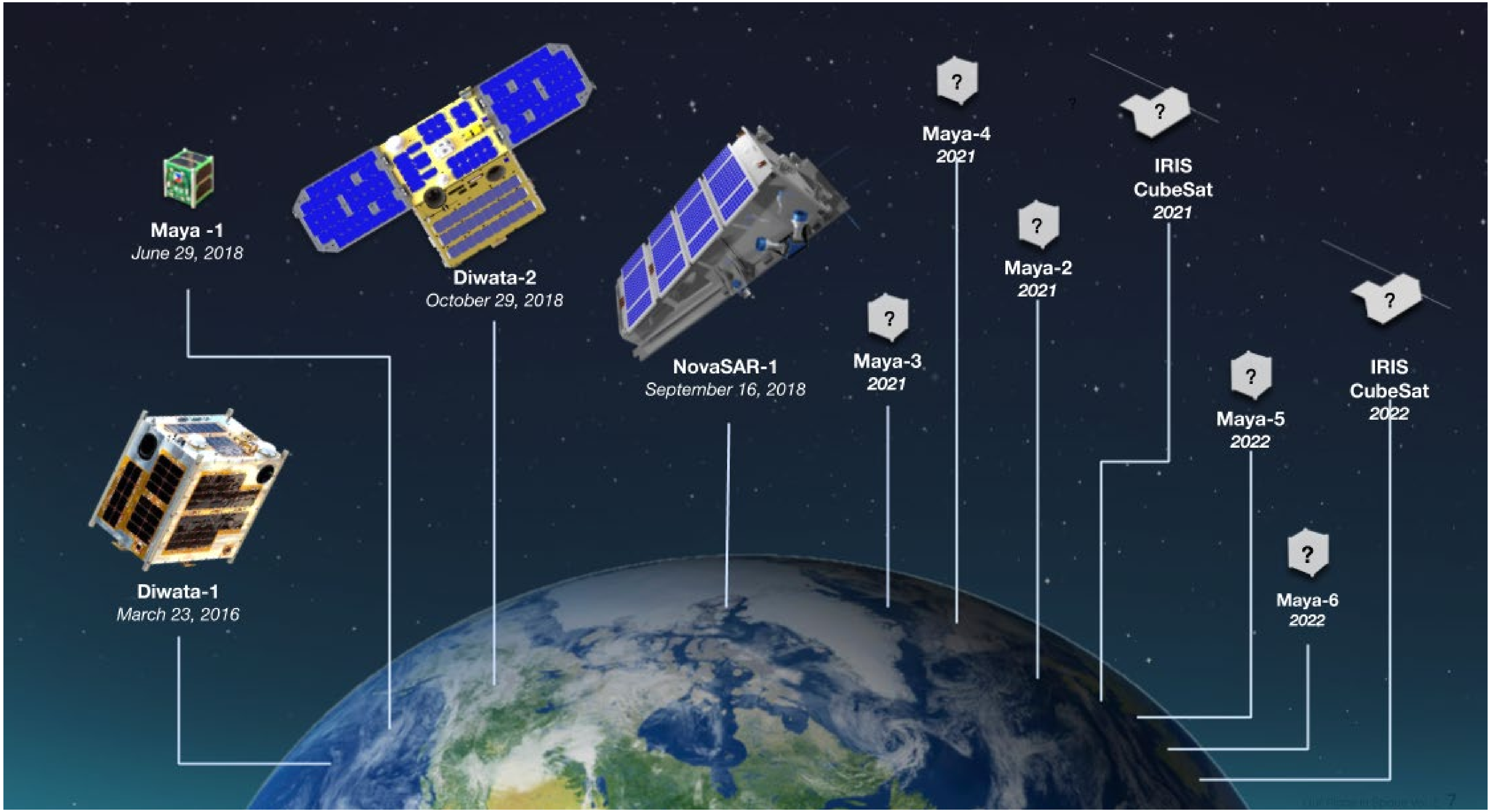
Earth Satellite Orbits



Philippine Satellite Development

Development of small satellites in collaboration with partners

NovASAR-1 is a mission partner of the PEDRO Center while the IRIS series is an initiative of the National Cheng Kung University of Taiwan involving 2 Filipino engineers .



Satellite Bus Technologies

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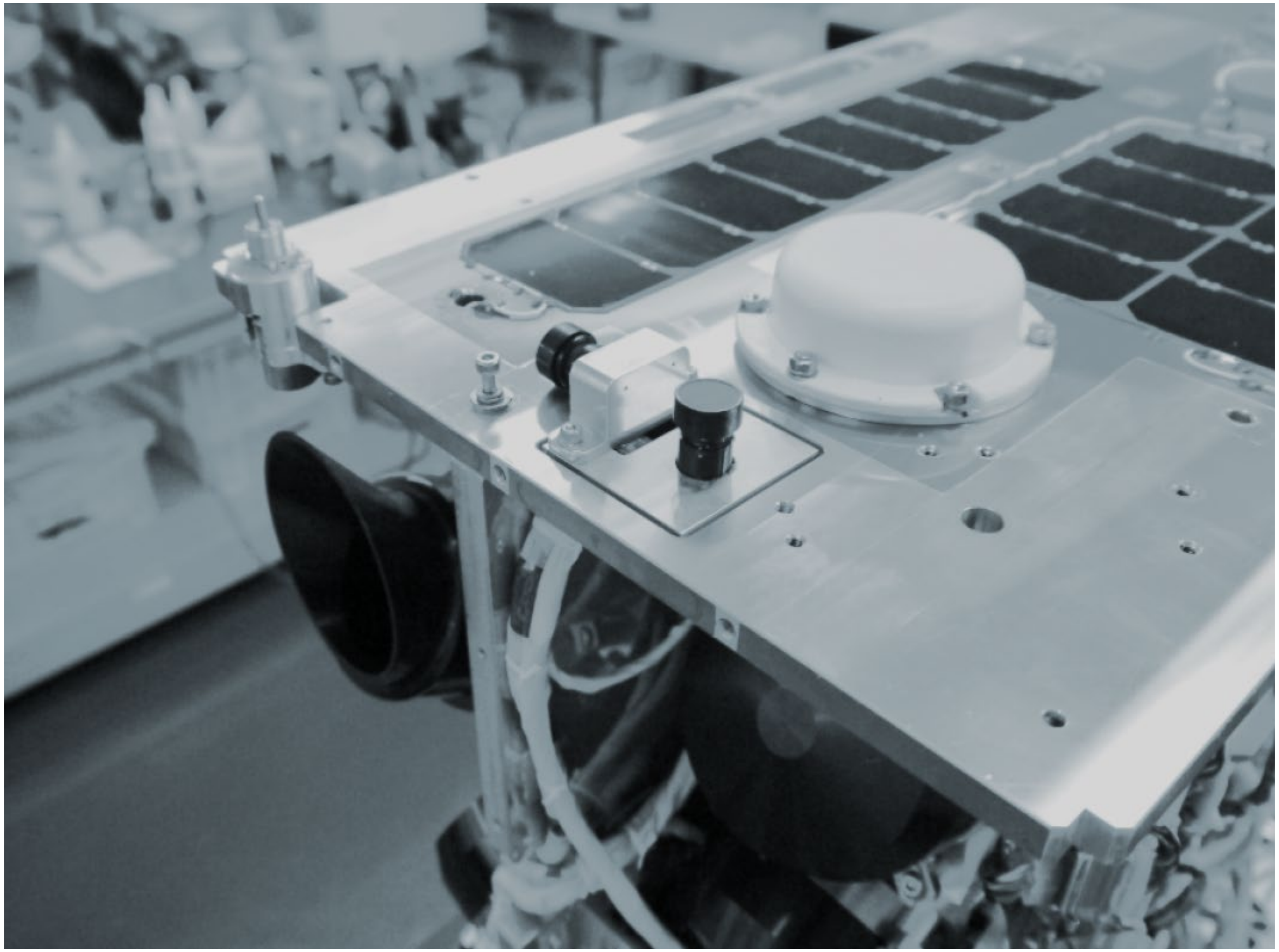


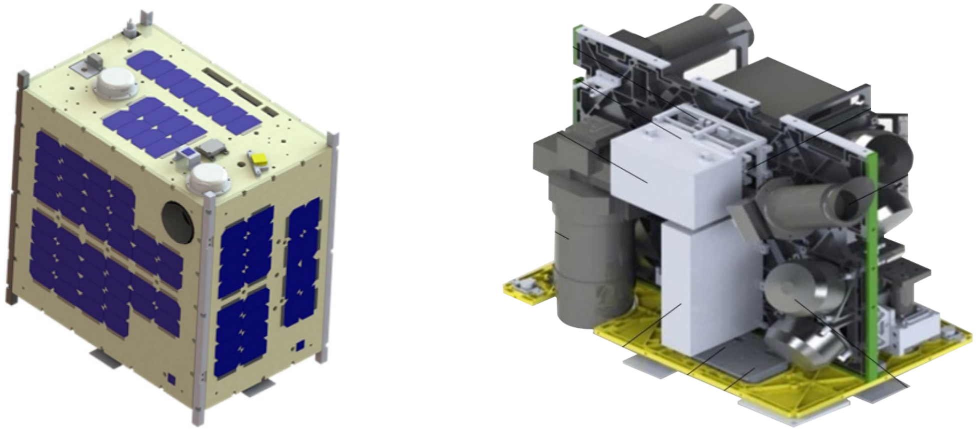
The Satellite Bus

Overview

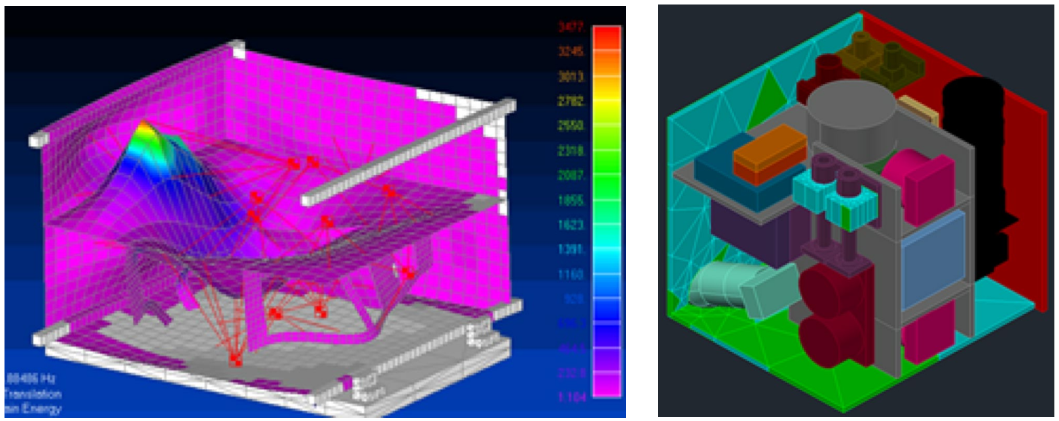
One of the most immediately visible parts of a satellite is the bus, which is the infrastructure that holds all the on-board instruments together. It is made up of space-grade structural, electrical and mechanical subsystems that comprise a large percentage of satellite development.

In this chapter, we focus on the 1kg (Maya-1) and 50kg bus platforms (Diwata-1 and Diwata-2) and dissect their various subsystems, namely: structure, power supply, onboard computing, and navigation and control systems.

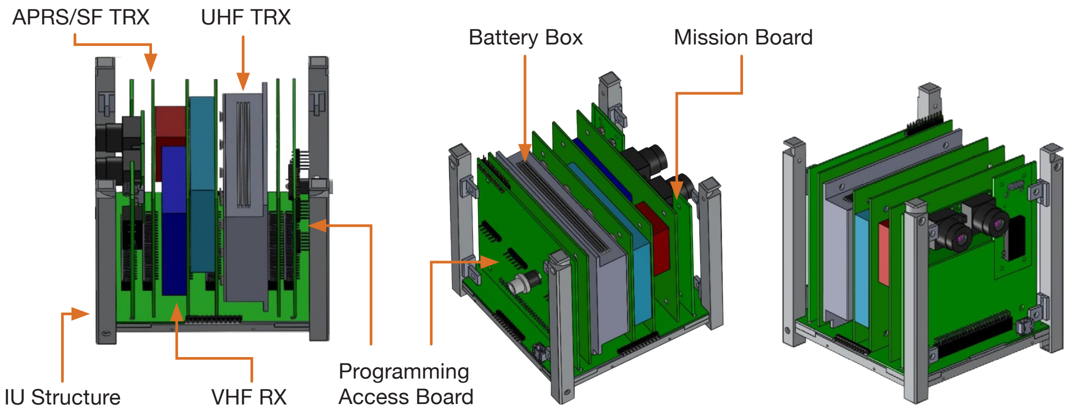
The initial 1kg and 50kg bus designs were built by Filipino engineers under the guidance of their respective Japanese partner universities, Kyushu Institute of Technology and Tohoku University. Through continuous research and development done by the local teams based in the University of the Philippines Diliman, they will serve as platforms that will power the future generations of Philippine satellites.



Actual view (left) and internal view (right) models of Diwata-1



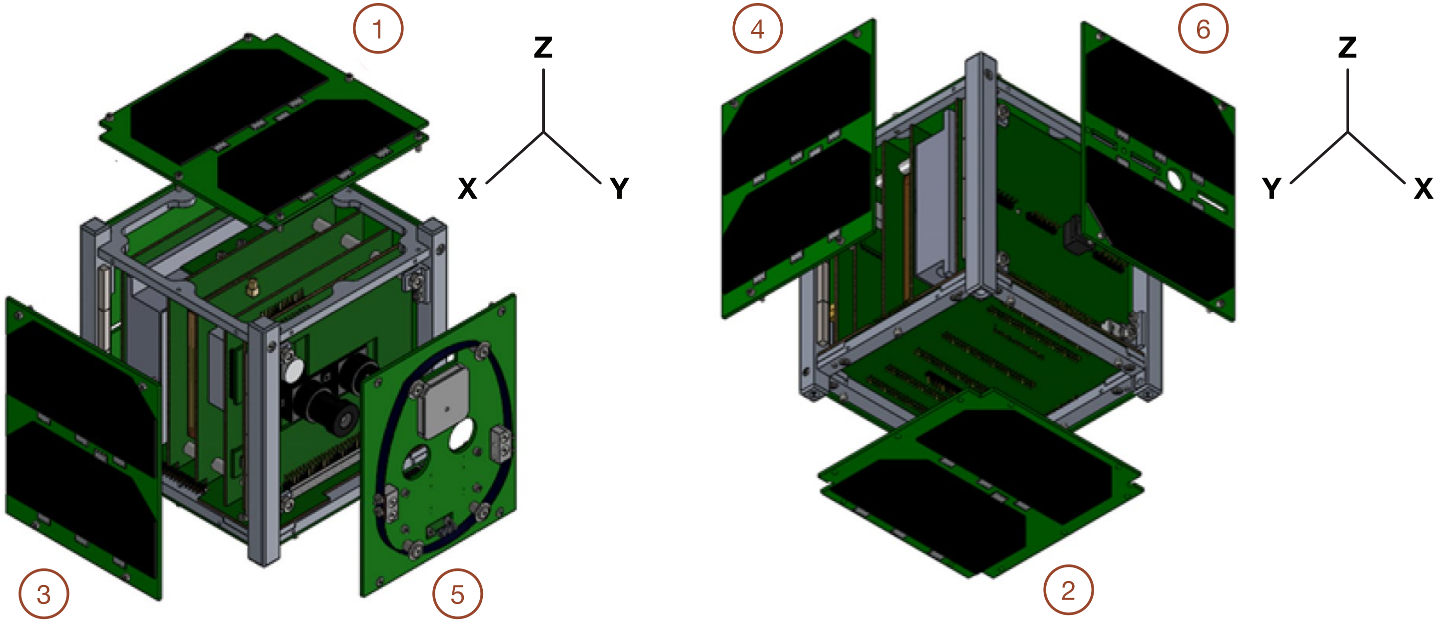
Diwata-1 Vibration simulation (left) and thermal view (right) models of Diwata-2



Maya-1 internal view model

The Maya-1 Bus

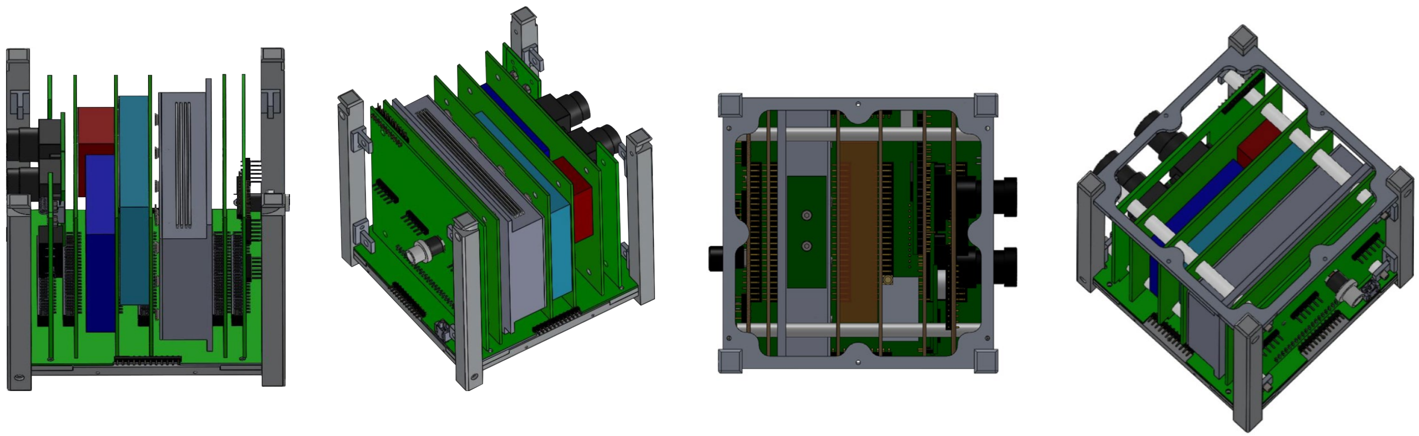
1kg Cube Satellite (CubeSat) Platform



The Maya series are 1kg nanosatellites that belong to the 1U CubeSat category platform. They are primarily developed to provide hands-on training on satellite development and operations, and to serve as platform fo scientific experiments and technology demonstration.

Like the 50kg platforms discussed in the succeeding pages, the Maya series also has structure, power, communications, and onboard computing subsystems packed within a 10 cubic cm frame. The smaller size is achieved by using smaller, cheaper commercial off-the-shelf parts and by reducing redundancies, at the expense of processing power, performance, and reliability.

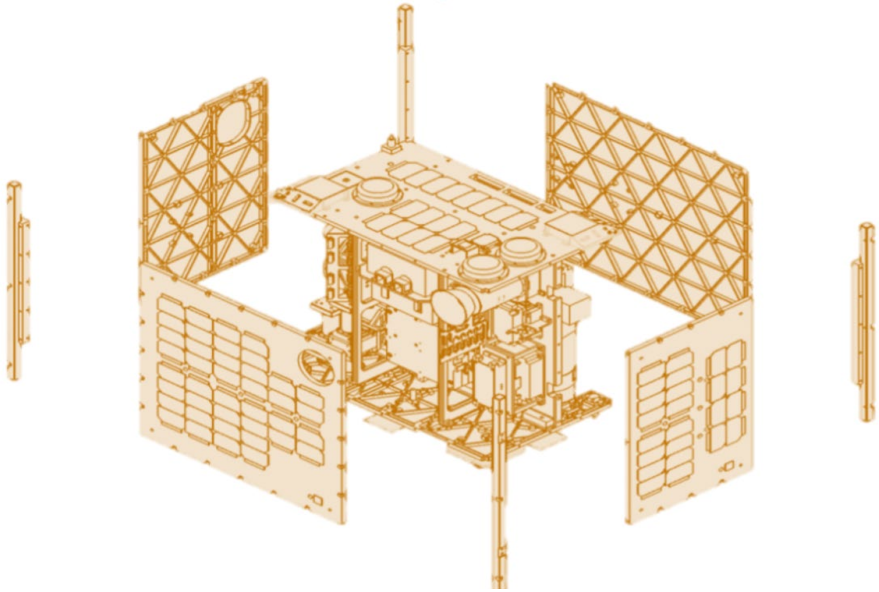
The bus design for each generation of Maya satellites incorporates enhancements to accommodate more advanced missions.



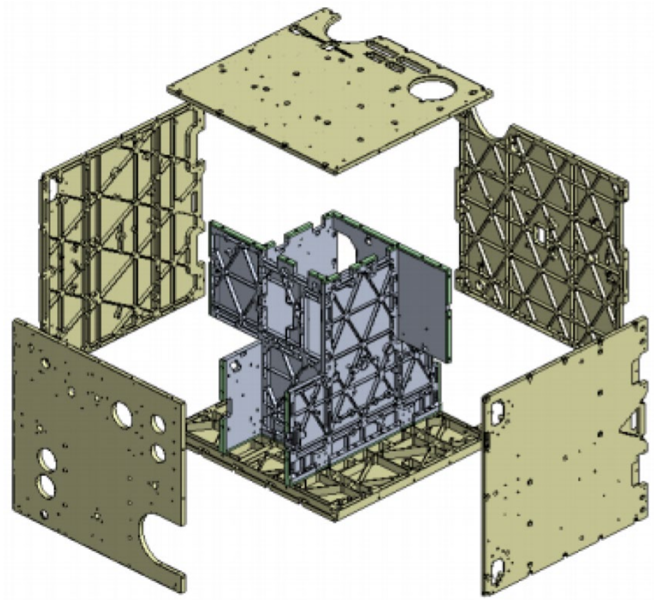
The Diwata-1 and Diwata-2 Bus

50-kg Microsatellite (Microsat) Platforms

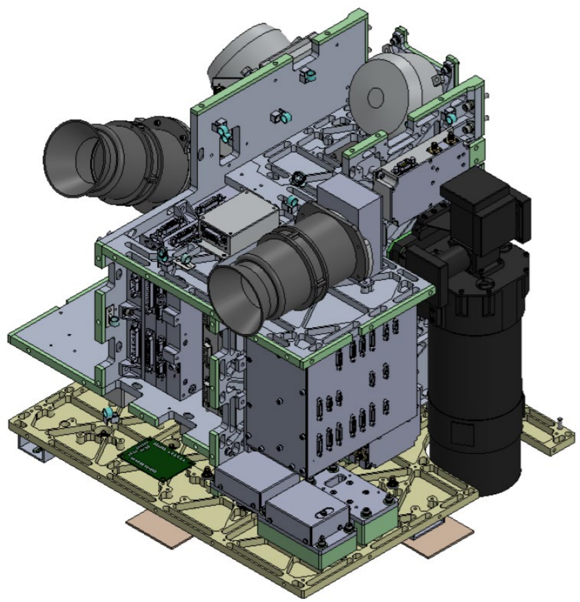
These Philippine Scientific Earth Observation microsatelites both belong to the 50kg category platform. They were meticulously designed to house the scientific and optical payloads designed according to the mission determined by the mission planning team at the onset of the program. Both Diwata-1 and Diwata-2 buses contain structural, power supply, onboard computing and navigation control systems, but significant enhancements were made to Diwata-2. This includes the improvement of its power supply and navigation and control systems, as well as accommodations made for an additional camera and an Amateur Radio Unit (ARU). Under STAMINA4Space, a team is dedicated to build on the gains made under PHL-Microsat by constructing a localized version of a 50-kg microsatellite bus platform that is capable of accommodating future science mission payloads.



Diwata-1 Bus System Diagram



Diwata-2 Bus Structure Diagram



Diwata-2 Bus Electronics Diagram

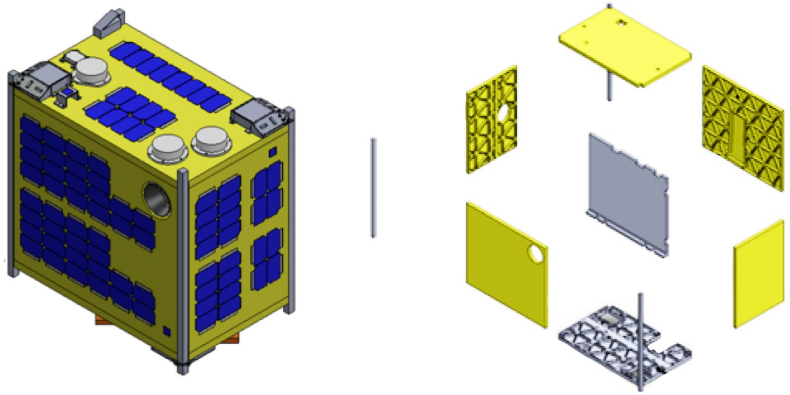
Structure

The satellite's architecture

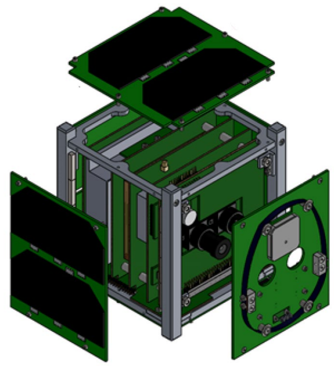
The structural design of both Diwata-1, Diwata-2 and Maya-1 is made of space-grade materials. They were started with general physical sketches, which were was digitally drafted in the computer-aided design (CAD) software SolidWorks by Dassault Systems.

The Diwata-1 structural and component layout was designed from the ground up in conformance to the Japanese Small Satellite Orbital Deployer (J-SSOD-50) specifications. The design process took several iterations from start until fabrication, with changes based on the simulation performance and the needs that arose relevant to the bus architecture. The general structure contained six exterior panels, four exterior guide rails, one major central panel, and two internal supporting pillars.

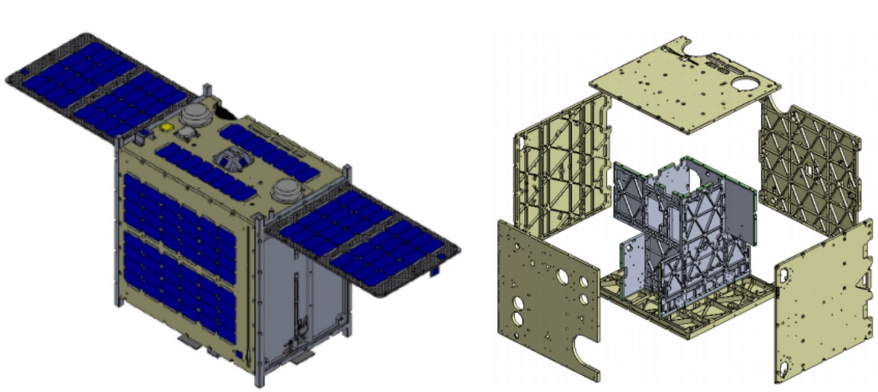
In Diwata-2, several additions and enhancements were made to the structure such as the design of the locks, panels and hinges, the addition of deployable solar panels, a deployable antenna, the development of a power distribution board, the relocation of different Diwata-2 modules, and the optimization in the structure. Each item is discussed in the following subsections.



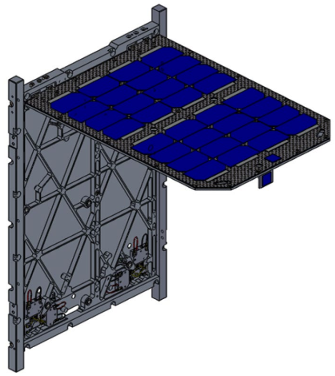
Diwata-1 isometric view (left) and exploded view (right)



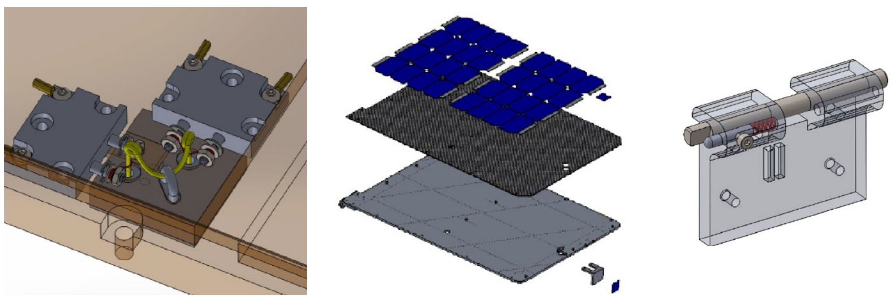
Maya-1 exploded view



Diwata-2 rendered structural design (left) and exploded view (right)



Diwata-2 Deployable Solar Panels



Diwata-2 locks, panels and hinges

Diwata-2 Deployable Antenna

Power Supply

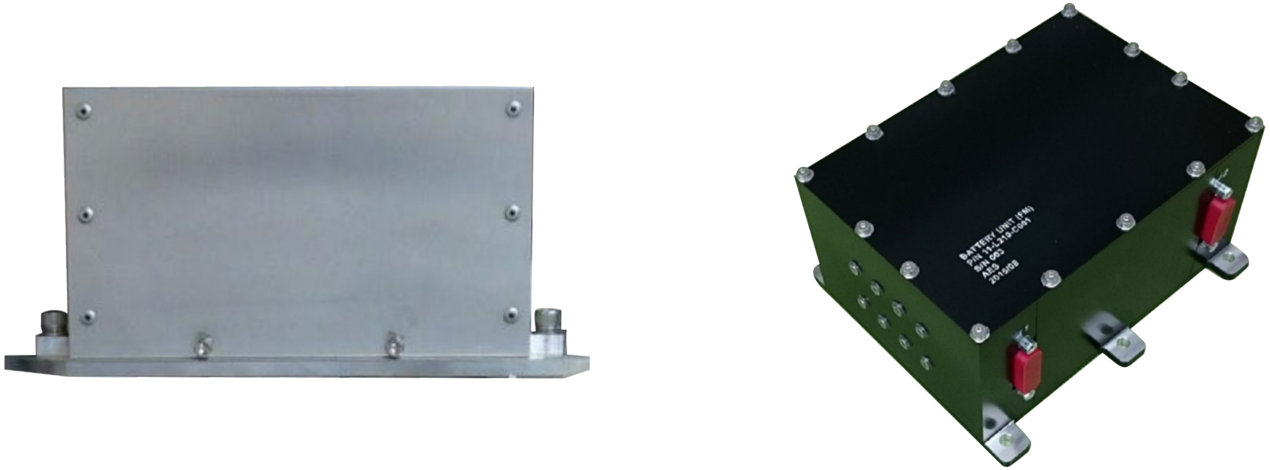
Bringing the satellite to life

The power supply is a subsystem that provides the satellite with the necessary power generation, power storage, power management, and power distribution system.

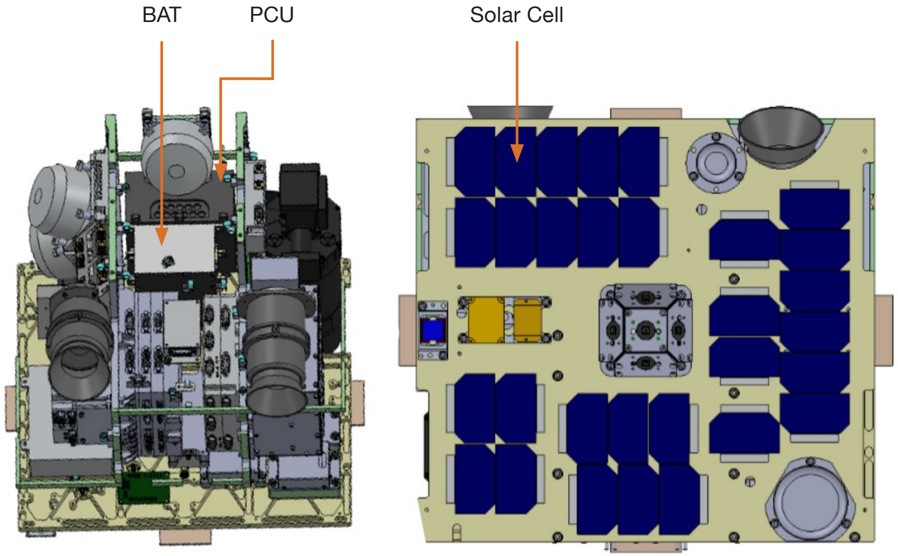
Both Diwata and Maya satellites are powered by a rechargeable battery, Power Control Unit (PCU) and Solar Cells.

In Diwata-2, several enhancements were made such as a power distribution board and additional solar cells on the solar panels added to the structure, as well as additional cells that can be inserted—making that a total of 168 solar cells (21 parallel strings composed of 8-solar cells). These can generate a total power of approximately 44.22W at 28 degrees Celsius.

Aside from the additional solar cells, having an active attitude control allows the team on the ground to make the deployable panels and the top of the satellite face the sun regularly so it can optimize its solar cells and gain added power.



Diwata-1 and Diwata-2 Battery Modules



Diwata-2 Power Supply system location diagram

Diwata-2 Power Supply System

Battery (BAT)

- Provides power to the satellite
- Rechargeable

Power Control Unit (PCU)

- Main power controller module
- Primary functions: Power management of solar cells, power distribution, and battery charge/ discharge

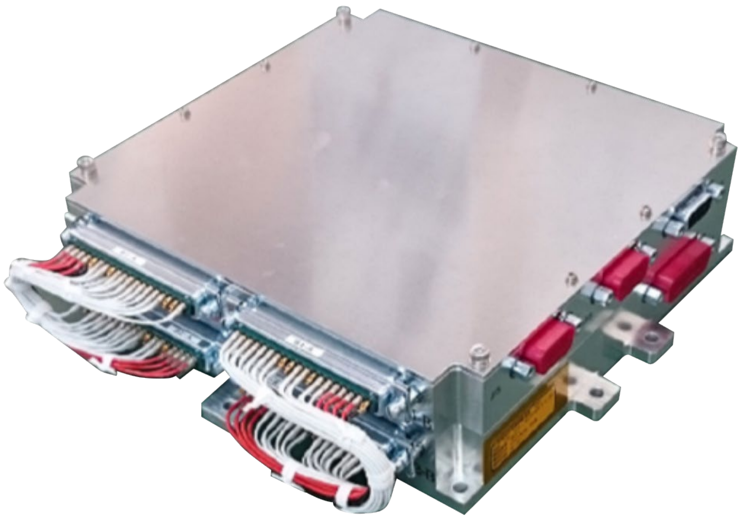
Solar Cell

- Power generation
- Absorbs sunlight and converts it directly into electricity via photovoltaic effect

Onboard Computing

The satellite's "thinking" units

Satellites are basically computers in space. The Diwata satellites have the following major on-board computers:



Attitude Computing Unit (ACU)

Mass measurement of Diwata-2 Satellite Central Unit (SCU)

Satellite Central Unit (SCU)

- Main interface to satellite communications modules
- Handles ground station command parsing and distribution to satellite subsystems
- Manages satellite housekeeping data and local telemetry information from subsystems for downlink broadcast
- Handles satellite command and routine scheduling
- Provides analog to digital conversion of sensors
- Synchronizes timing within subsystems via GPS information

Attitude Computing Unit (ACU)

- Conducts satellite attitude (orientation) determination and provides control directions to attitude actuators
- Manages the satellite's rotation stability
- Manages the measurements of the various attitude and navigation sensors of the satellite
- Conducts the calculation required for specific attitude maneuvers: Target pointing, Nadir (towards center of Earth) pointing, and Offset-from-Nadir pointing

Science Handling Unit

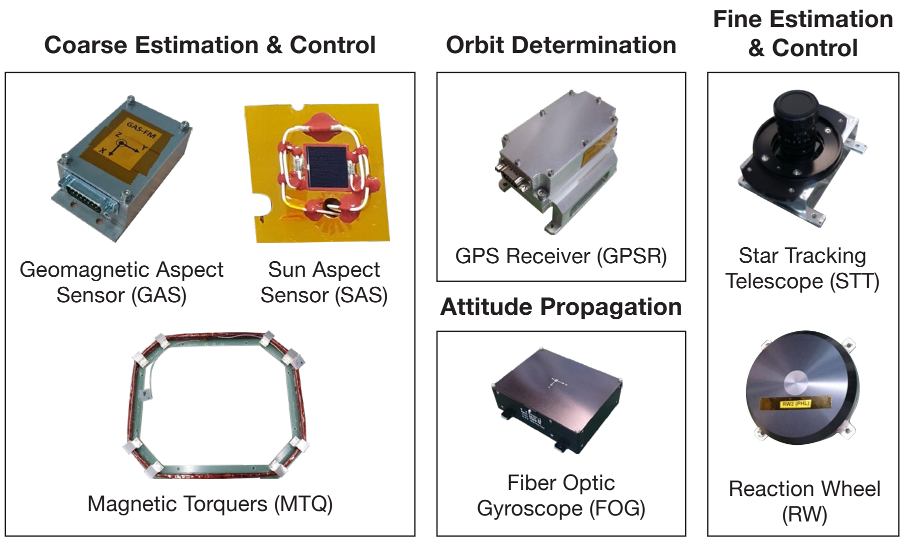
- Manages the control and parameter settings of the satellite's scientific payloads
- Handles the mission data and instrument housekeeping information produced by the various payload
- Manages the on-board storage/ retrieval of mission data via mass memory units

Navigation and Control

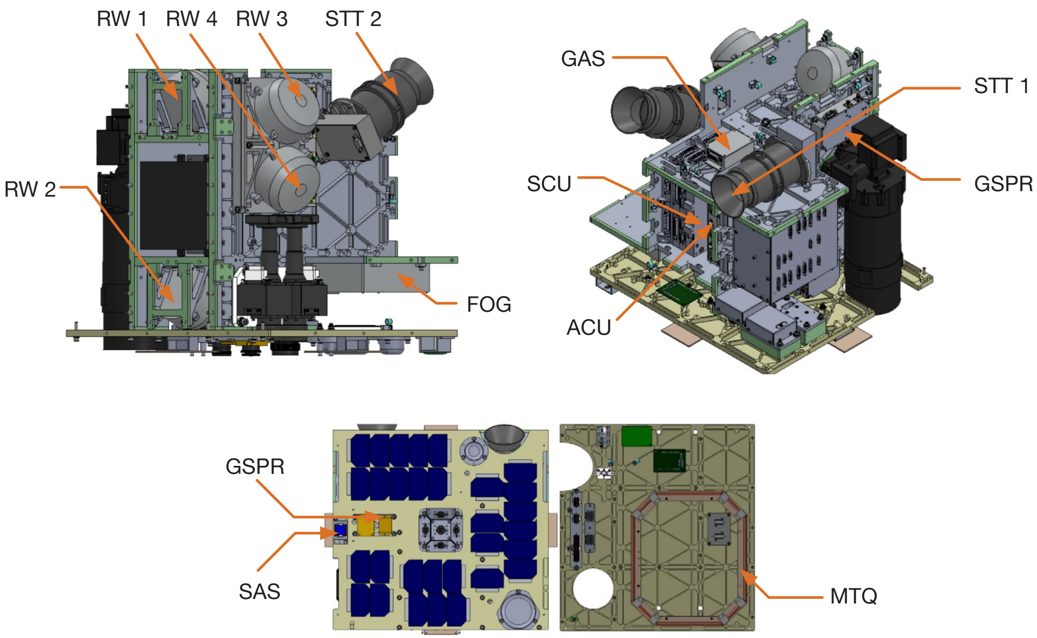
Guiding and maneuvering the satellite

Knowing the satellite's orientation and location is crucial for its remote sensing missions, where high accuracy is needed in capturing images of identified areas. When the satellites are tasked to capture an image, the Attitude Determination and Control System (ADCS) points it to the targeted location.

The ACDS consists of a Magnetic Torquer (MTQ) for coarse attitude control and and Reaction Wheel (RW) for fine attitude control. These controllers are used together with attitude sensors, which include sun aspect sensors (SAS), geomagnetic aspect sensor (GAS), and In Diwata-2, Star Tracker Telescopes (STTs).



A diagram of Diwata-1's ADCS modules



Geomagnetic Aspect Sensor (GAS)
Measures the magnetic field information of the Earth based on the satellite's orbital position

GPS Receiver Module (GPSR)
Processes the signals received by the GPS antenna; outputs the longitude, latitude, satellite velocity, and altitude position

Satellite Central Unit (SCU)
Main central computer that handles telemetry signals and various satellite module operations

Attitude Control Unit (ACU)
Main computer for attitude estimation, determination, and control; with a minimum of two position vectors, it can calculate an estimate for the satellite attitude

Magnetorquer (MTQ)
Used for coarse attitude control; utilizes the magnetic field of surroundings for satellite re-orientation

Star Tracker Telescope (STT)
Captures a CCD-based image of stars; Calculates satellite attitude using an onboard computer

Reaction Wheel (RW)
Uses momentum produced by rotating wheels to finely control the orientation of the satellite in space

Fiber Optic Gyroscope (FOG)
Senses the angular velocity of the satellite

Sun Aspect Sensor (SAS)
Sensor used to detect sunlight; measured data determines the solar vector

Navigation and Control

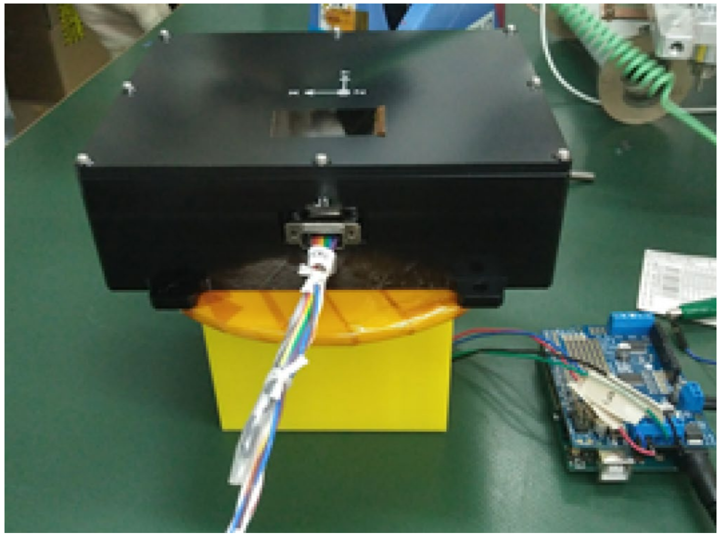
Diwata-2 modules being developed

Other enhancements made to Diwata-2 include a fiber-optic gyroscope (FOG) to track the movement of the satellite and serve as a secondary source of attitude, additional high-accuracy, locally developed sun aspect sensors (SAS-Z) which provide accurate solar direction for satellite attitude determination during mission operations, and an ACU-Ex which aims to improve the accuracy of attitude control maneuvers to error angle of below 1 degree. The error angle minimization aims to go less than 1-degree error from the satellite's rotational perspective, this translates to different actual ground error depending on the satellite altitude.

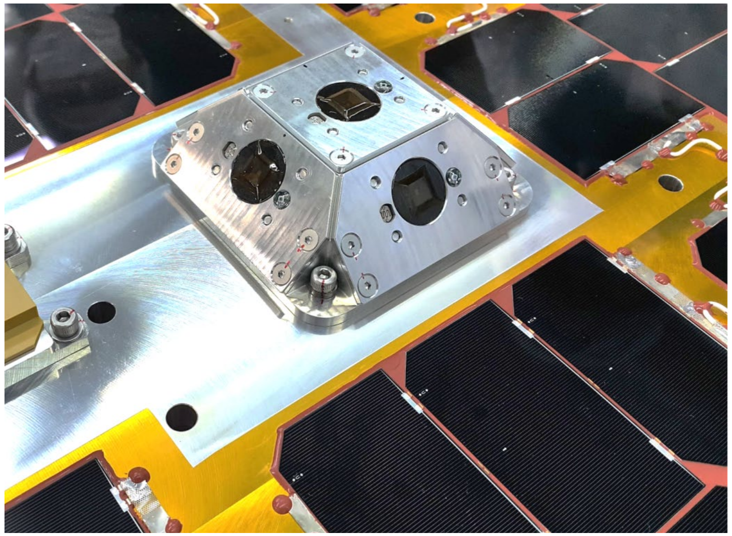
Trivia

Other enhancements made to Diwata-2 include modules containing off-the-shelf inertial measurement units and computing board for conducting satellite attitude estimation, as well locally designed architecture, PCBs, and software.

Diwata-2's Experimental Attitude Computing Unit (ACU-Ex)



Fiber Optic Gyroscope (FOG) subjected to a quick rotation check using a custom rotation table by bus development team

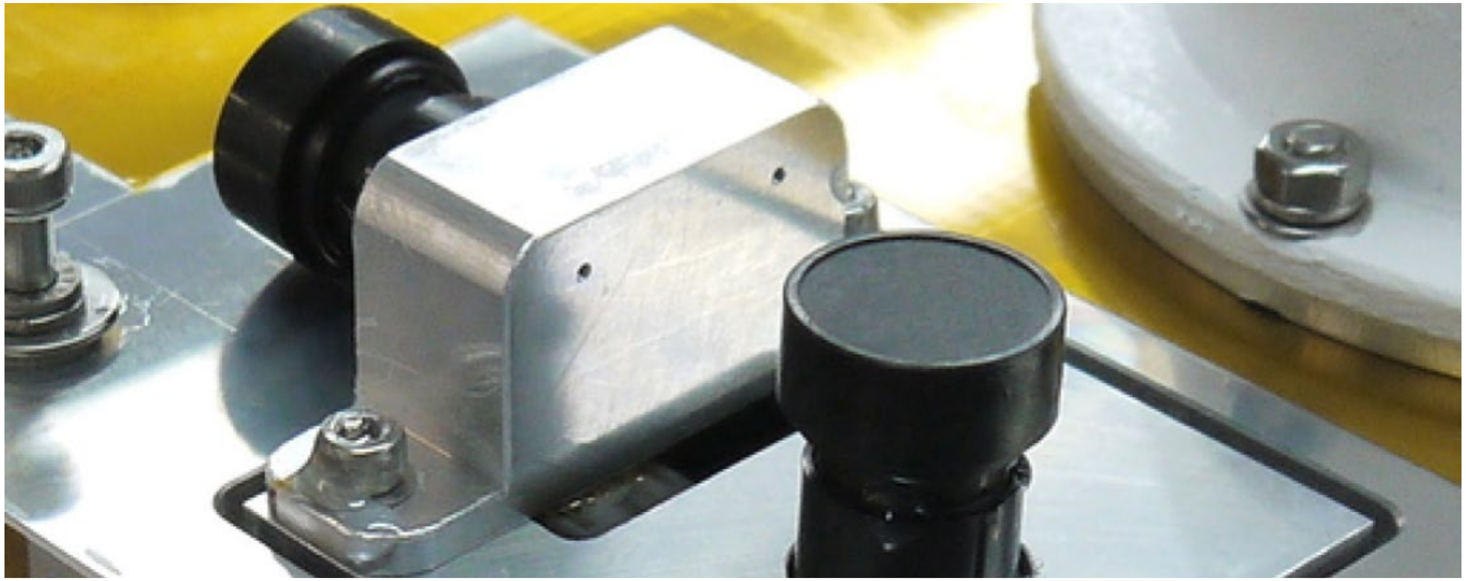


Diwata-2's Sun Aspect Sensor in Zenith Direction (SAS-Z)

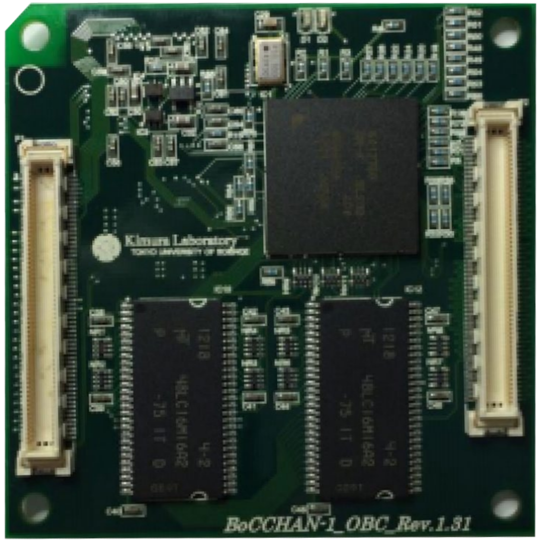
Localization of Bus Modules

Innovating bus components

In addition to optical and communication payloads, there are also other modules currently being developed by the local teams. This includes an engineering payload named PHL-Mini or TAMU System, which was developed as a secondary attitude determination system for Diwata-1. This mini system consists of an on-board computer, a CMOS camera, and attitude sensors. Aside from being used as a platform for data gathering and testing of algorithm, it also provided an opportunity for attitude algorithm experimentation.



Philippine mini attitude determination and computing subsystem (PHL-Mini) protruding from Diwata-1.



Onboard computer (left photo from UNISEC Japan) and imager (right) used for the PHL-Mini component.

Satellite Payload Technologies

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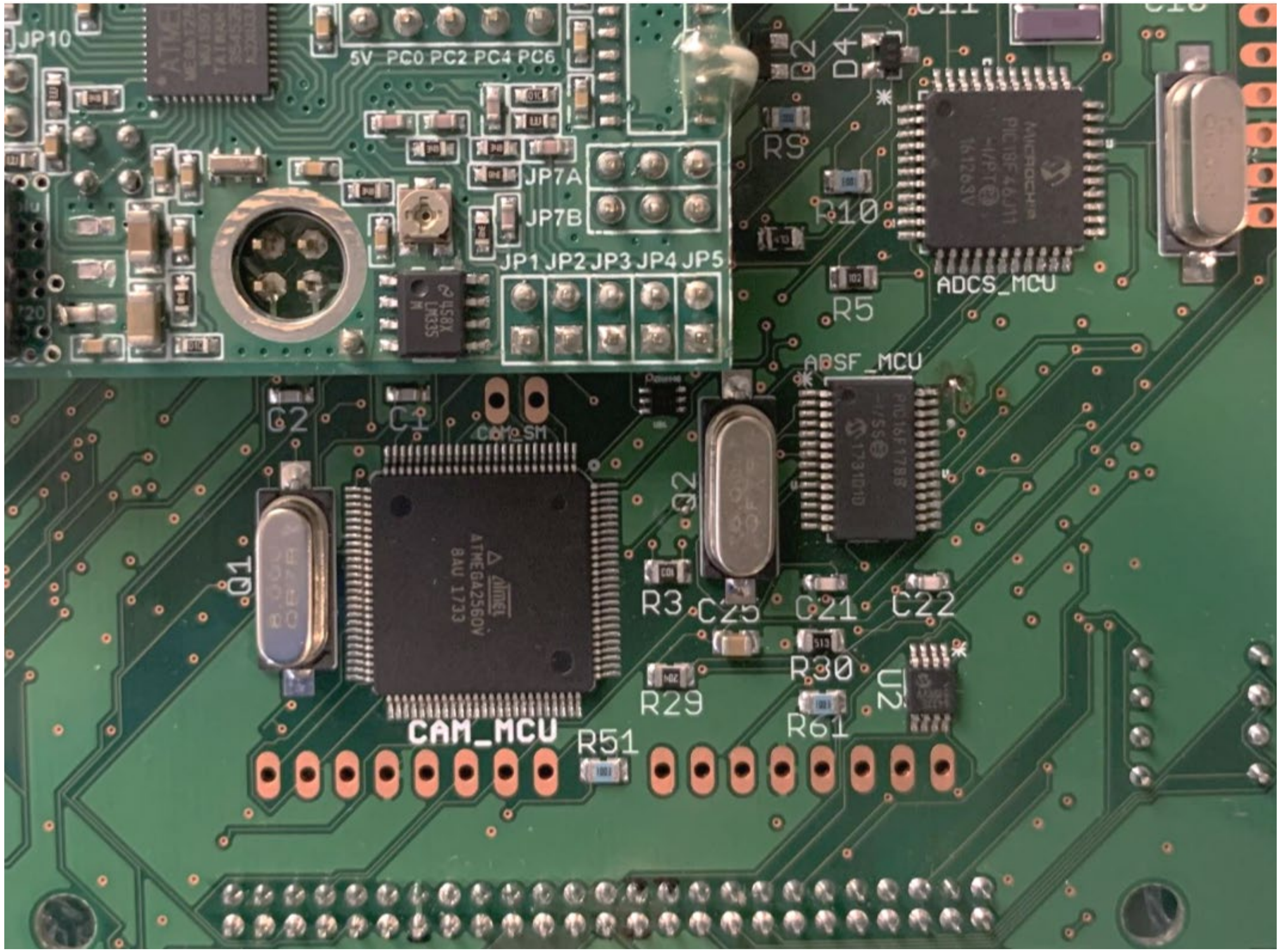
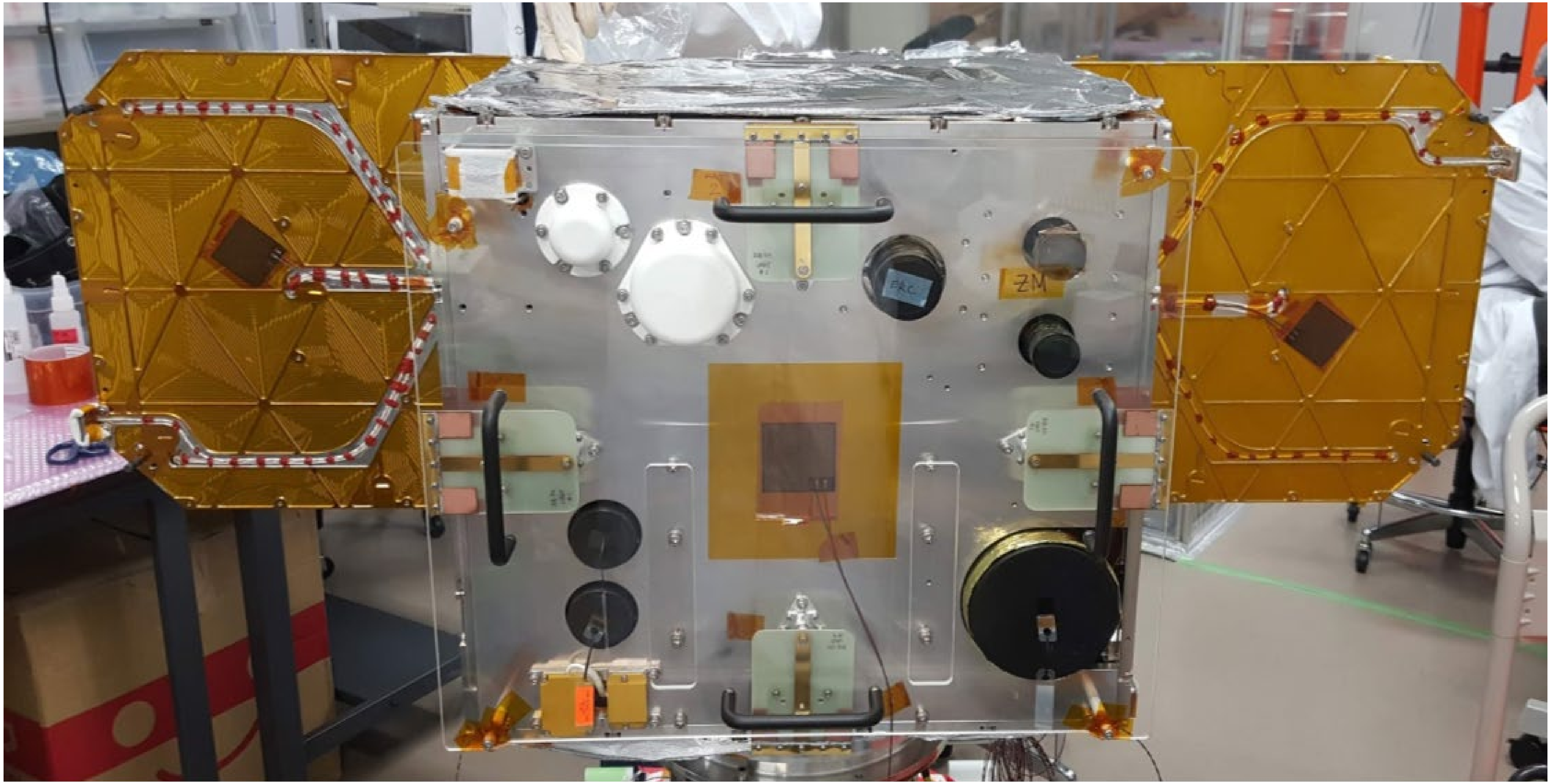


Satellite Payloads

Overview

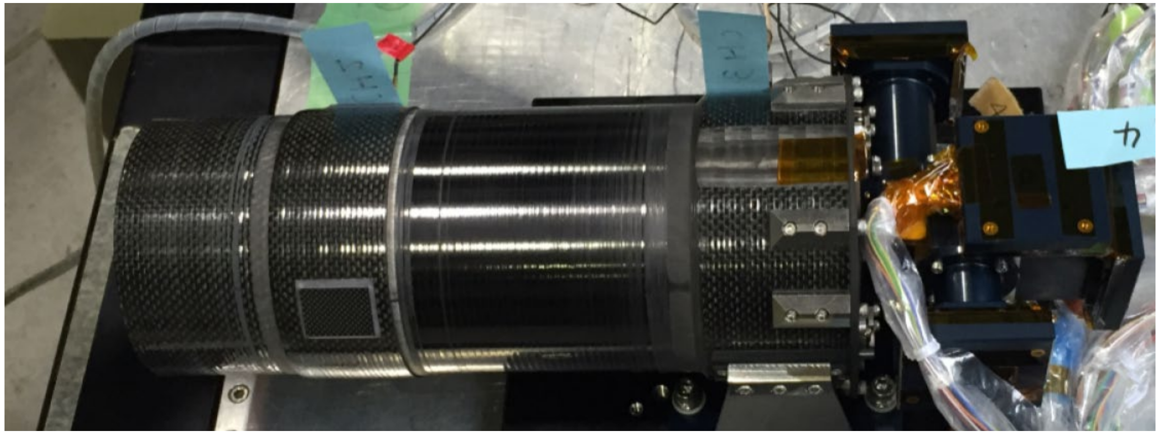
Payloads are the instruments on board the satellite, which are designed to perform the missions determined. In this chapter, we take a closer look at the different payloads onboard the Diwata and Maya satellites, as well as in NovaSAR.



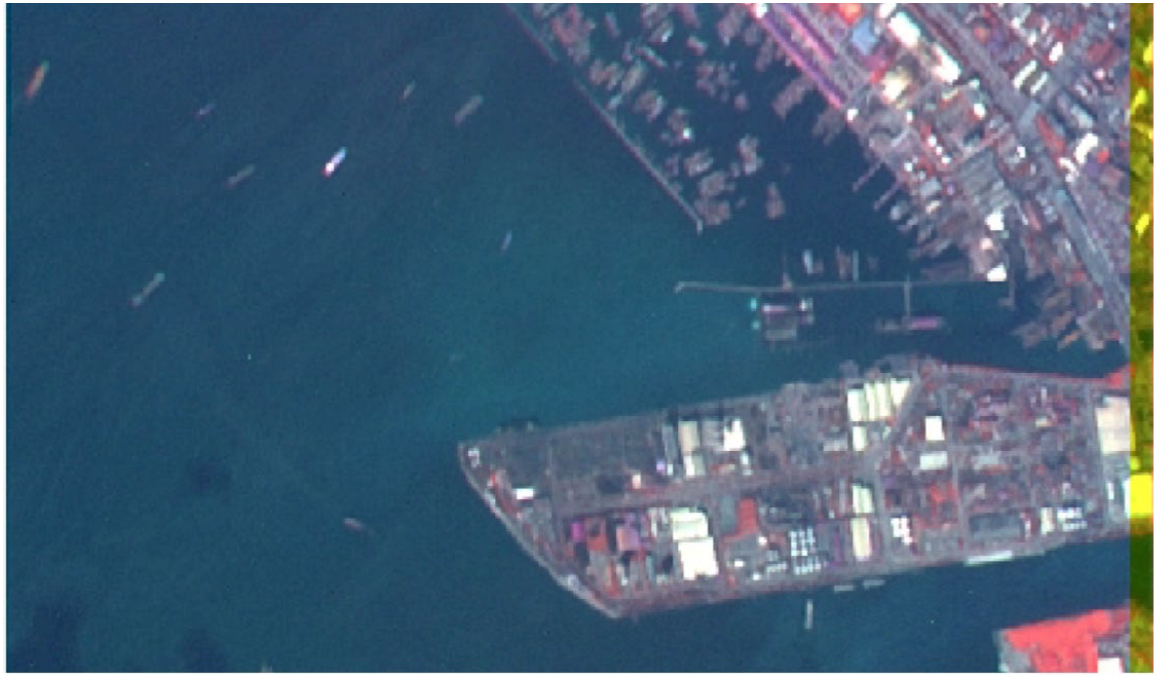
High Precision Telescope (HPT)

Imaging at very high resolution allows us to see many features of a particular object. Higher resolution means being able to see smaller and smaller details, making objects more identifiable with very good precision. Diwata-1 and 2's High Precision Telescope (HPT) provide such high resolution images. These images are used to capture images for determining the extent of damages from disasters, providing critical information for fast disaster response and right resource allocation, provide support in rehabilitation plans and recovery, and profiling and archiving of cultural and natural heritage sites.

	Diwata-1	Diwata-2
Field of View	1.9 x 1.4 km	2.9 x 2.2 km
Spatial Resolution	3 m	4.45 m



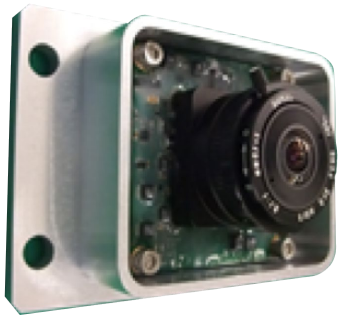
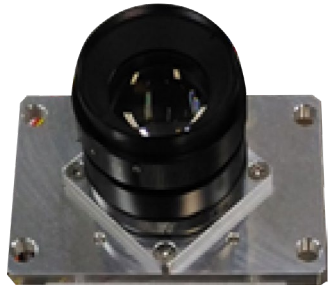
Actual HPT



The image above shows a false color image of Manila Harbor taken by the Diwata HPT. Image of parked cargos and ship can be seen. Such image may be used to monitor port activities and traffic flow.

Simple Cameras

Diwata-1 and Diwata-2

Actual Image					
Payload	Wide Field Camera (WFC)		Middle Field Camera (MFC)		Enhanced Resolution Camera (ERC)
Use	Primarily used for the observation of cloud patterns and weather disturbances		Assists in determining the locations of images captured by HPT and SMI		New addition to Diwata-2 used to sharpen the images captured by the SMI to reveal more details in the image
Satellite	Diwata-1	Diwata-2	Diwata-1	Diwata-2	Diwata-2
Field of View	180 ° x 134 °	180° x 139 °	121.9 x 91.4 km	287 m	87 x 65.3 km
Spatial Resolution	80 m	7 km	185 m	189 x 142 km	52.9 m

Simple Cameras' Sample Images

1

Wide Field Camera (WFC)

Image of Typhoon Tisoy (Kammuri) captured by Diwata-2's WFC on 09 December 2019.

2

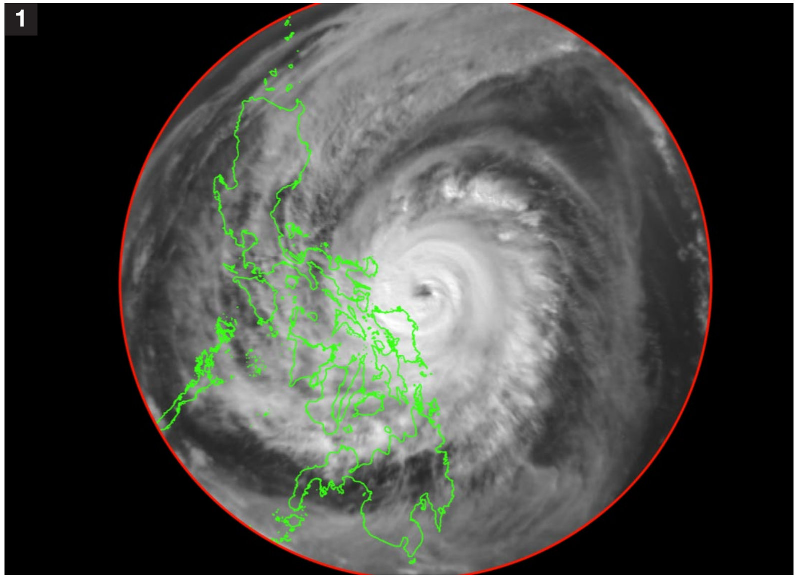
Middle Field Camera (MFC)

A portion of the Earth captured by Diwata-1's MFC on 27 October 2016.

3

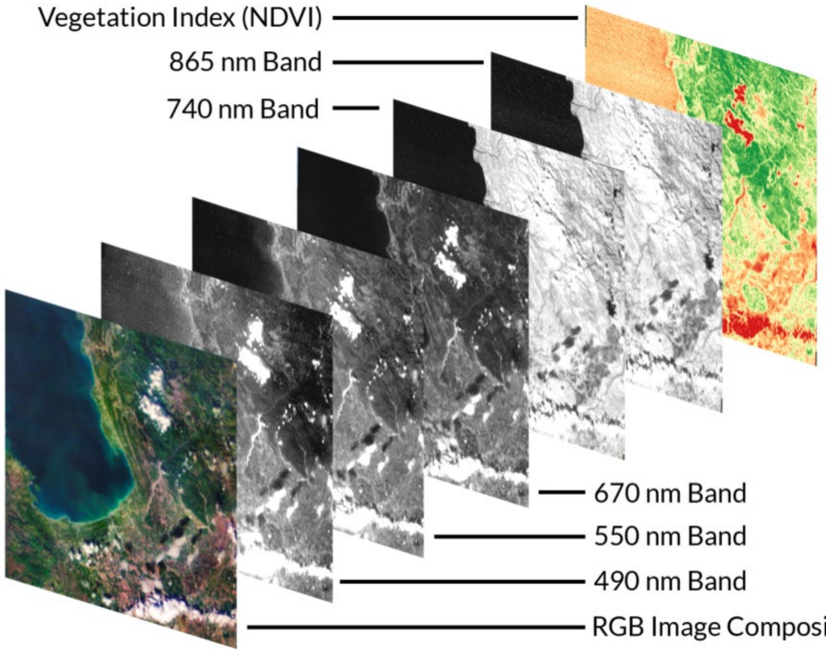
Enhanced Resolution Camera (ERC)

An image of Cebu City captured by Diwata-2's SMI on14 December 2018 with ERC pansharpening.



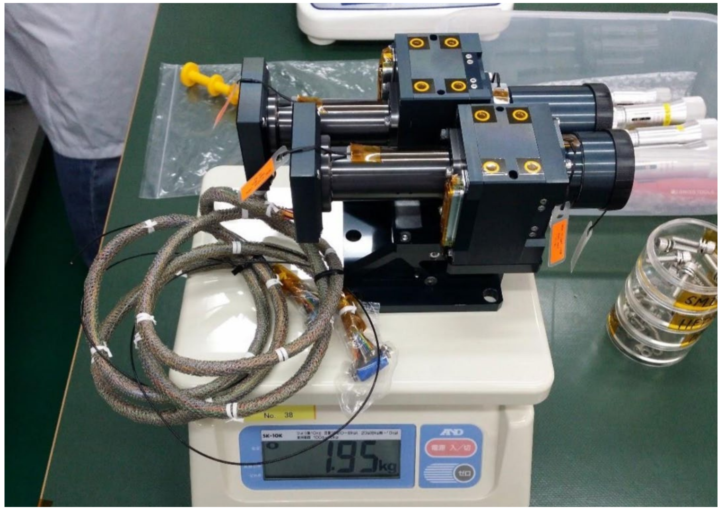
Space-borne Multi Spectral Imager (SMI) with Liquid Crystal Tunable Filter (LCTF)

Identifying an object uses not only shape and texture, but also the color. Color is physically described in terms of wavelengths of light, either absorbed, transmitted, or reflected. The amount of light reflected at a particular wavelength depends on the object's structure, composition, orientation, and other features normally hidden when looking at the brightness of the object. Wavelength therefore becomes a signature of the object. The SMI can select the wavelength using the LCTF. This ability allows us to identify objects in an image which results to information useful for assessment of changes in vegetation, ocean productivity. This information is particularly useful to researchers in the agriculture, fisheries, forestry, and other relevant sectors.



Trivia

The image on the left shows a multispectral image of Pangasinan and some areas of Central Luzon captured using the SMI of Diwata-2. Using different band combinations, different product and information may be derived such as the natural color image, vegetation indices, and spectral signatures. The natural color or RGB image can be derived using the 670, 550 , and 490 nm bands. On the other hand, the Normalized Difference Vegetation Index (NDVI), which is used to assess vegetation health and productivity may be computed using the red (670 nm) and NIR (865 nm) band.



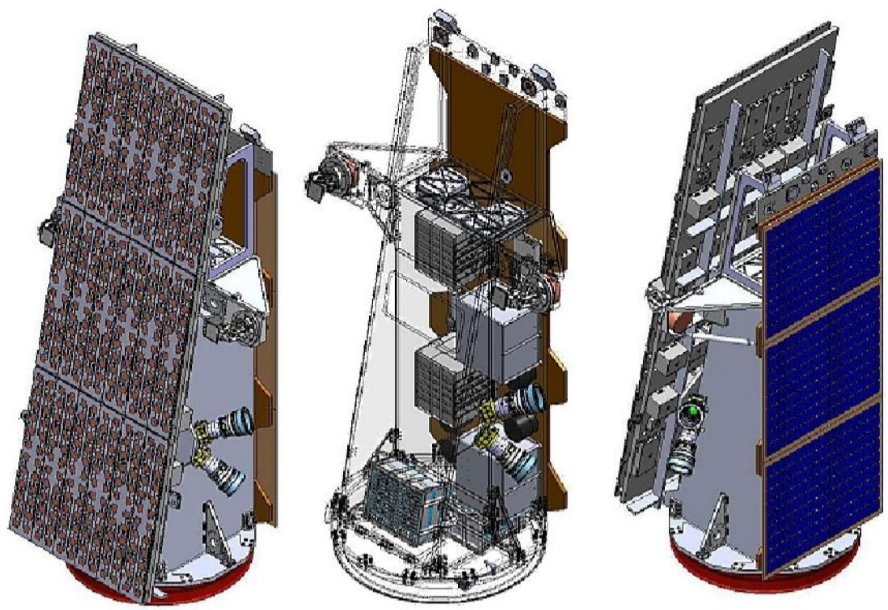
	Diwata-1	Diwata-2
Field of View	32 x 43 km	81 x 60.7 km
Spatial Resolution	66 m	122.9 m

Actual Image of the SMI with LCTF

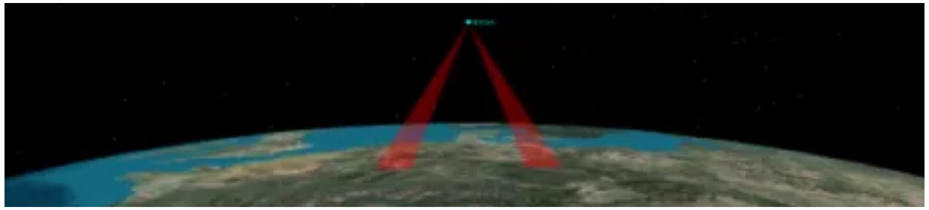
S-band Synthetic Aperture Radar (SAR)

Maritime and terrestrial domain awareness

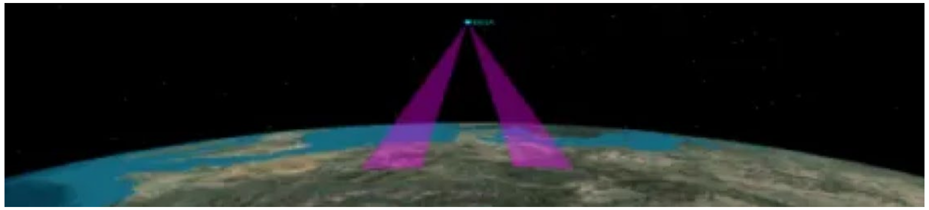
NovaSAR-1 has an S-band SAR payload capable of imaging the earth's surface through high cloud cover. The S-band antenna is a microstrip path phased array of 3m x 2m in size, constrained to meet low cost requirements. S-band performs better compared to X-band for adverse weather conditions and ground penetration. This payload transmits and receives both horizontal and vertical polarizations providing incoherent dual and triple polarizations. ScanSAR mode has resolution of 20 meters, while ScanSAR wide has resolution of 30-45 meters with larger swath. Stripmap mode has detailed resolution of 6 meters but with smaller swath. Maritime mode is an additional experimental imaging mode to enable ship detection over a 400 km ultra-wide swath on higher incidence angles.



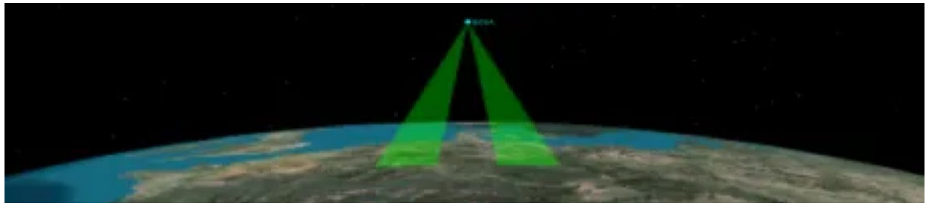
NovaSAR-1 spacecraft with payload antenna (left), component accommodation (center), and solar panel (right). Image courtesy of SSTL, Airbus DS.



Stripmap



ScanSAR



ScanSAR Wide

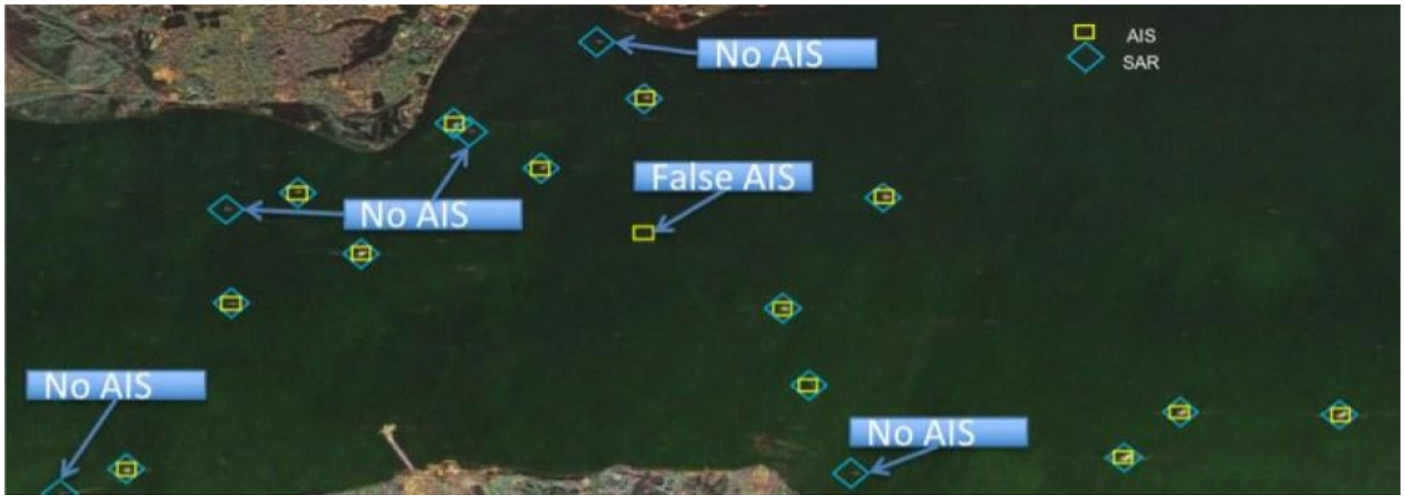
Maritime

Automatic Identification System (AIS)

Satellite-based ship tracking and monitoring

NovaSAR-1 has an AIS receiver that can detect AIS signals from ships. It is a low-power AIS receiver optimized for the highest first pass detection rate. The AIS receiver uses Direct Radio Frequency Sampling (DRFS) that supports two antenna interfaces sampled by high-performance A/D converters and clocked by a low-noise clock. It has 2 orthogonally mounted antennas that provide near omnidirectional coverage which can monitor approximately 20 million km2. The satellite can decode AIS signals immediately after detection (on-board processing) or store raw signals for later processing on the ground station (on-ground processing). SAR imagery with AIS data provides additional information on vessels that are not transmitting AIS signals.

AIS-MS03 satellite-AIS receiver manufactured by Honeywell International in 2018



Correlating SAR and AIS data can monitor suspicious activity and reveals detected ships that are not transmitting AIS signals. Image credit: SSTL

Amateur Radio Unit (ARU)

Diwata-2's communication payload

In addition to Earth observation instruments, Diwata-2 also carries a communication module: the Amateur Radio Unit (ARU). The ARU, also commonly known as a ham radio, was built and designed locally for voice and data messaging services. This can be used as an alternative means of communication in times of emergencies and disasters. Diwata-2's ARU was designated by the AMSAT as Philippines-OSCAR 101 (PO-101) on April 11, 2019, and was announced ready for service on April 26, 2019. It is now accessed by licensed ham users worldwide. On times are posted at the @Diwata2PH Twitter account.

ARU UHF Antenna: *Antenna used in receiving signals from the ground through the amateur radio band frequency.*

ARU VHF Antenna: *Antenna used to transmit signals to the ground through the amateur radio band frequency*

Testing of ARU Voice Repeating Capability in UP Diliman

Parameter	Value
Callsign	DW4TA-1
Downlink Frequency (APRS, VR, Beacon)	145.9 MHz
Uplink Frequency (APRS, VR)	437.5 MHz

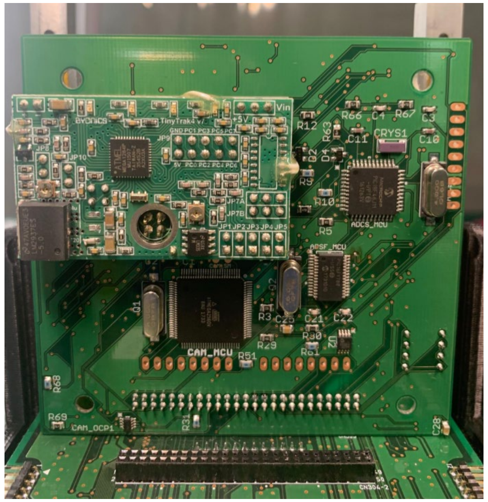
The Diwata-2 ARU

Store-and-Forward

Maya-1's remote data collection

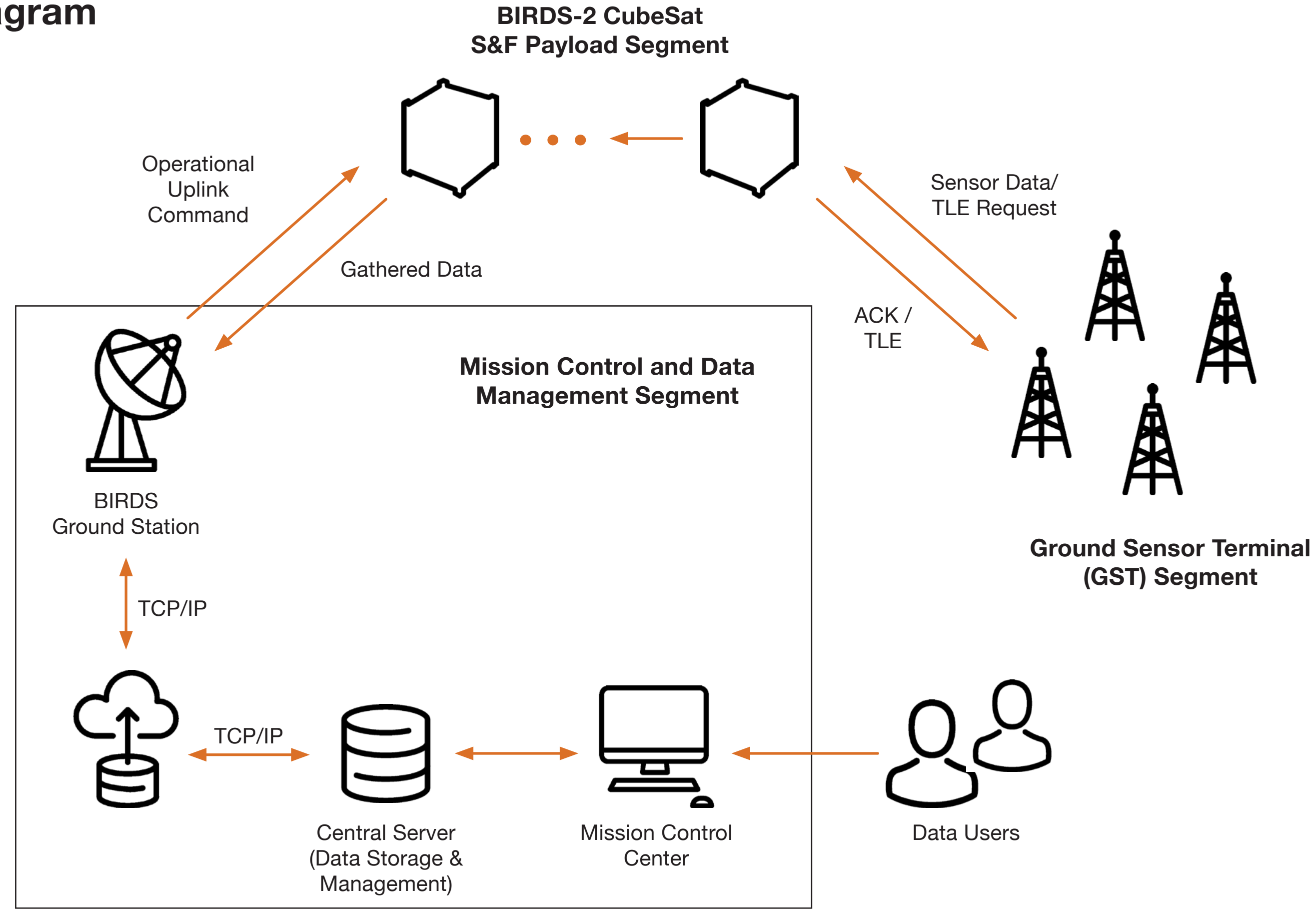
The Maya series of satellites carry a Store and Forward (S&F) payload that enables a satellite-based remote data collection system. In the Store phase, the payload collects data from ground terminals and stores them in memory. In the Forward phase, the collected data are downloaded to a ground station for processing and distribution.

The Store and Forward payload can be used to provide temporary communication link to remote areas to collect ground information that can be used for scientific studies, monitoring, and other applications.



Store-and-forward payload that will board Maya-3 and Maya-4 CubeSats to demonstrate nanosatellite-based remote data collection system

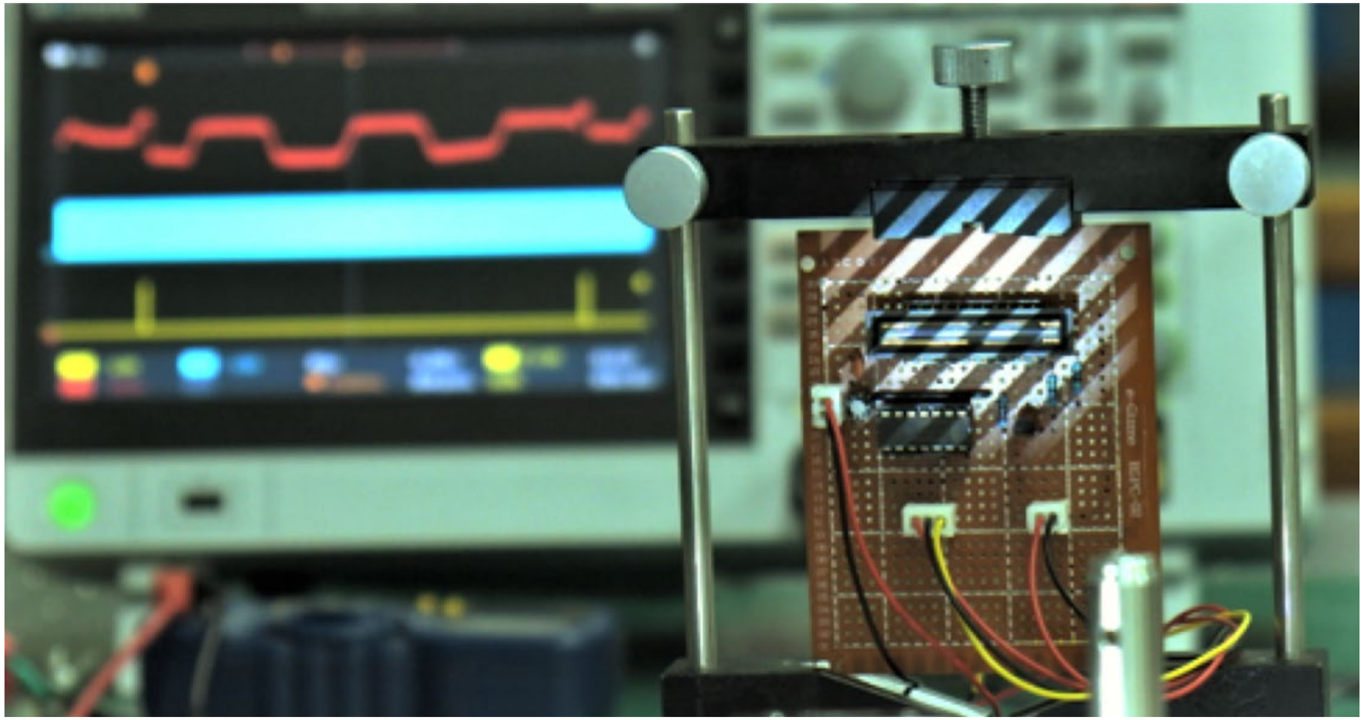
Store-and-Forward Diagram



Localization of Payloads

Pushbroom cameras

Unlike the common cameras, pushbroom cameras obtain images by taking a picture of a slice of the target then stitching them together to form a full image. When coupled with a good optical system, it has the potential to capture high resolution multispectral or hyperspectral images, while maintaining a relatively wide field of view. This payload is currently under development via project OPTIKAL of the STAMINA4Space program.

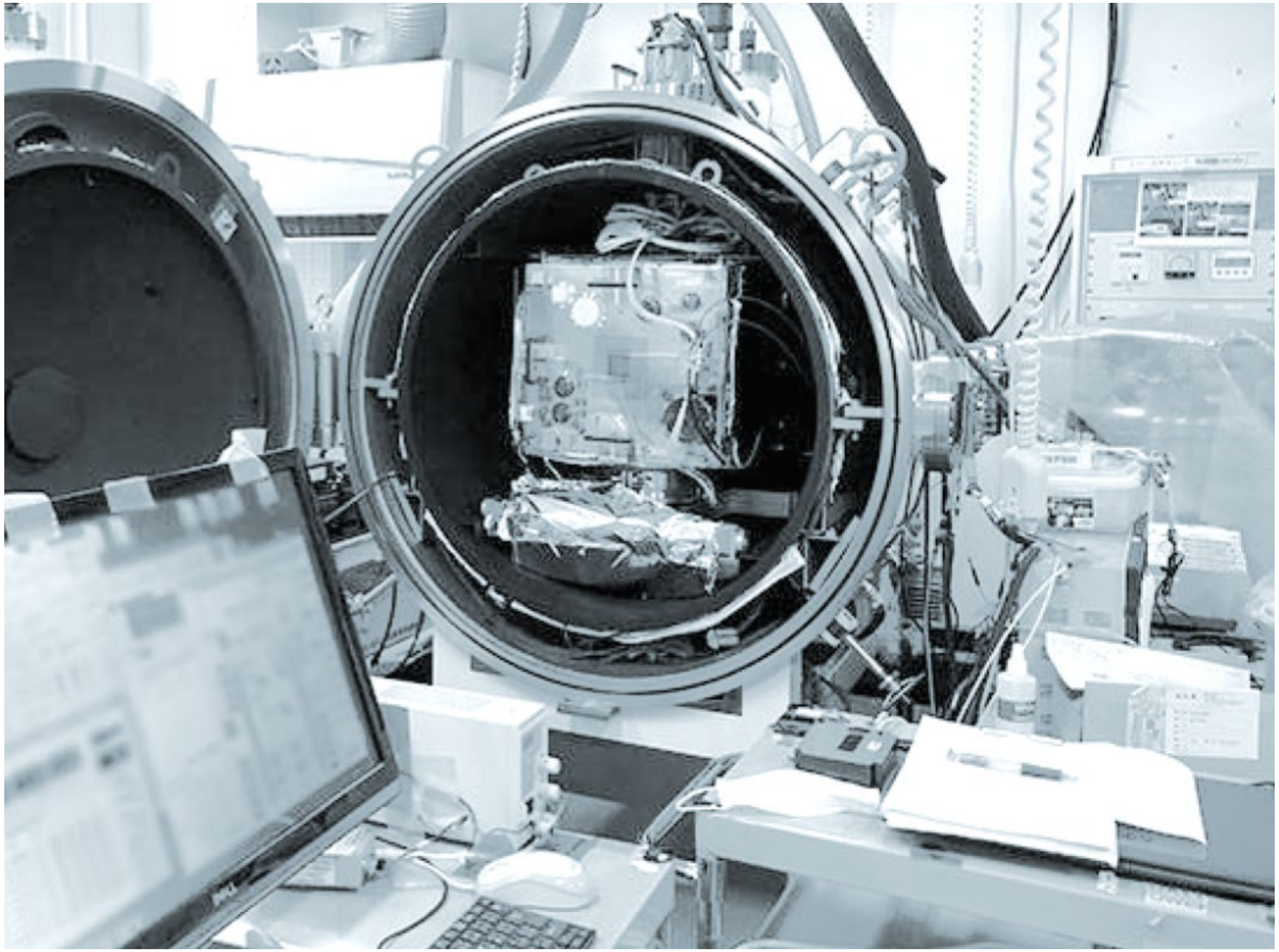


Projected rolling image for testing a line scan camera in the Optical Payload Laboratory

Satellite	Diwata-1
Target Field of View	Single line scan: 283.5 km x 52.5 m
Target Spatial Resolution	52.5 m
Target Spectral Range	Panchromatic Multispectral Hyperspectral

Satellite Assembly, Integration and Testing

3

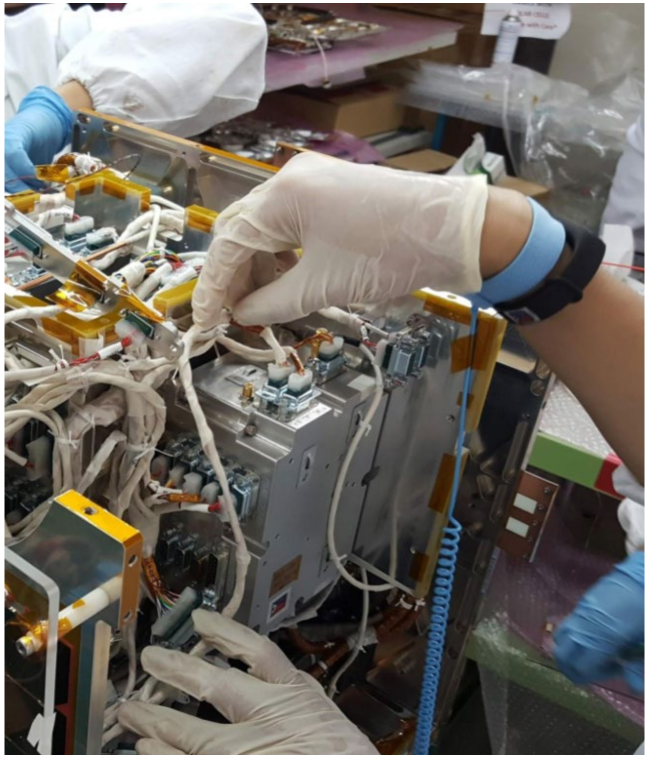


Assembly, Integration and Testing

Incorporating and testing satellite components

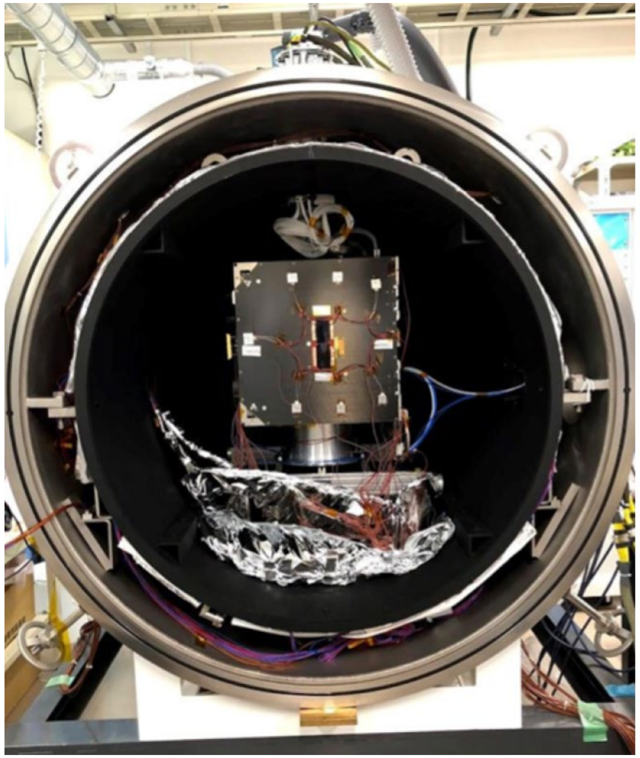
The assembly, integration & testing (AIT) phase synthesizes various small satellite components and payloads from different manufacturers and development teams into one coherent, functional, and space-ready system capable of achieving its mission.

Assembly



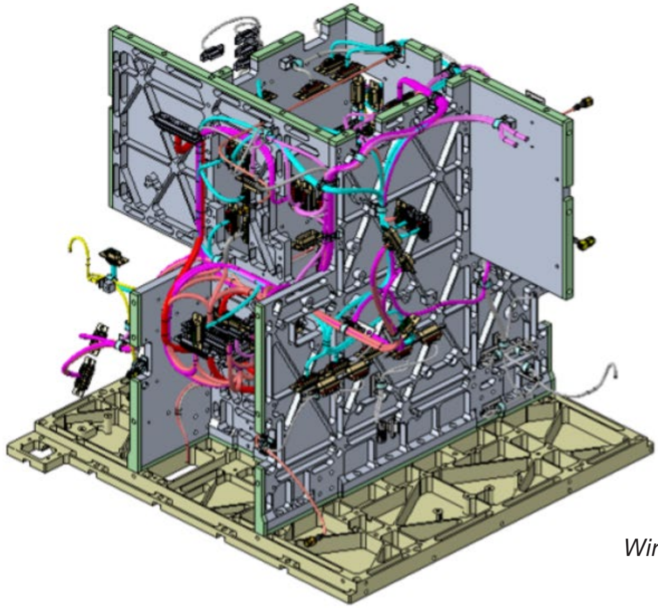
Integration

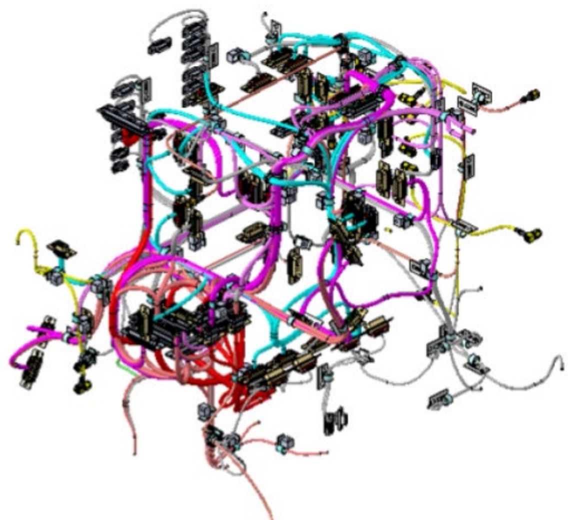
Testing



Assembly

Diwata-1 electric wiring harness

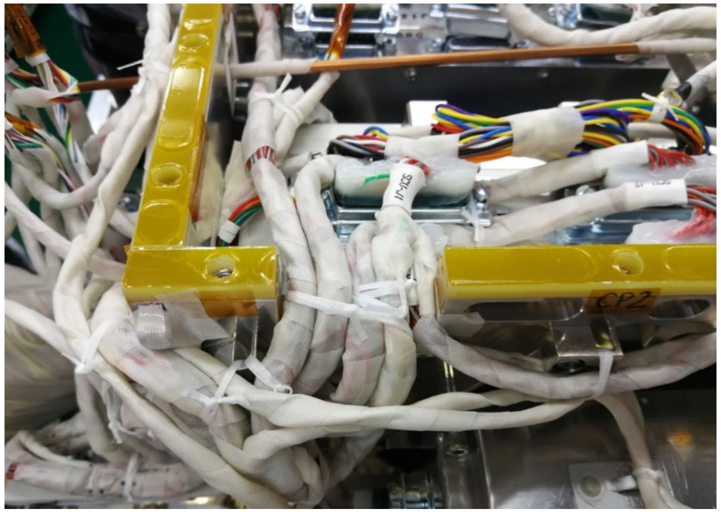


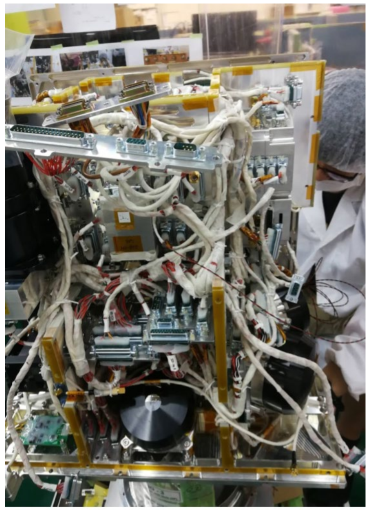


Wire harness modeling pre-fabrication

The main conducting element that links the modules together in the bus is the electrical wiring harness. The wiring topology used in Diwata-1 is a star wiring configuration, with the main computer units (PCU, SCU, and ACU) as the major nodes of this star topology. The wire measurements and routing planning was done through the use of the mockup.

A wiring harness master document was made to contain the details of specific pin-to-pin connection of every module connection in the microsatellite with the corresponding twist pairing details and connector type, wire connection length, and routing plan. The document was composed of four main components: the pin assignment table, the wire length summary, and the connector type table. This master document was made for both the manufacturers and the bus development team, to serve as a concrete guide during the actual assembly, test, and debug of the bus system.





Integration of wire harness during assembly phase

Weighing of all wire harnesses for mass budget calculations

System Integration

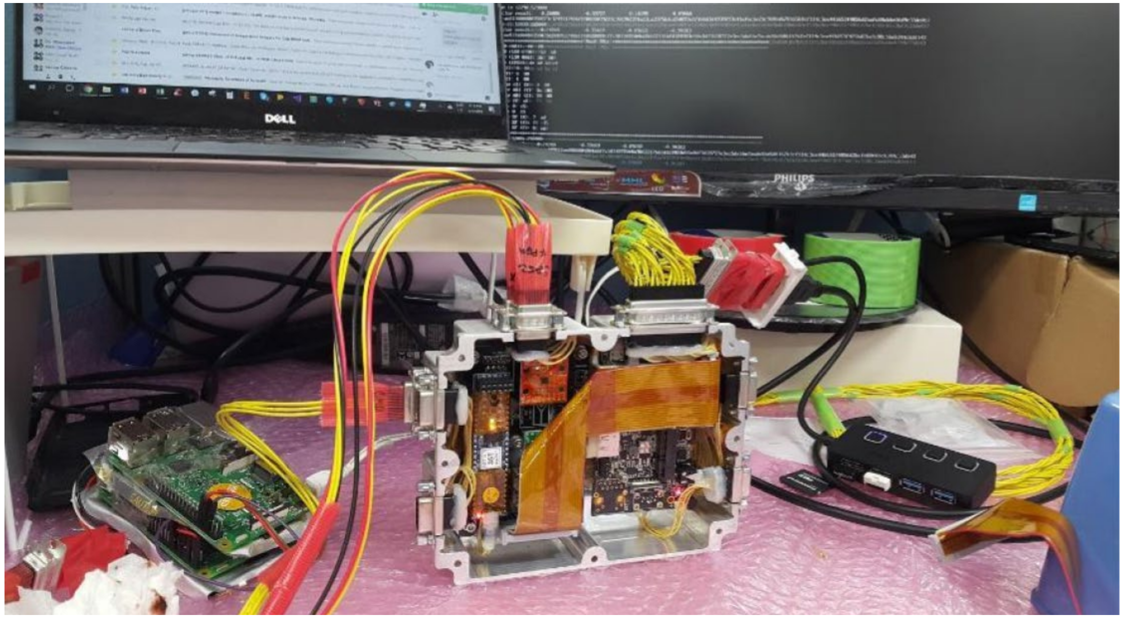
Electronic functionality test

Key electronic functionality tests are done to the fully assembled satellite to ensure that it can perform the intended operations and respond similar to previous benchmark performance results. This setup also allows for the satellite's functionality to be assessed after major environment testing of the satellite, ensuring that no major failures have occurred to any of the subsystems.

Once the engineers return the satellite to the laboratory after each test, they conduct an electrical check of the satellite's bus system to confirm nominal working conditions. During electrical tests, the satellite developers check the satellite's capability to work on a system level. Hence, actual operation telemetry and command servers are utilized to check satellite status and send user commands, respectively. The following activities are also done in the process:

- Orbital Calculations
- Solar and Magnetic Modeling
- Inter-module communication/interfacing
- IMU Sensor Read-out
- Sun-sensor Read-out
- Attitude Computation
- Target Calculation
- Attitude Control Value Calculation
- Statistical Filtering and Estimation

Diwata-1 Module



Diwata-2 ACU-Ex

System Integration

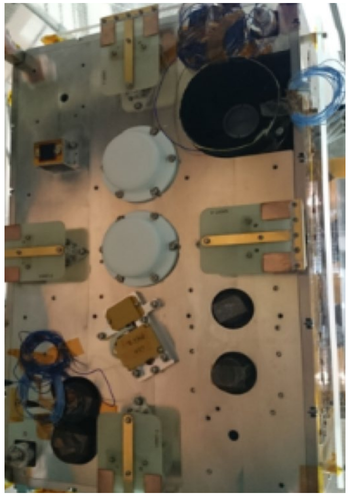
Satellite assembly and electronic functionality tests

The engineering team listed a step-by-step procedure to facilitate the satellite assembly. This guide document (DIWATA2B-Assembly Procedure Summary) gives precise details such as the location, number, and torque required on a given bolt.

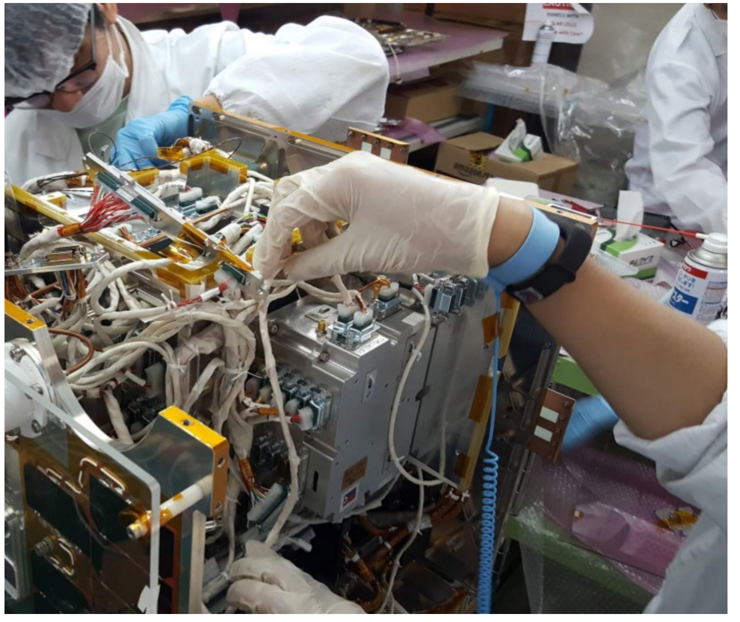
It also dictates the order of assembly, informing the developers to perform a prerequisite task before proceeding with another. More importantly, this document serves as a checklist that indicates what steps was already done by the developers in the case of interrupted work or another developer continuing a task.

Diwata-1 Assembly and System Integration

Assembly of satellite of Diwata-1 Flight Model



A closer look at the payloads integrated into the bus



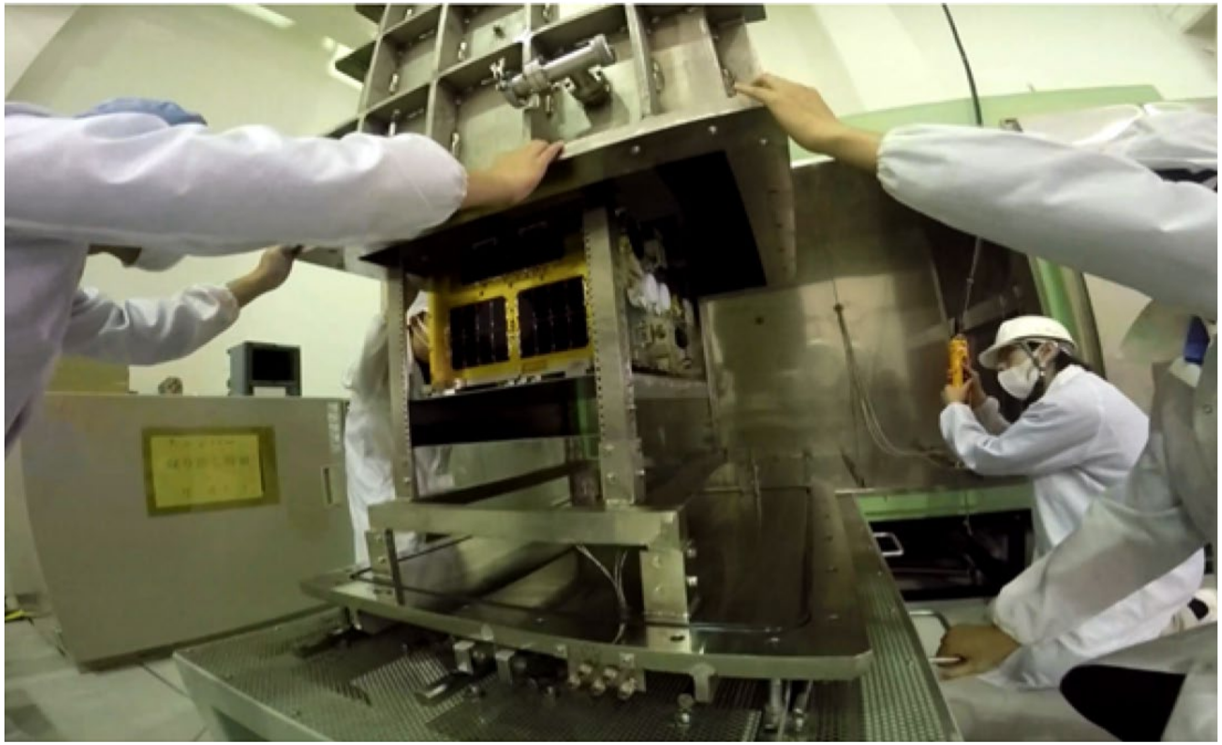
Diwata-2 Assembly and System Integration

Space Environment Testing and Qualification

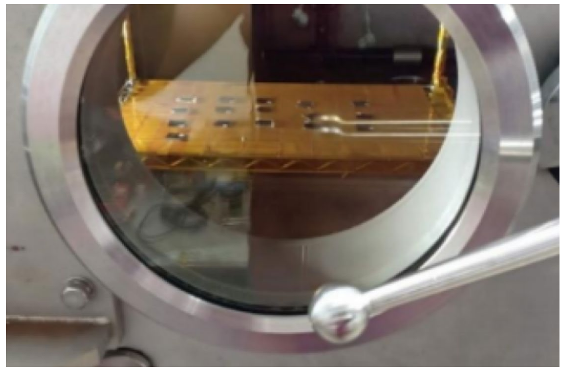
Off-gas Testing

Outgas is a major concern for any electronic component intended for use in vacuum environments like space. It is the released gas trapped within a solid. It has affected many missions due to its degrading effect on the performance of camera lenses and charge-coupled-device sensor often mounted on satellites. So, while on the ground, satellites are subjected to accelerated-lifetime conditions at a high temperature of at least +30°C for 24 hours. In this case, Diwata-1 was exposed to +50°C for 72 hours inside a vacuum chamber.

Finally, this test also ensures the safety of astronauts living on the space station. After launch but before the release of Diwata-1 into space, the satellite will stay on the cargo bay of the International Space Station for a month. Before the actual release maneuver from ISS, astronauts must handle and prepare Diwata-1 into the Kibo-module's robotic arm system. Therefore, off-gas tests must be conducted and passed on the ground. The off-gas machine, shown in the top image, records any gas emissions from the Flight Model, and report on any content and concentration that is deemed harmful.



Diwata-1 before undergoing off-gas testing at JAXA's facility in Tsukuba, Japan

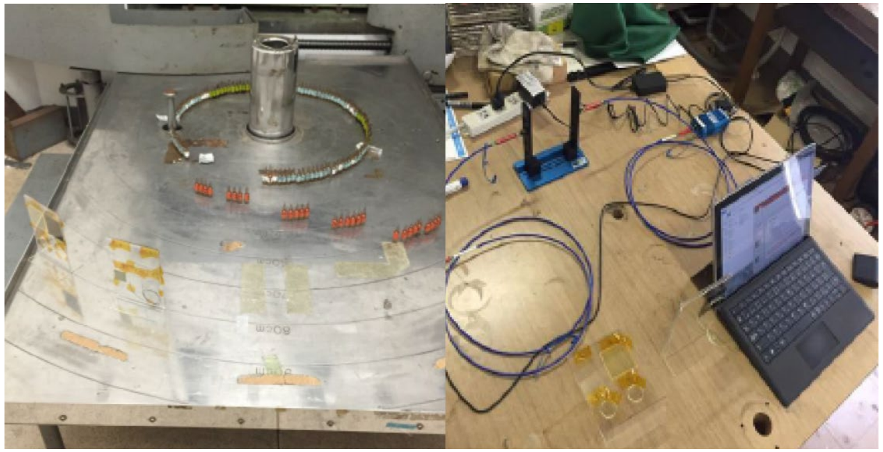


Maya-2 Thermal Vacuum Test

Space Environment Testing and Qualification

Unit level radiation testing

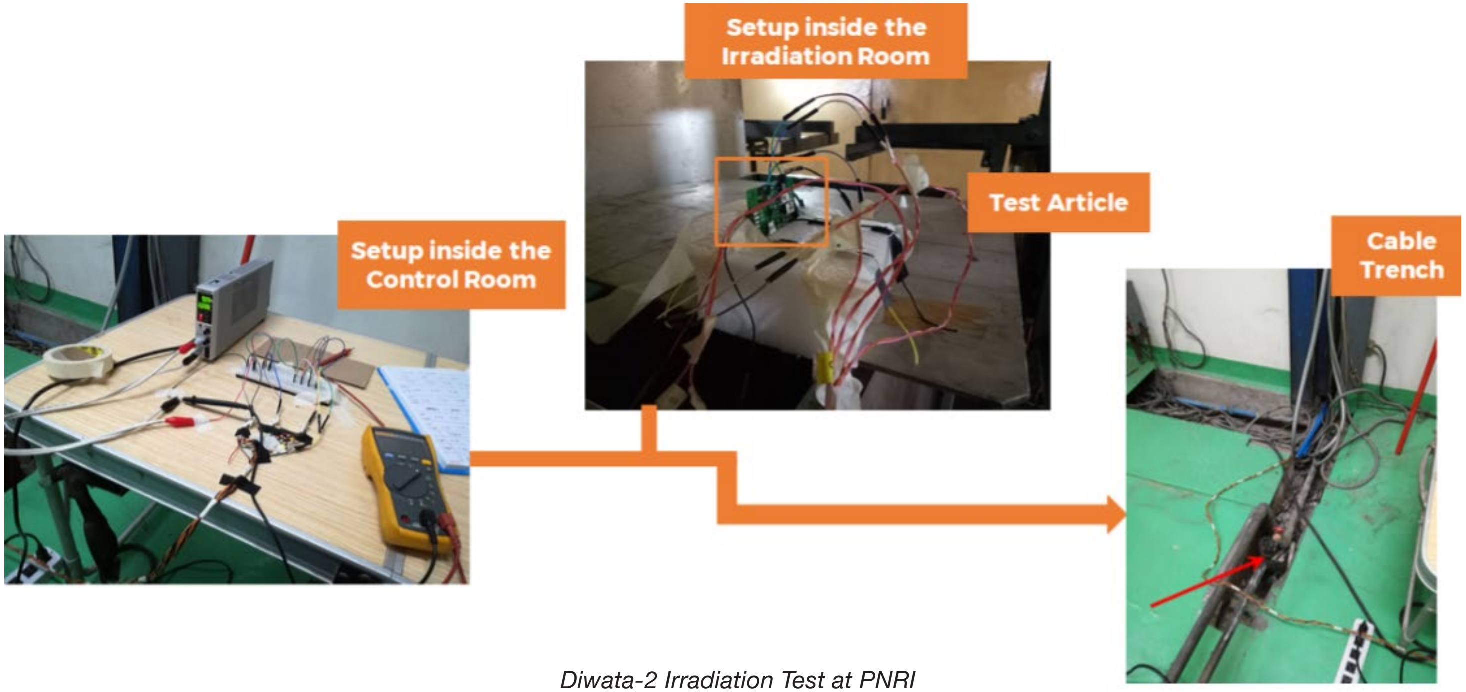
Diwata-1 Radiation Testing at Tokyo Institute of Technology's Radiation Testing Facility



Diwata-2 IHPT Radiation Testing

Understanding how the satellite components behave when exposed to space radiation is mission-critical. Various tests must be performed in order to estimate Total Ionizing Dose (TID) tolerance, Single Event Upset (SEU) and Single Event Latch-Up (SEL) characteristics. These tests are used to determine the expected lifetime of the component, and the time interval between SEU and SEL, respectively.

These tests are conducted to simulate and foresee possible issues that satellite components/modules might encounter during their operation life. Modules subjected to radiation are checked for possible signs of degradation.



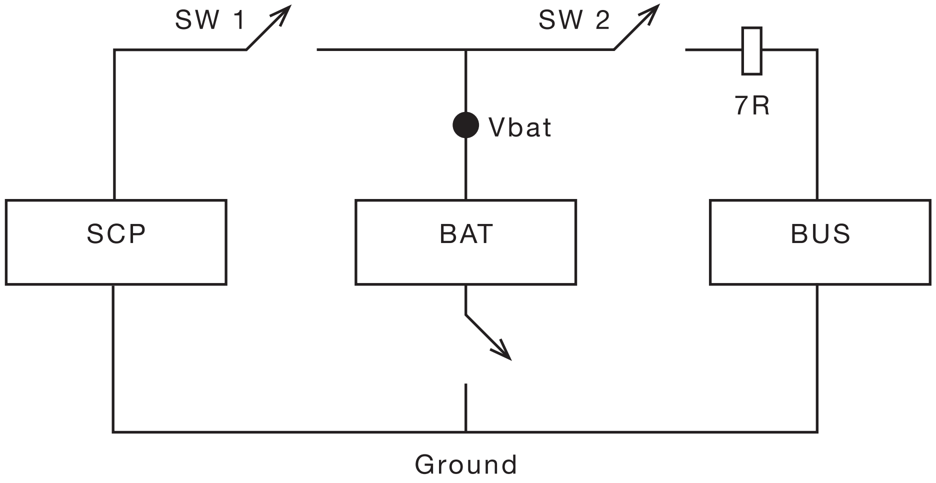
Diwata-2 Irradiation Test at PNRI

Space Environment Testing and Qualification

Power Control Unit (PCU) Test

One of the most crucial components of the microsatellite is the PCU.

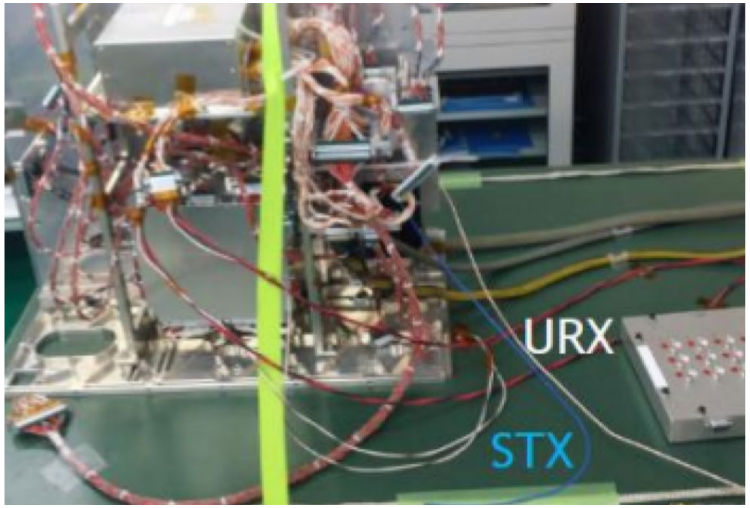
PCU Test is conducted to ensure that proper switching sequence is observed.



PCU-BAT Separation Switch Configuartion

Battery Testing

This is done to ensure that batteries will not change by more than 0.1% when tested in a vacuum container and placed in a controlled temperature environment.



Satellite Control Unit Test

Performance of the SCU, particularly the communication modules were tested with attenuation and simulated noise factor. This is conducted to ensure the uplink and downlink communication and functionality.

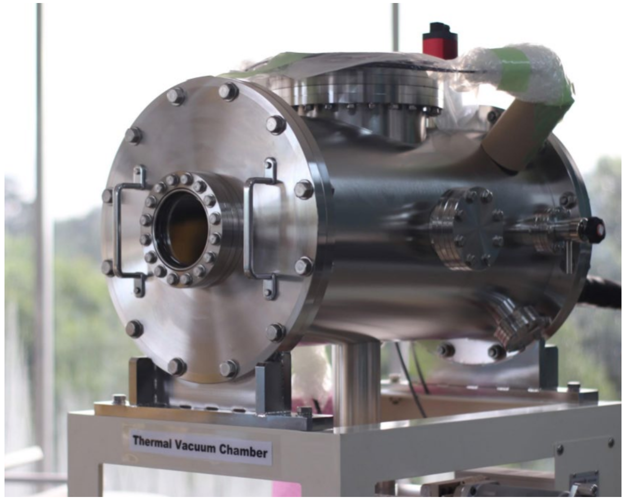
Space Environment Testing and Qualification

Thermal Vacuum Cycling Test

Thermal vacuum testing simulates space environment by removing air and pressure, and cycling very high and very low temperatures. By testing in an environment that simulates real world conditions as closely as possible, thermal vacuum exposure can identify design issues before a satellite is launched into space.

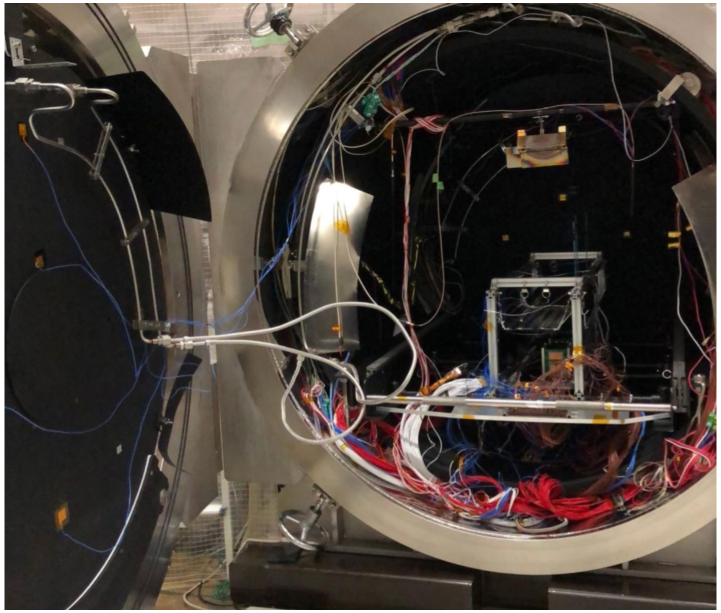
Typically the thermal environment is achieved by passing liquid nitrogen (LN2) through a thermal shroud of the vacuum chamber for cold temperatures or through the application of tape heaters for high temperatures.

To verify performance in space, functionality tests are performed while the satellite is inside the chamber. A series of commands are carried out when the satellite experiences extreme cold and hot temperatures based on finite element simulations.

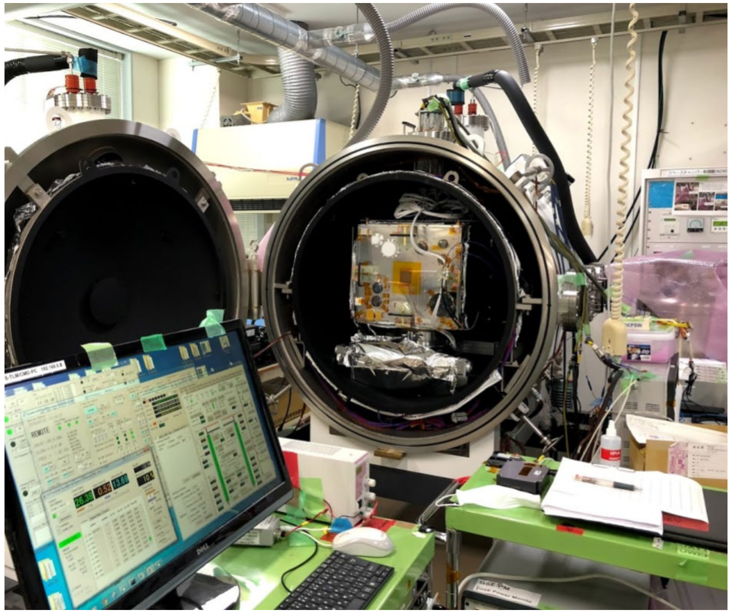


Thermal Vacuum Chamber in ULySS3ES Research Laboratory

Vacuum chamber in Hokkaido University loaded with Liquid Nitrogen via refillable tanks.



Maya-1 FM thermal vacuum test



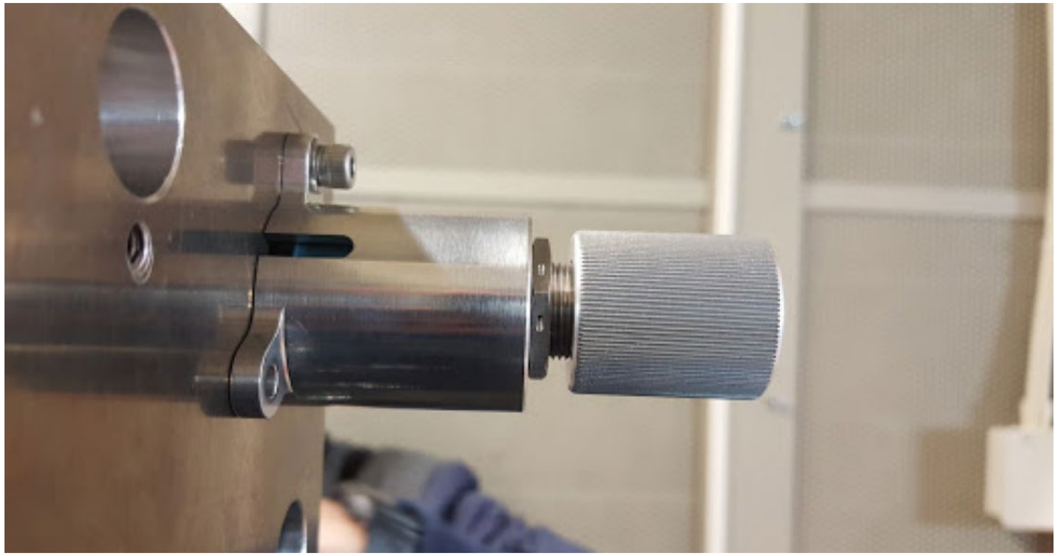
Diwata-2 Flight Model thermal vacuum test

Space Environment Testing and Qualification

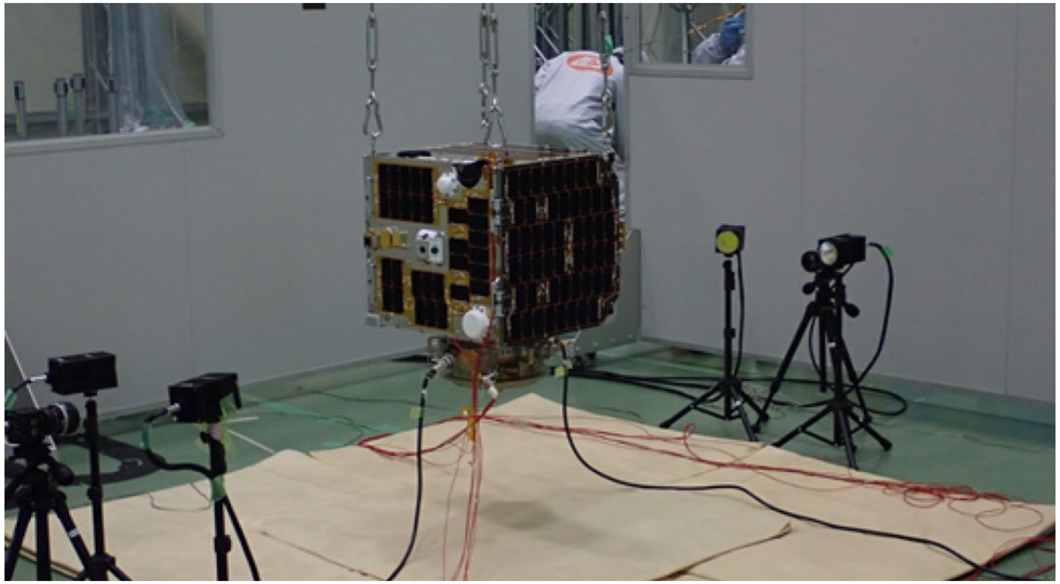
Separation Shock Test and Shock Test

The satellite experiences a violent force when released from the rocket deployer mechanism. The sudden massive impact felt by the satellite originates from the contact point with the rocket. Once it's time to release the satellite, a controlled explosion cuts the bolts tethering the satellite to the launcher's body. The engineers ensured through a dedicated deployment switch shock test that the deployment switches do not fail since its failure would mean the failure of the satellite itself. Figure 1 shows the set-up for this dedicated deployment switch (DEPSW) shock test. The test verified that the DEPSW could withstand the shock by still being normally-open.

In a more comprehensive test, the engineers, in cooperation with JAXA, subjected the satellite flight model (FM) to a separation shock test inside JAXA's Tsukuba facility. Figure 2 shows the FM tethered above ground by crane hooks and attached on designed contact points with the launch vehicle is a dummy explosive device that cut the attachment bolts. After the test simulated the actual shock condition that the satellite faced in space, the team performed a comprehensive damage check to both the physical and electrical components. The inspection did not yield any sign of damage, clearing the satellite for launch barring any issues with the vibration test.



Diwata-2 deployment switch with cap attached during the shock test inside the Miyagi Technical Test facility.



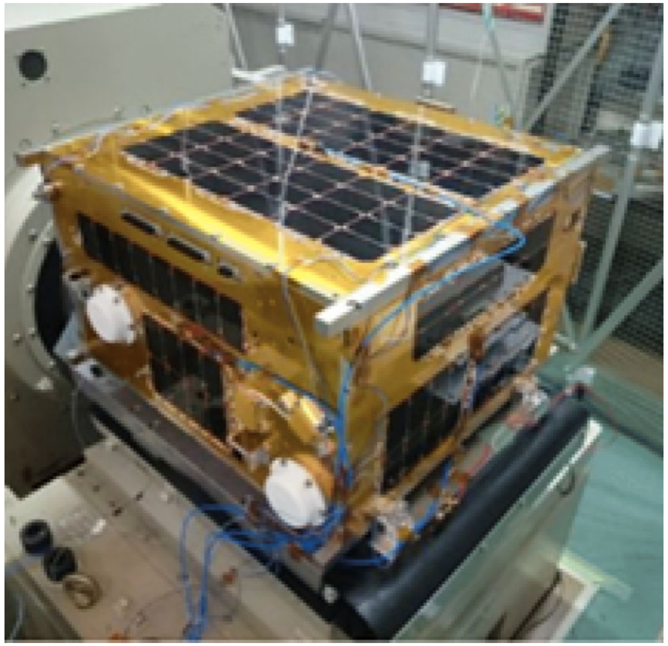
Diwata-2 deployment switch with cap attached during the shock test inside the Miyagi Institute of Technology Industrial Test facility

Space Environment Testing and Qualification

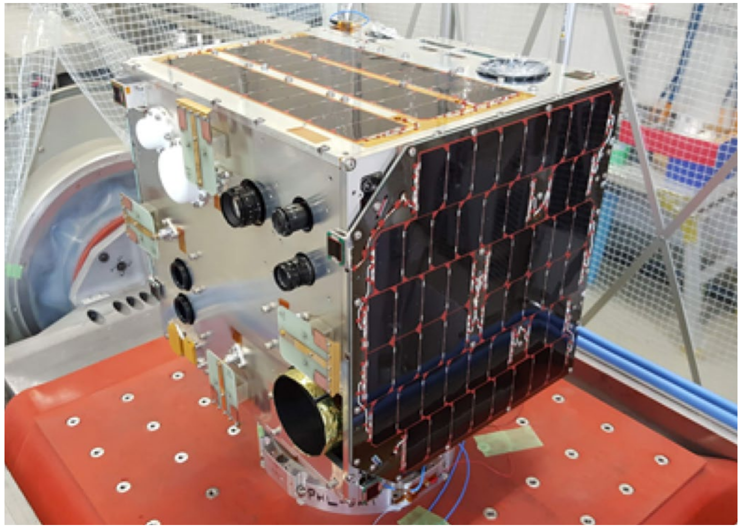
Vibration Test

A critical testing requirement for satellite acceptance is the system vibration test. The vibration loads and conditions are primarily dictated by the launch provider which will be used to launch the satellite into orbit

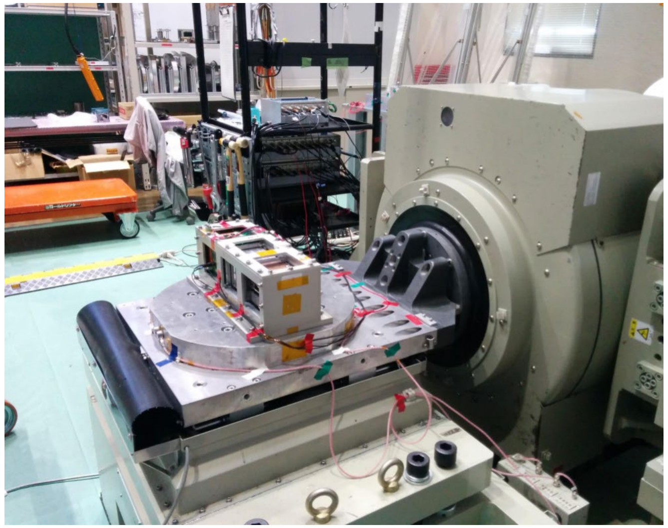
By process, the structural integrity requirements were fully taken into account right from the start of the digital design process; thoroughly reviewed with Finite-Element software simulations and analysis. The physical vibration test serves as the conclusive validation and verification of the design.



Diwata-1's Flight Model vibration testing phase was done in Kyushu Institute of Technology's Center for Nanosatellite Testing (CeNT) and Miyagi Institute.



Diwata-2 satellite vibration testing

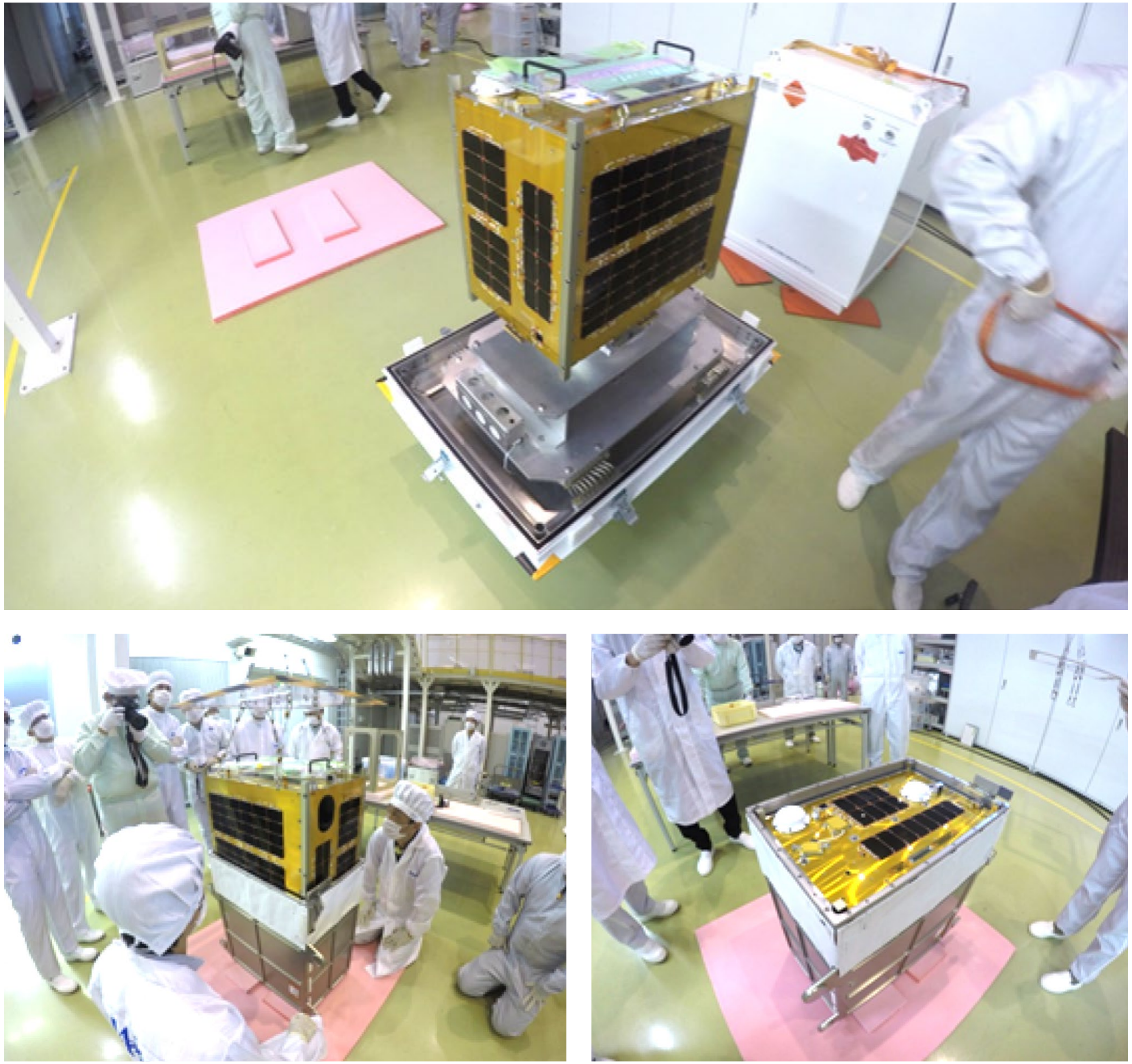


BIRDS-2 vibration testing

Space Environment Testing and Qualification

Fit-check tests

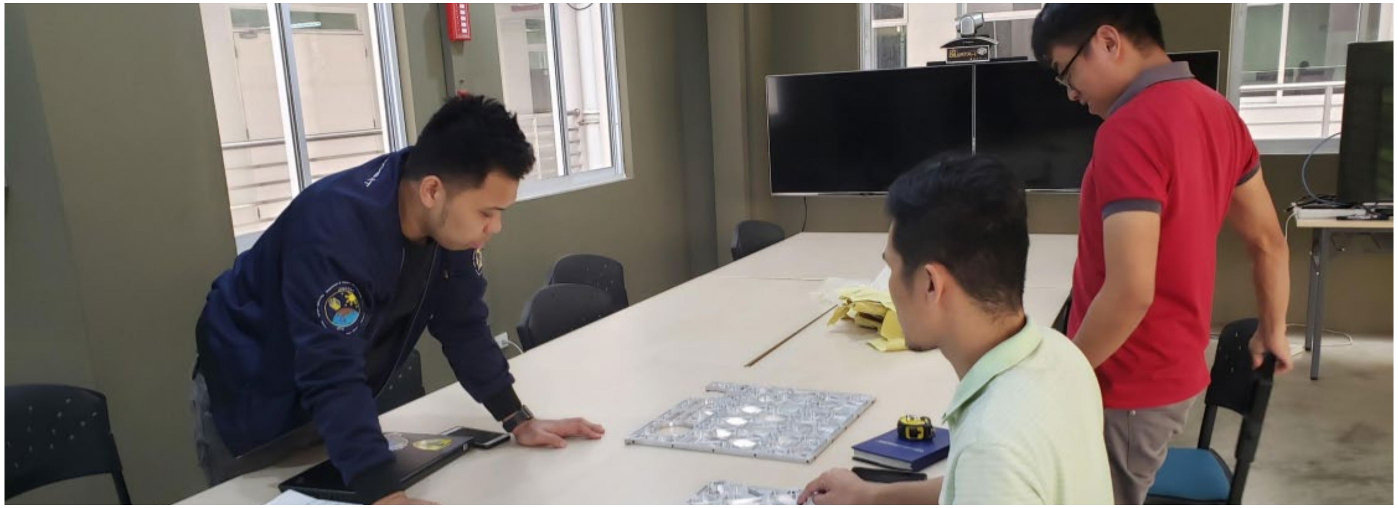
The orbit insertion of Diwata-1 was planned to be conducted via robotic-arm release from the ISS, as assisted by the Japanese Small Satellite Orbital Deployer (JSSOD) system. To facilitate this orbital insertion, the Diwata-1 satellite was directly stowed into the JSSOD at JAXA's Tsukuba Center facility on the ground. Several fit-checking tests of the satellite into the JSSOD container was made, to ensure that no unnecessary obstruction and friction occurs between the container and the satellite. This was also a conclusive check, ensuring that the maximum structural envelope was maintained even after rigorous vibration tests on the ground. Possible issues that could happen after environmental tests are: skewing and contortion of the satellite after vibration tests, deployment switch misalignment with the pressing points within the container.



Diwata-1 fit-check test

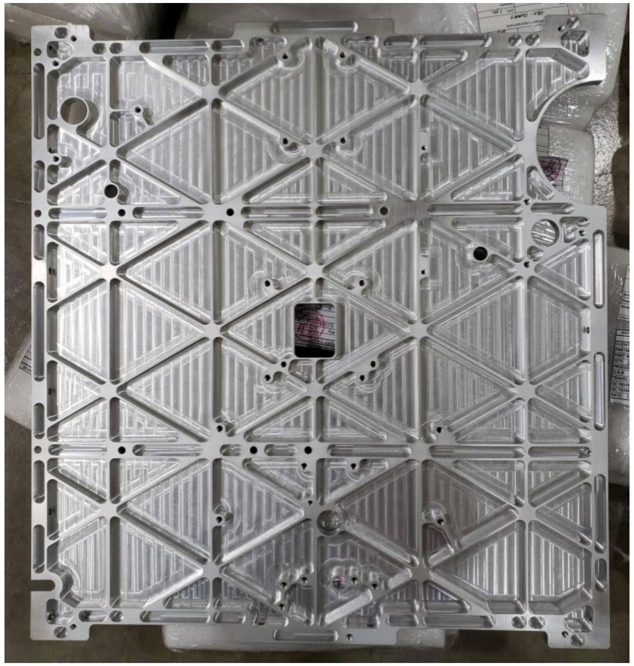
Space Environment Testing and Qualification

MTM fabrication and workmanship Inspection



Meeting with local company to discuss manufacturing errors and ways to improve material handling

As part of the localization activities of the bus structure, one of the STAMINA4Space teams met with local companies to discuss manufacturing processes and material handling and point out some manufacturing errors. This includes the fabrication of dummy masses for hemispherical air bearing setup and at the same time to evaluate capability of local company in preparation for the PHL-50 bus structure. The team also performed quality inspection of fabricated dummy masses.



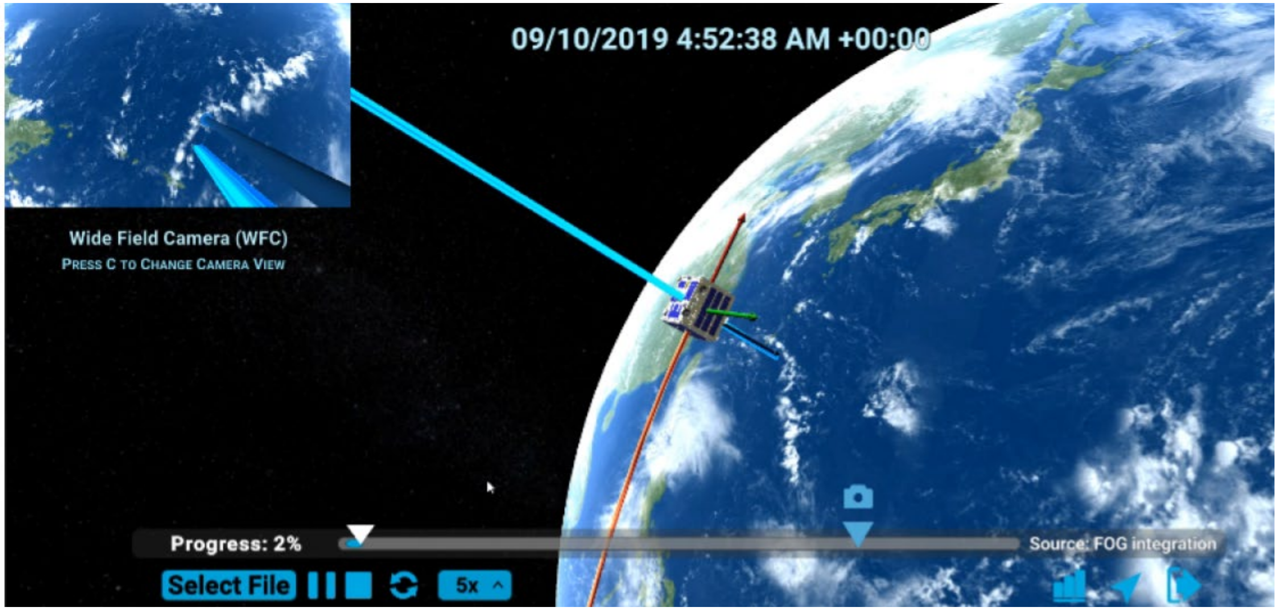
Sample fabricated dummy masses

Space Environment Testing and Qualification

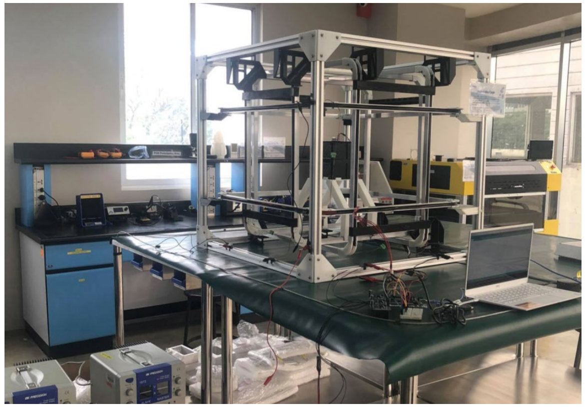
Simulating the space environment in a laboratory setting

In August 2019, DOST and UP Diliman inaugurated the University Laboratory for Small Satellites and Space Engineering Systems (ULyS3ES). This was built to be an academic hub for small satellite r&d, housed in the university's Electrical and Electronics Engineering Institute (EEEI). It contains two buildings that are equipped with research spaces and laboratories designed to simulate the space environment for various small satellite activities.

The small satellite simulation system contains hemispherical air bearings that offer inherent friction-free motion on three rotational axes. It allows the user to simulate the microgravity environment in space by establishing a thin air film separating the ground section and the moving section with the use of pressurized air. Testing the satellite components in these conditions are important in the research process. It gives the team valuable information about how the satellites will behave in their eventual space environment.



Diwata-2 Flight Data Visualization which allows us to get valuable data about the satellite, such as orientation, battery power, satellite temperature and communication link



The Helmholtz Cage provides a dynamic, 3-axis, uniform magnetic field to cancel the Earth's magnetic field and at the same time create an environment similar to the geomagnetic field a satellite would experience on-orbit.`

Small Satellite Simulation system

Space Environment Testing and Qualification

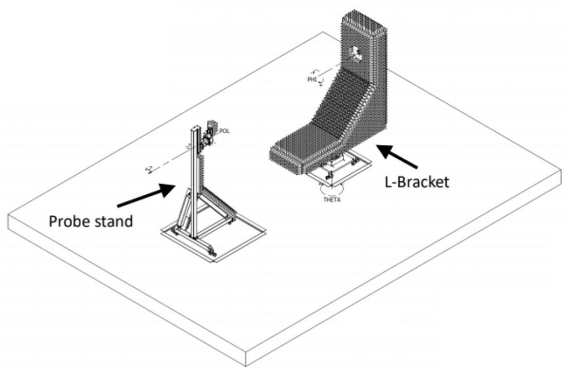
Full Anechoic Chamber

A Full Anechoic Chamber (FAC) was built in the ULyS3ES annex building. It is used to measure and test the radiation pattern of antennas. The first of its kind in the Philippines, it enables faster development cycle for a satellite's communication system through (in situ) antenna measurements and performance verification of the onboard radios or transceivers. The efficient performance of antennas and radio systems is a crucial ingredient in ensuring the success of the satellite mission.

To enable spherical measurements, the chamber is equipped with a probe stand and an L-bracket positioner. The antenna to be measured is mounted on the L-bracket positioner then rotated in 2 axes (phi and theta as shown in the diagram).

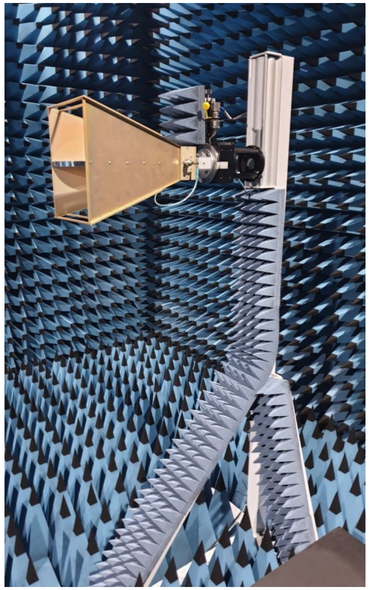
Measurement Probes

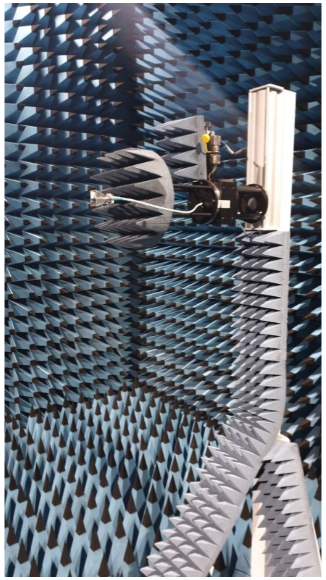
Double Ridged Broadband Horn Antennas are used as measurement probes in the Full Anechoic Chamber. The facility has three antenna probes to cover the operating bandwidth of the chamber from 600 MHz to 26.5 GHz. Two of them are shown in the pictures below, with the third probe installed inside the Full Anechoic Chamber. Their wide frequency ranges enable less work in manually changing probes for antenna testing.



Full Anechoic Chamber L-bracket positioner


Full Anechoic Chamber


Measurement Probe
Model: DRH370
Frequency range: 370MHz - 6 GHz
Material: Aluminum Alloy


Model: DRH50
Frequency range: 4.5 GHz - 50 GHz
Material: Aluminum Alloy

Space Environment Testing and Qualification

Electromagnetic compatibility test

Electromagnetic compatibility (EMC) is the ability of electronic devices/equipment to work as intended in the presence of other devices that emit electromagnetic waves in their electromagnetic environment. This means that each piece of an electronic component in the device that emits electromagnetic waves and disturbances must be limited to a certain level and these components must also be immune to the electromagnetic disturbances from the environment it is meant to function in.

Electronic products from the Philippines have a better chance of penetrating the international market after the Electronics Product Development Center (EPDC), the Philippines's premier electronics testing center, gained its ISO 17025:2017 accreditation for electrical testing. Awarded by the American Association for Laboratory Accreditation (A2LA). The ISO 17025 positions the EPDC of the Department of Science and Technology (DOST) at par with electronics testing centers worldwide. It recognized several testing methods of the center for its international compliance.. (Source: EPDC)

Semi Anechoic Chamber in EPDC
Photo courtesy of EPDC

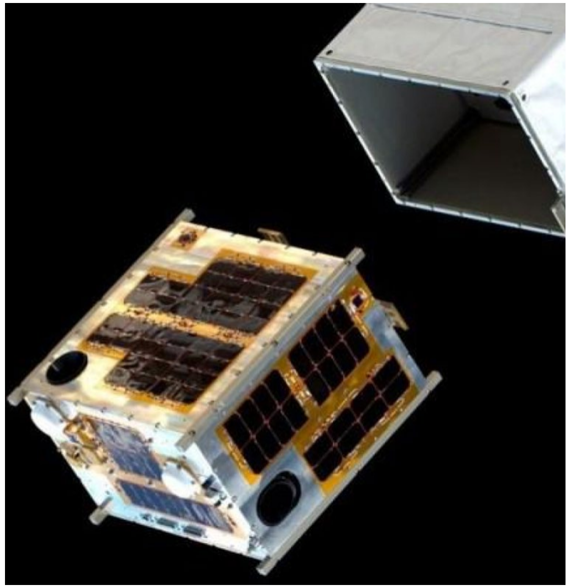
Satellite Handoff, Launch, and Release

Sending the Diwata satellites to space

Last October 29, 2018, Mitsubishi Heavy Industries, Ltd. successfully launched H-IIA Launch Vehicle No. 40 at the Tanegashima Space Center, a rocket launch site facility owned by JAXA. The images on the right show the rocket launch, which contains the main payload IBUKI-2 (GOSAT-2) and a secondary payload, KhalifaSat. It also contains two 50-kg class satellites: Ten-Koh, and Diwata-2. Also included in the launch are 1-U CubeSats AUTcube2 and STARS-AO.

Diwata-1 turnover to JAXA

Atlas V Rocket carrying Diwata-1 to the International Space Station (ISS) on 23 March 2018



Diwata-1 released on April 27, 2016 from the International Space Station (ISS)

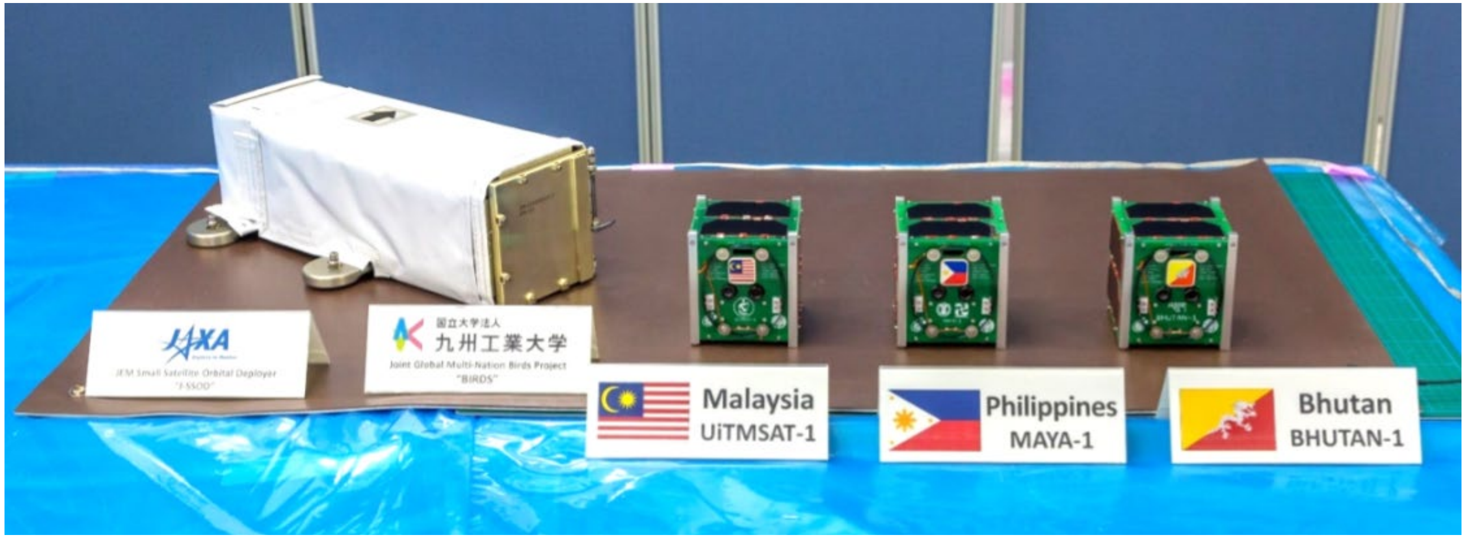
Diwata-2 turnover to JAXA

H-IIA F4 rocket carrying Diwata-2 lifts off from from Tanegashima Space Center, Kyushu, Japan on 29 October 2018

Satellite Handoff, Launch and Release

Sending Maya-1 to space

Maya-1 was launched together with BHUTAN-1 (Bhutan) and UiTMSAT-1 (Malaysia) on June 29, 2018 on board a SpaceX Falcon 9 rocket that lifted off Cape Canaveral, Florida. The rocket was headed to the International Space Station (ISS) as part of a SpaceX CRS-15 commercial resupply service mission. It was released from the ISS on August 10, 2018.



JEM Small Satellite Orbital Deployer (J-SSOD) and the three cubesats (Image source: JAXA/NASA)

Diwata-1 released on April 27, 2016 from the International Space Station (ISS)
Image source: ESA/Alexander Gerst

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Calibration and Validation

4

Overview

Onsite Calibration and Validation

Calibration and Validation

An overview

Calibration

Validation

Calibration and Validation

Testing optical payloads on the field

One of the important activities in testing the remote sensing instruments on board satellites is to test it on the field. Under PH-Microsat, a team was dedicated to the development of a calibration method to be applied for the remote sensing instrument, generating a set of calibration parameters for the remote sensing instrument to maintain image spectral fidelity and consistency, and generating an authoritative spectral signature database/library of key ground objects of significance and/or importance that are especially endemic to the Philippine conditions.

Images show joint field calibration and validation of the LCTF Camera by members of PHL-Microsat Project 4, Project 5, Hokkaido University and IHI Corporation on August 1-6, 2015 in Catarman, Samar

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Ground-based Satellite Technologies

5

Overview

DOST-ASTI Ground Receiving Station (GRS)

Davao GRS

Philippine Earth Data and Resource Observation (PEDRO) Center

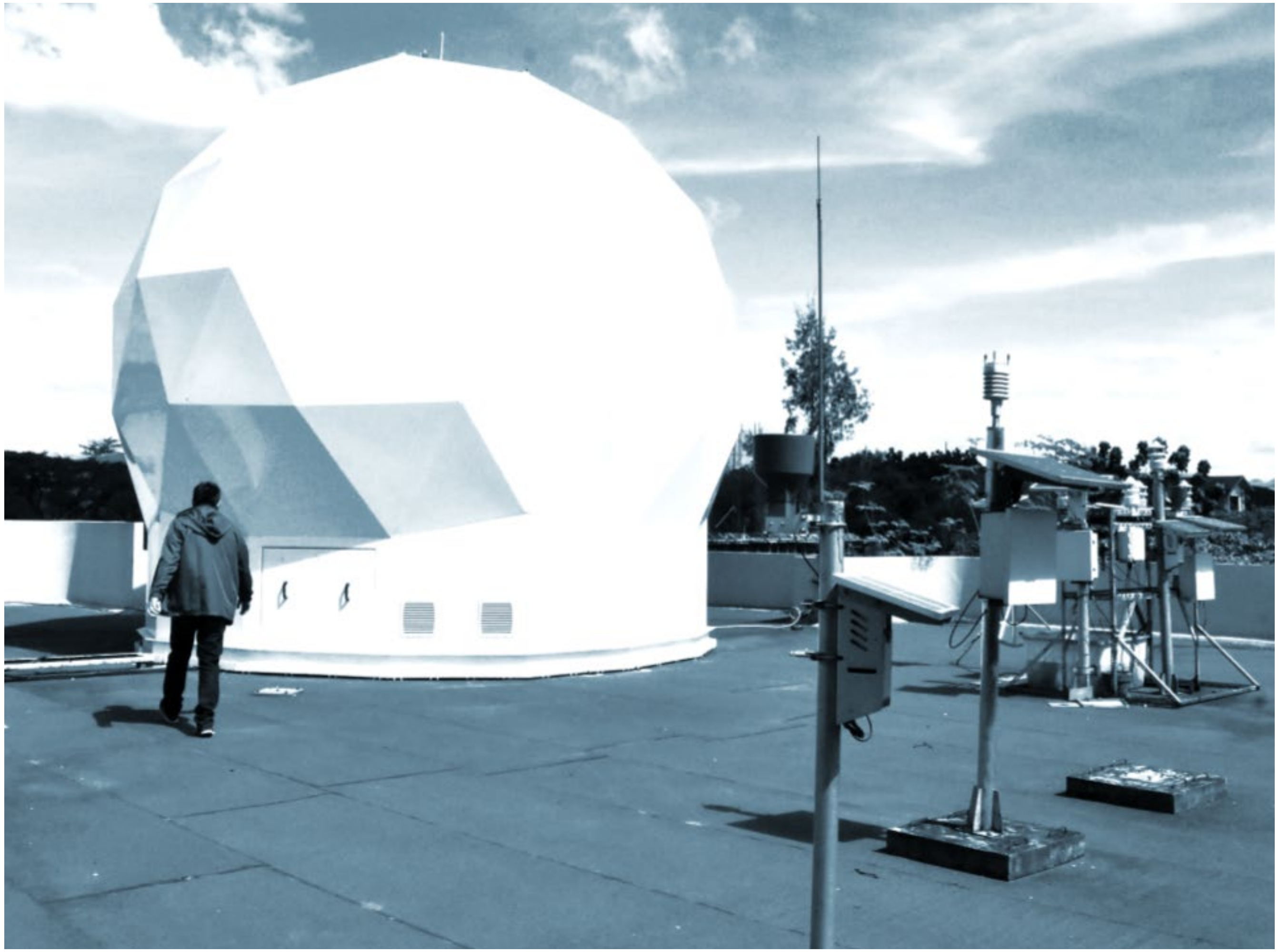
Amateur Radio and Satellite Station(ARSS)

Computing and Archiving Research Environment (COARE)

Remote Sensing

Data Processing

Data Distribution



Ground-based Satellite Technologies

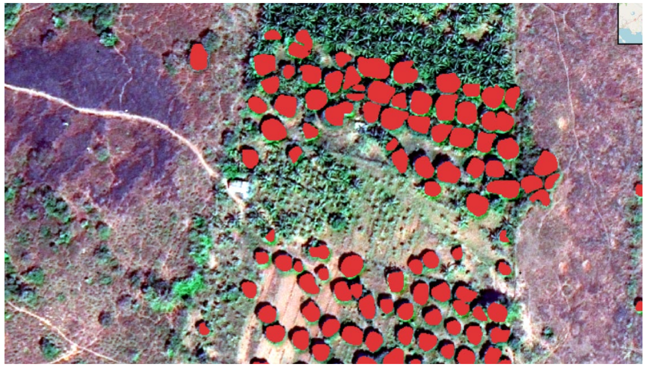
Overview

Part of the downstream component of the space ecosystem are the ground-based technologies such as the ground receiving station which receives data from and uploads commands to the local satellites, and capacities in data processing, distribution, processing, archiving, and high-performance computing facilities.

Ground Receiving Station

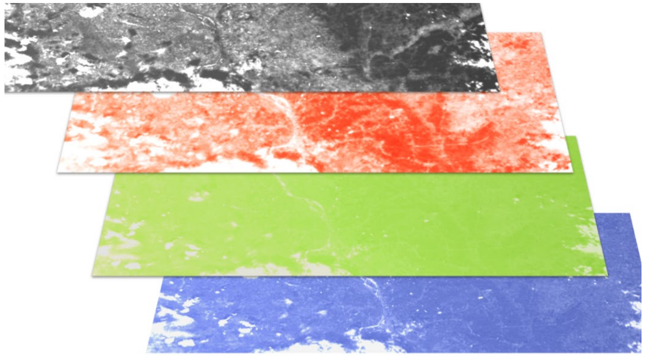
Remote Sensing

Artificial Intelligence

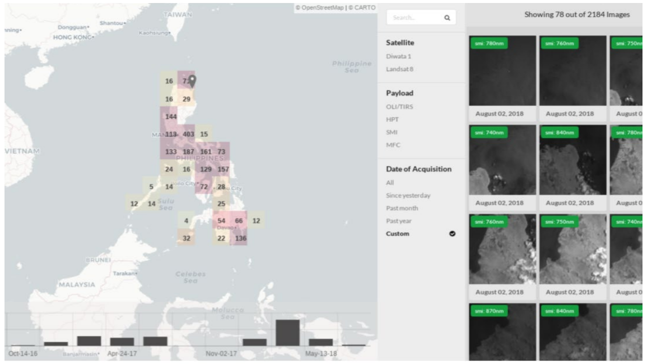


Computing and Archiving

Data Processing



Data Distribution



Ground Receiving Station (GRS)

Infrastructure

In order to operate Philippine satellites, the Philippine Earth Data Resource and Observation (PEDRO) Center was established in 2016. It serves as a multi-mission ground receiving station (GRS) facility for operation of the Philippine satellites and data acquisition from commercial satellites

Currently, PEDRO Center operates Diwata-1 (until it was decommissioned on April 6, 2020) and Diwata-2. The GRS can also directly download images from other satellite subscriptions such as KOMPSAT-3, KOMPSAT-5, KOMPSAT-3A, GeoEye-1, WorldView 2, 3 and 4, Cosmo-Skymed and NovaSAR-1 (see page X for more details about these satellites).

The country currently has two GRS in operation, one in Metro Manila and one in Davao City. The construction of the third GRS in Iloilo is still ongoing. With the creation of the Philippine Space Agency (PhilSA), the facilities of the PEDRO Center will be transitioned to the agency.

Location of the three Ground Receiving Stations of the PEDRO Center

DOST-ASTI Ground Receiving Station , Quezon CIty

The Davao Ground Receiving Station 7.3-meter satellite tracking antenna in the CAAP Facility, Davao CIty

Iloilo Ground Receiving Station, Dumangas, Iloilo. The construction of this GRS is still ongoing.

Ground Receiving Station (GRS)

Fast Facts: DOST-ASTI GRS

Antenna type	Tracking antenna
Location	Quezon City, Metro Manila Lat: 14.647202° Long: 121.0714719°
Antenna diameter	3.7 meters
Transmitting power	100W ~50dBW
Transmit Frequency Range	S -Band
Receive Frequency Range	X-Band, S-Band
Pointing Accuracy	< 0.1°
Velocity	5° per second
Acceleration	10° per sec. sq.
Polarization	LHCP and RHCP
Antenna Gain	~48.7dBi @ 8GHz ~36.7dBi @2.2GHz

The antenna in ASTI is equipped with a fiberglass weatherproof radome.

Ground Receiving Station (GRS)

Fast Facts: Davao GRS (D-GRS)

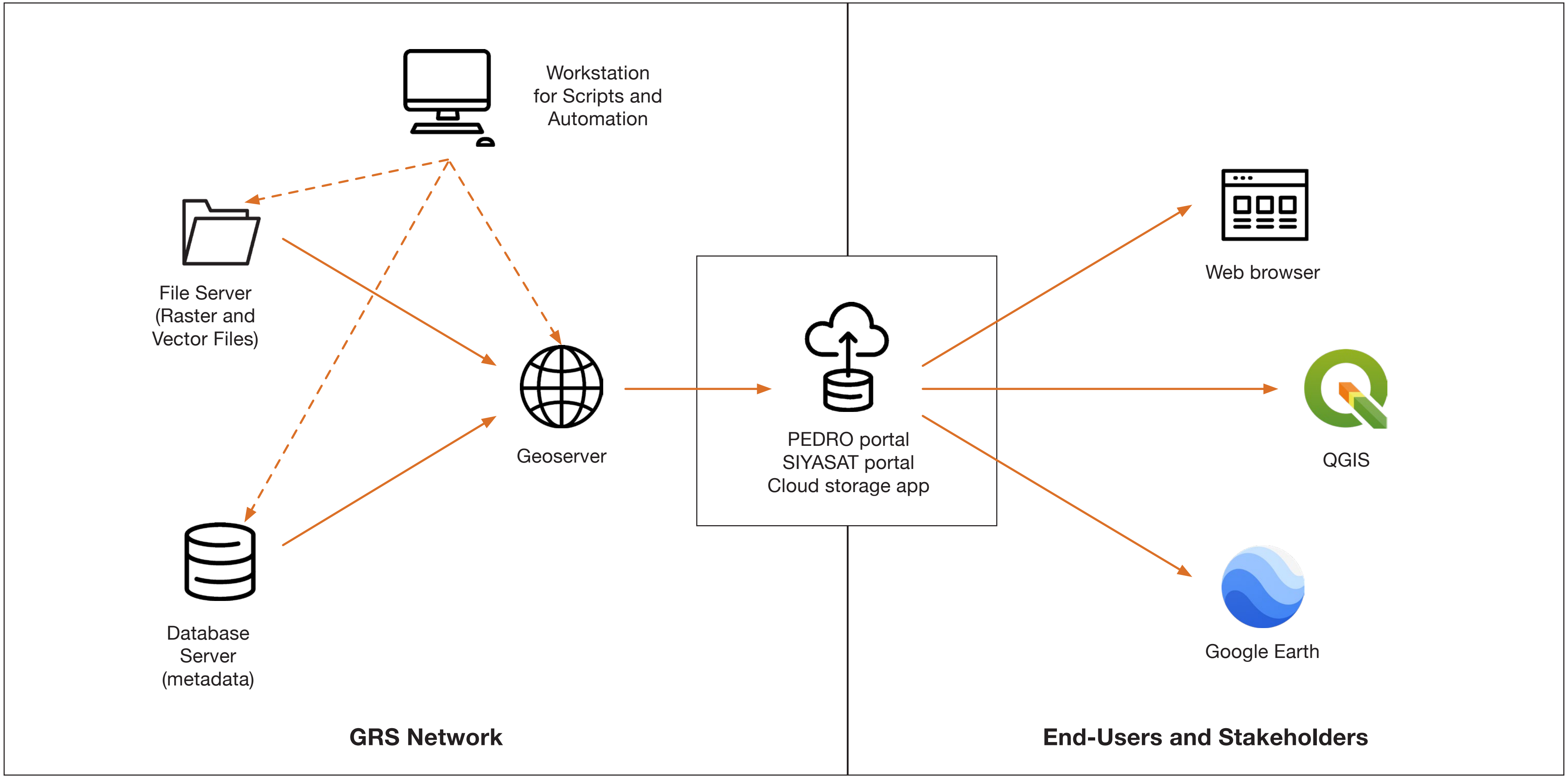
Antenna type	Tracking antenna
Location	Davao City, Davao del Sur Lat: 7.137° Long: 125.6504°
Antenna diameter	3.7 meters
Transmitting power	100W ~50dBW
Transmit Frequency Range	S -Band
Receive Frequency Range	X-Band, S-Band
Pointing Accuracy	< 0.1°
Velocity	5° per second
Acceleration	10° per sec. sq.
Polarization	LHCP and RHCP
Antenna Gain	~48.7dBi @ 8GHz ~36.7dBi @2.2GHz

The antenna in Davao is equipped with a fiberglass weatherproof radome.

Ground Receiving Station (GRS)

Automation of Data Archiving and Distribution

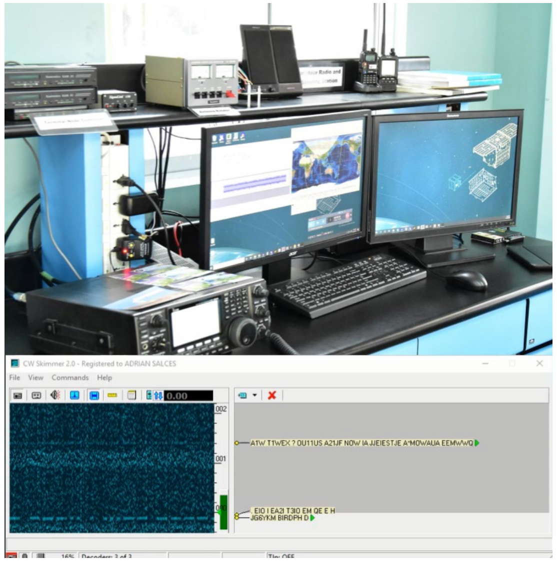
To accommodate the large number of image requests, the PEDRO GRS uses automated scripts to process the satellite images that will be distributed to stakeholders. Images downloaded from the satellites are archived to multiple storage servers. Image metadata are indexed in geospatial databases for fast spatial queries and data retrieval. These are made available through the PEDRO Portal and SIYASAT Portal where users can download them. A geoserver has been deployed to serve images on-the-fly thru GIS platforms.



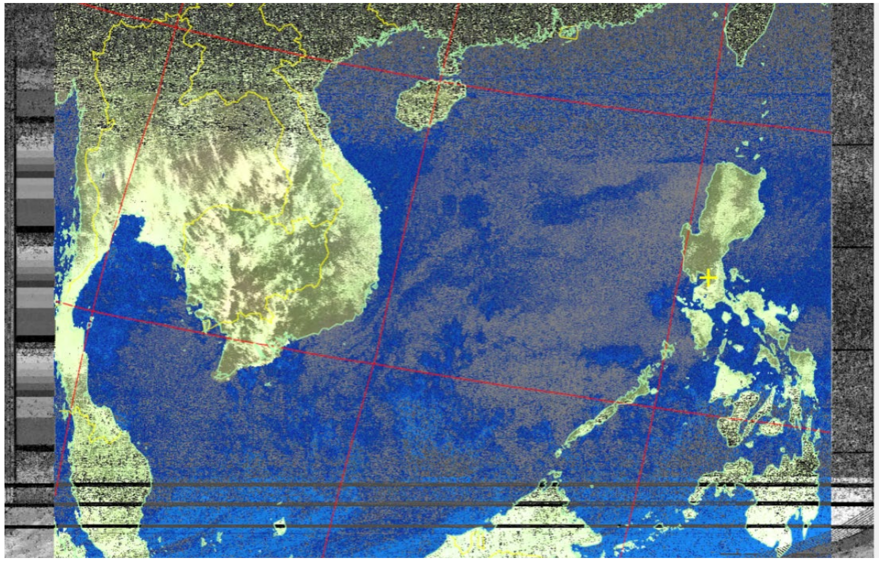
Ground Receiving Station (GRS)

Amateur Radio and Satellite Station

The ARSS supports operation of satellites in amateur bands (144-146 MHz and 435-438 MHz) and serves as a training ground to establish terrestrial and satellite communications in the amateur radio bands. The ARSS also serves as an avenue to promote awareness and interest in satellite technology. Here, students and researchers are given the chance to experiment on amateur satellite communications and develop new hardware and software methods in electronics and radio communication. With the ARSS, UPD-EEEI is able to collaborate with other universities and institutions in amateur satellite operations.



Amateur Radio and Satellite Station(ARSS) in ULyS³ES



Automatic Picture Transmission (APT) from NOAA 15 (137.6200 MHz). Other satellites that can be used: NOAA 18 (137.9125 MHz) and NOAA 19 (137.1000 MHz)

ARSS laboratory set-up in Mindanao State University - Iligan Institute of Technology (MSU-IIT)

Antenna tower installed in University of San Carlos

Ground Receiving Station (GRS)

Philippine Earth Data and Resource Observation (PEDRO) Center

Planning

The Ground Receiving Station prepares the commands for the satellite. These commands contain instructions such as the area that it has to capture.

Upload

The satellite tracking antenna in the GRS communicates with the satellite when it passes over the horizon. This is when monitoring of satellite health and upload of commands occur.

Capture

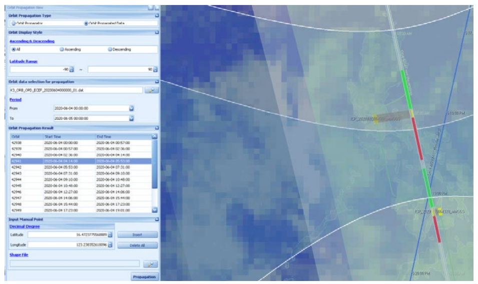
Upon successful upload of commands, the satellite can now capture images of over the area of interest.

Download

After the satellite captures the image, the GRS will download the image upon next contact. Satellite images will be processed for distribution to stakeholders.

Equipment

Image collection planning system



Equipment

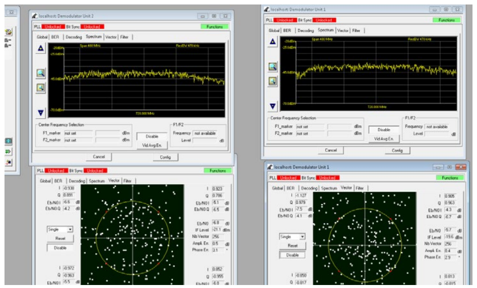
Data uplink

Equipment

Satellite Payloads

Equipment

Demodulators



Computing and Archiving Research Environment

Data Archiving, High-Performance Computing, and Science Cloud

Supercomputers are powerful machines that function to solve deeply complex problems that could result to breakthroughs in global research and development.

The COARE facility uses parallel processing (think of multiple computers clustered together in one convenient place) to combine computing power. This power is then utilized for the analysis of huge amounts of data and for the processing of calculations at high-level speed.

Presently, the COARE facility offers its HPC, Data Archiving, and Science Cloud services for free. It caters to diverse users that includes meteorologists, weather scientists, climate researchers, marine scientists, bioinformatics and genomic scientists and researchers, and students.

COARE
COMPUTING AND ARCHIVING RESEARCH ENVIRONMENT

HPC Service
2,320 logical cores (CPU)
20,800 cuda cores (GPU)
956 TB STORAGE
12.5 TB RAM
1,488 gaming laptops

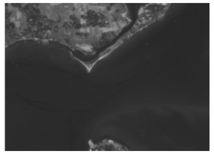
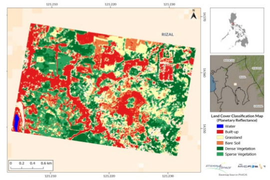
Science Cloud
2,304 CPU
435 TB STORAGE
2 TB RAM

Data Archiving
255 TB STORAGE
2,698 1TB hard drives

Remote Sensing

Optical Imaging

Through the images captured by the optical cameras on board both the Philippine-made satellites and foreign satellite subscriptions, remote sensing has been able to gather data about the physical characteristics of surfaces. In the case of the Philippines, this is largely used in Earth Observation. The PEDRO and STAMINA4Space teams then create products and applications based on the remotely sensed data gathered from space.

Level				Sample
0	10-bit Image in DN			10-bit Image in DN
1 *Processing (Geolocation and Radiometric Calibration)*	Georeferenced DN **L1A**	Calibrated Radiance **L1B**	TOA Reflectance **L1C**	 Raw Image w/ Radiometric Correction  Mosaic and Stacking of Multispectral Bands
2 *Processing (Product Development)*	Water-Leaving Reflectance **L2A**	Cloud and Aerosol Product **L2C**	Surface Reflectance **L2T**	 L2T: Ideal output after Level-2 Processing  L1C
3 *Processing (Generation of Land and Water Products)*	Turbidity Total Suspended Solids Chlorophyll-a **L3A** ***Aquatic***	Cloud Mask Aerosol Optical Depth 3D Cloud Reconstruction **L3C** ***Atmospheric***	Vegetation Indices Land Cover Classification Percent Tree Cover **L3T** ***Terrestrial***	 Level 2  Level-3 Land Product (Land Cover Map)

Applications

1. Post-Disaster Damage Assessment
2. Water Quality Assessment & Monitoring of Productive Turbid Inland Waters
3. Forest Monitoring
4. Land Cover and Land Use Applications

Artificial Intelligence

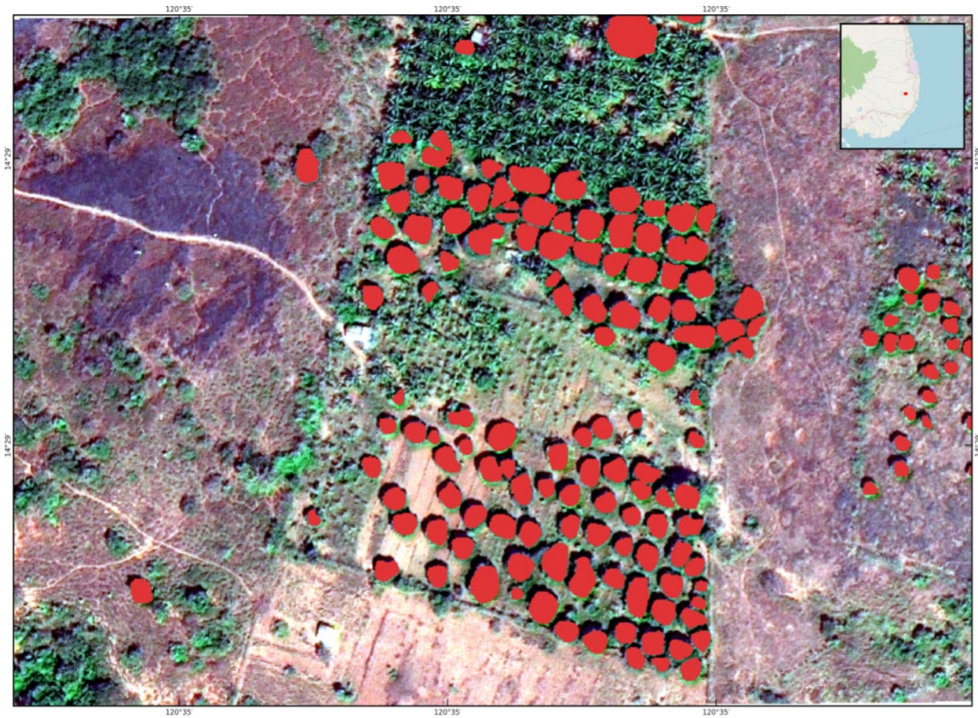
Using data to answer questions

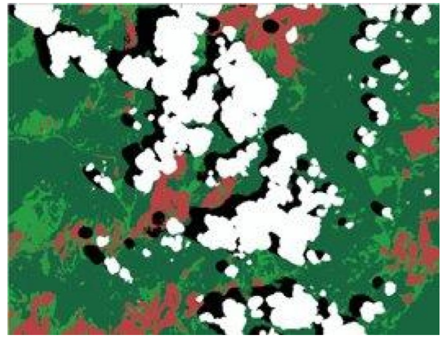
Land Cover Classification has three main stages: data gathering, data pre-processing and data-processing.

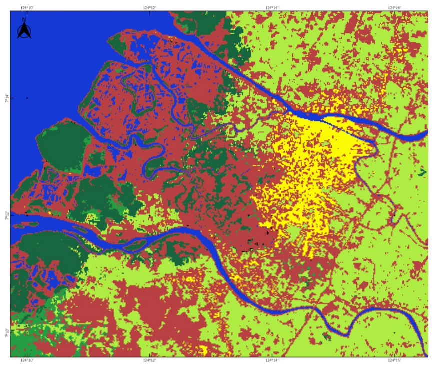
The data gathering phase comprises the downloading of data and research tools that might be useful for the enhancement of the process.

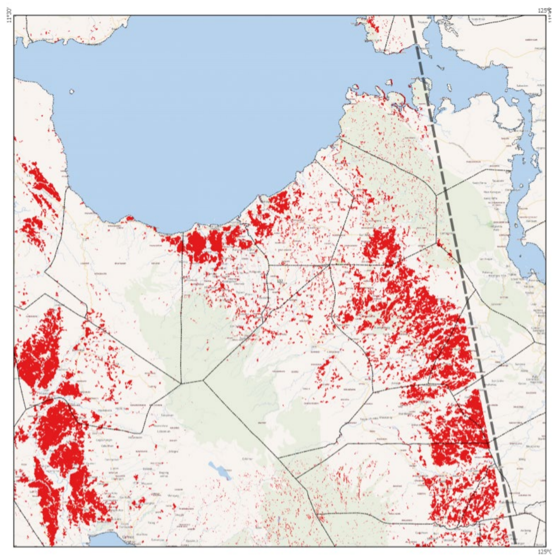
Data-pre-processing includes the normalization of data, creation of band indices, generation of an image for masking, and stacking of the normalized bands and indices.

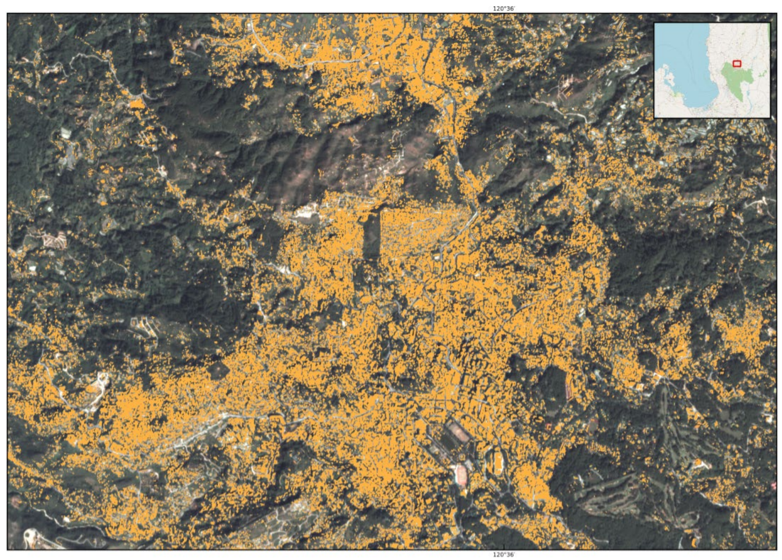
Data processing consists of classification of the stacked image and reclassification of the said image into images with two classes.











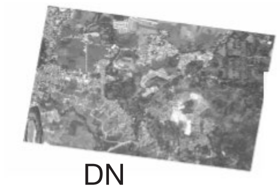
Data Processing

Diwata image processing

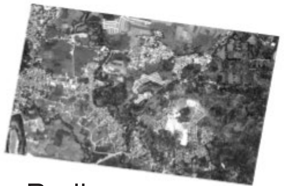
Diwata data is downloaded through the PEDRO Ground Receiving Station for the STAMINA4Space image processing team to convert into images we can see such as RGB images, and remote sensing products such as classification maps and the other products detailed in Volume 1. The process below shows how we arrive at such applications.

Pre-processing

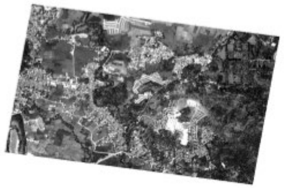
Converting DN to Radiance and TOA Reflectance



DN



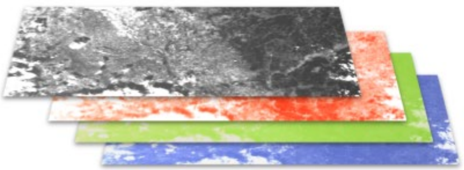
Radiance



Top-of Atmosphere Reflectance

Image Mosaicking and Stacking

NIR Band
Red Band
Green Band
Blue Band



Result

Training

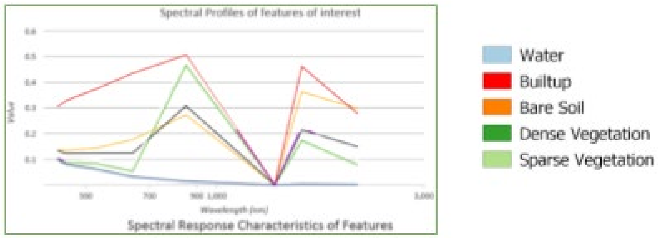
Training is the process of defining the criteria by which these patterns are recognized. We define recognized classes through Regions of Interests (ROIs). Contextual information and semantic relationships with neighbors is always used by photo-interpreters in visual analysis.

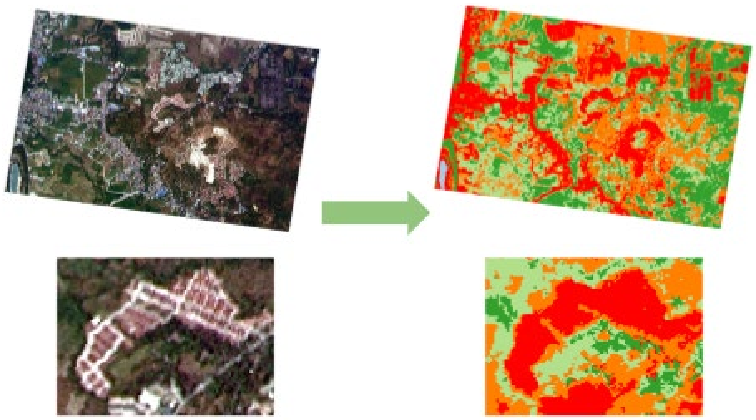
Data Processing

Diwata image processing

Classification

(CONT'D.) Classification proceeds by statistical processing where every pixel is compared with the various signatures of the training data and assigned to the class whose signature comes closest

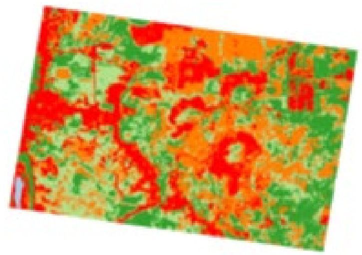




Accuracy Assessment

Lastly, we quantify the reliability of a classified image. The standard accuracy assessment procedure is to construct an "error matrix." This is a square matrix in which the rows and columns represent the land cover classes from the classified image. Classified image is cross checked with a reference of higher accuracy, e.g., high resolution maps, ground validation, official land cover maps.

Google Earth



1) Error matrix (confusion matrix):

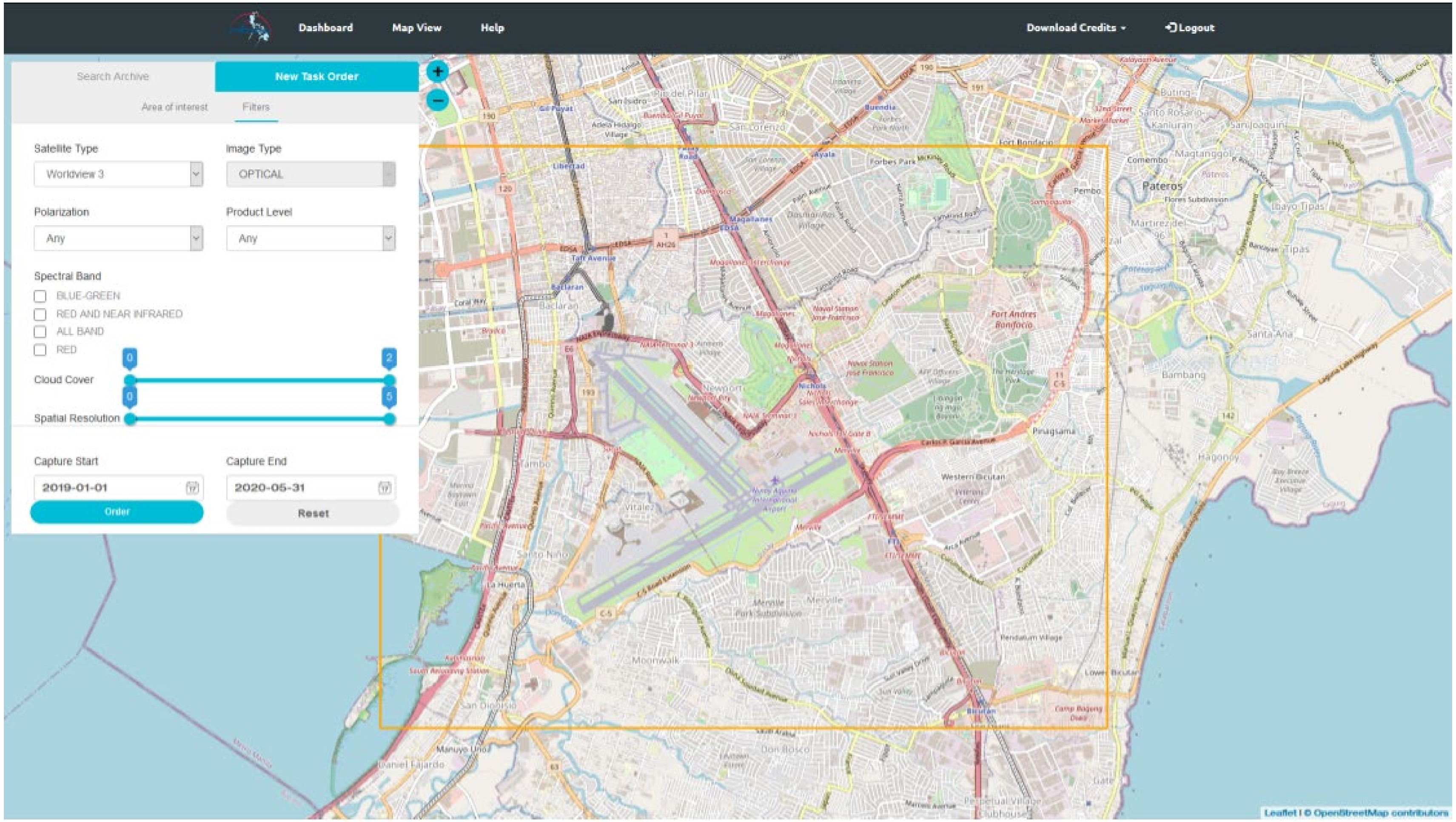
		Classified values								
		1 (Water)	2 (Builtup)	3 (Grassland)	4 (Baresoil)	5 (Dense Vegetation)	6 (Sparse Vegetation)	Total	User accuracy	Total class area (ha)
Thematic raster classes	1	1	0	0	0	0	0	1	1.0	2.10007
	2	2	91	2	5	0	1	101	0.90099	162.25432
	3	0	16	53	15	0	5	89	0.59551	144.08777
	4	0	13	1	24	0	0	38	0.63158	60.78643
	5	0	1	2	0	59	12	74	0.7973	115.16174
	6	0	3	7	5	6	72	93	0.77419	149.75004
	total	3	124	65	49	65	90	396		638.28038
	Producer accuracy	0.33333	0.73387	0.81538	0.4898	0.90769	0.8		0.75758	

Data Distribution

PEDRO Portal

The PEDRO portal enables users to view and download satellite images from the PEDRO image archive as well as submit new task orders. Due to the End User License Agreement with the satellite image providers, users of the portal is limited to government agencies and state funded universities.

Users can search available images on the archive or request for new task orders. by specifying important details such as area of interest, date of capture and preferred satellite.



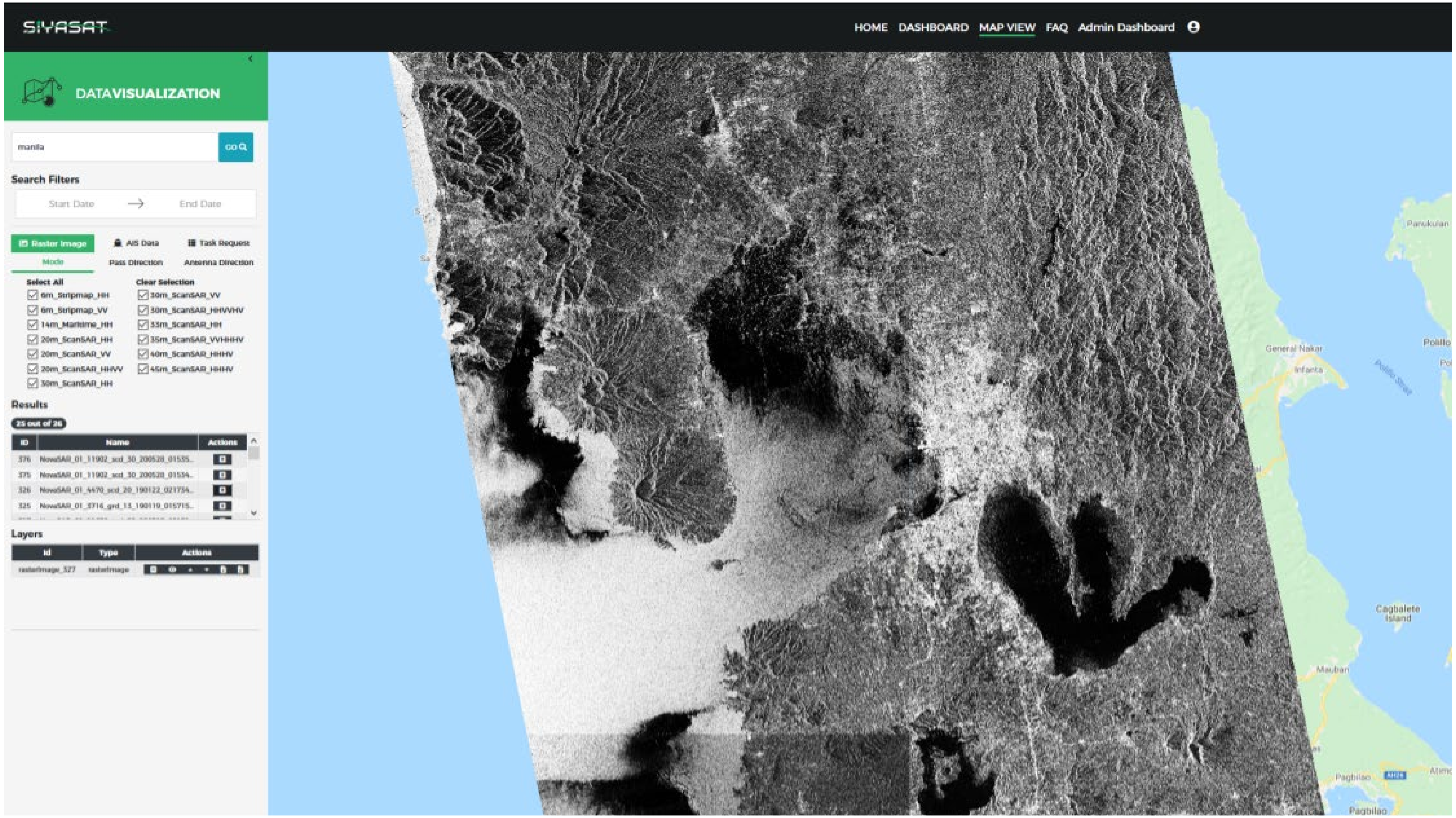
Data Distribution

SIYASAT Portal

The SIYASAT Portal enables partner agencies to task image capture requests for the NovaSAR-1 satellite. Partner agencies can track current and future paths of the NovaSAR-1 satellite to anticipate capture opportunities for their area of interest.

By filling out details such as image capture mode, area of interest, image capture duration, etc., users of the portal can submit their task requests.

The Data Visualization module of the portal also allows users to search for available images in the archive. People can search up the area of interest specified using its geographical name. The available images can be filtered by start date and end date as well as image capture mode. Images can also be viewed in the web browser on-the-fly. This is possible through the use of a web mapping server. Images are available for download as well.



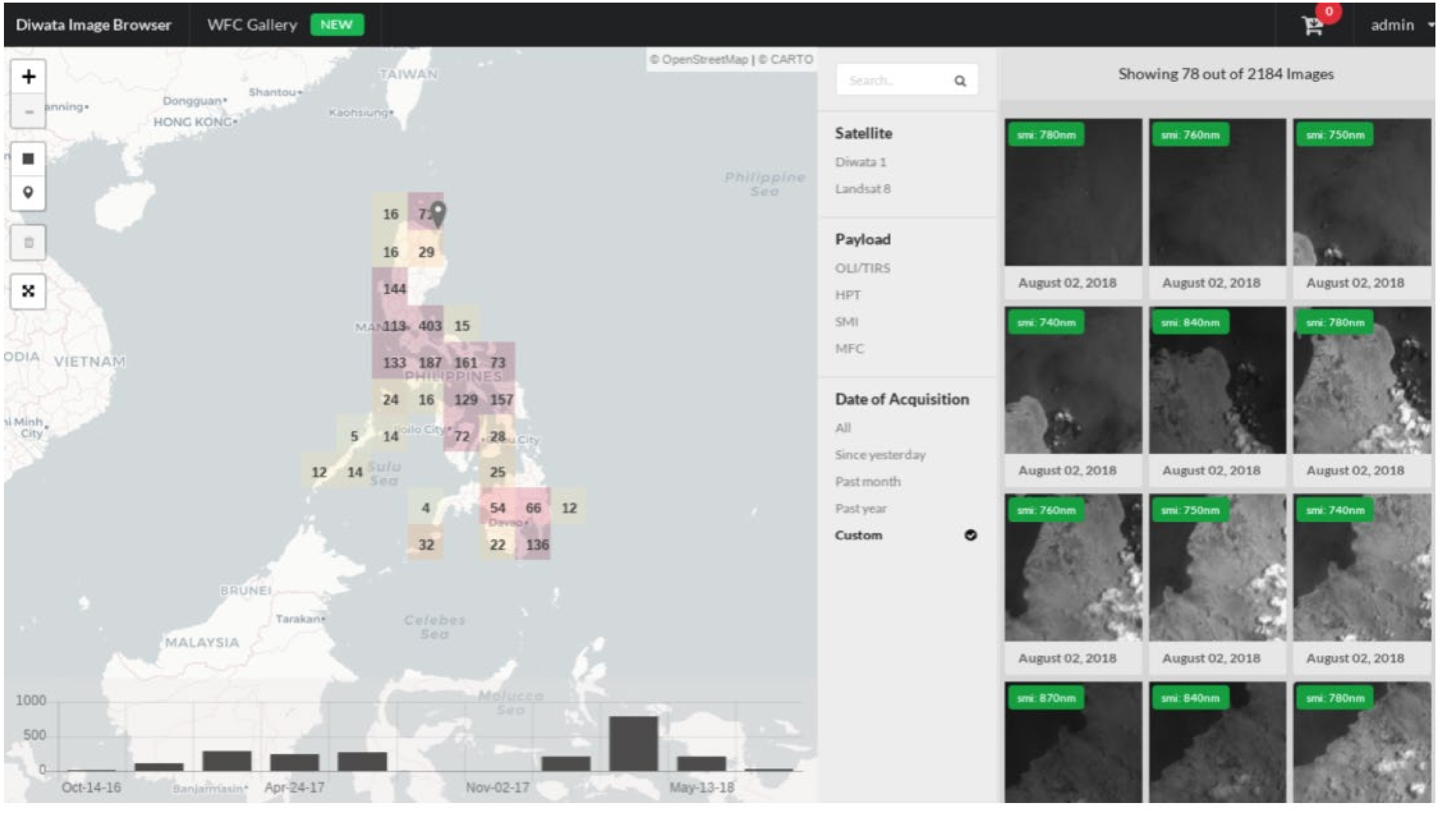
Data Distribution

PHL-Microsat/ STAMINA4Space Data Distribution SIte

To maximize the benefits from the development of Earth observation microsatellites, data from the PEDRO ground receiving station (GRS) is processed, archived, and distributed in a timely manner.

The STAMINA4Space program continues to operate and maintain the data portal built by PHL-Microsat. One of the program's components is focused on developing applicable in-house workflows, support software, and applications.

The current prototypes and implementations, while developed with Diwata data in mind, were designed to be adaptable and scalable to other RS data. The portal was built using free and open source software well and open geospatial standards.



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