Development of an Operating Strategy for On-Demand Earth Observation Missions of the Diwata-2 Microsatellite

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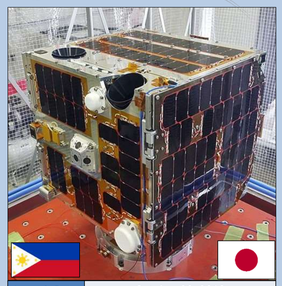
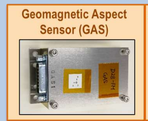
I. The Diwata-2 Microsatellite

- The 2nd Philippine-made satellite in collaboration with Tohoku University and Hokkaido University in Japan.
- Primary mission: Gather remote sensing data for post-disaster assessment, environmental studies, and resource management.
- For on-demand operation, Diwata-2 uses its attitude components capable of off-nadir observations by its optical payloads.



Launch Date	October 29, 2018
Orbit	595km x 616km, 97.84^o
Size & Mass	57 kg , 490mm x 490mm x 490mm
Ground Station Network	Quezon City, Philippines Sendai & Hakodate, Japan Kiruna, Sweden

Coarse Attitude Determination



Geomagnetic Aspect Sensor (GAS)

Sun Aspect Sensor (SAS)

Measures magnetic and light intensity in a Triad algorithm

Fine Determination

Star Tracker (STT)

Detects star patterns

FOG Integration

Fiber Optic Gyroscope

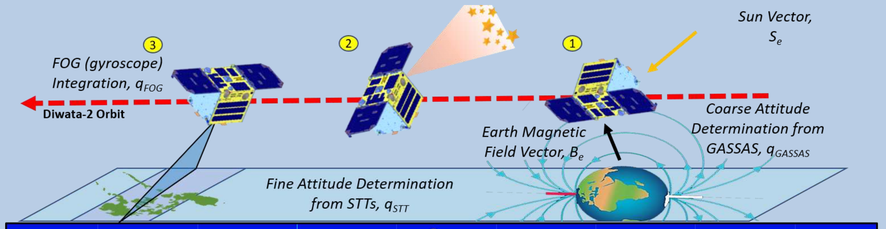
Propagates attitude readings

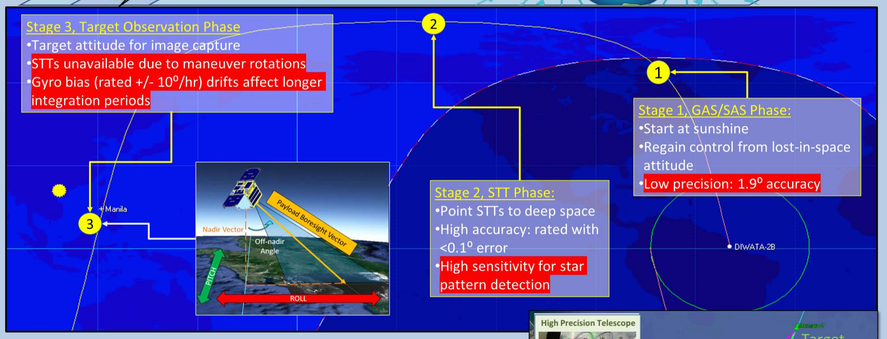
GOAL: It is aimed to achieve a 0.1^o target pointing accuracy of on-demand Earth observation operation by Diwata-2.

Diwata-2 Operating Strategy

- ❑ Pointing Performance Analysis
- ❑ Star Tracker Sensor Calibration
- ❑ Target Pointing Calibration
- ❑ Scheduling of Components

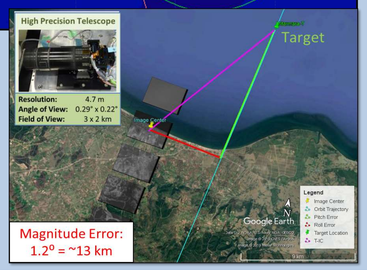
II. Earth Observation Mission Sequence



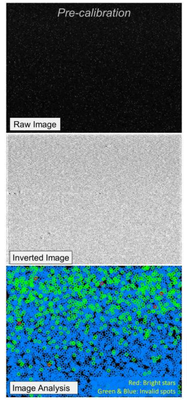


Initial Pointing Performance

- Earth observation trials were carried out using the High Precision Telescope (HPT) payload.
- Both nadir and off-nadir observation modes were tested.
- The recorded initial trials resulted into an average and standard deviation of **2.88°±2.06°** RMS.
- The initial trial results may be acceptable for payloads with a large FOV, but does not satisfy the < 0.1^o pointing requirement.

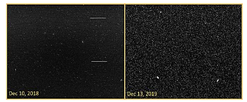


III. Star Tracker Sensor Calibration



- The initial STT images were analyzed using simulation ground software.
- An invalid star pattern detection caused failure in the Fine Attitude Determination.
- Initial poor precision may be caused by the lengthy propagation of the coarse GAS/SAS readings over an extended integration period.
- Possible causes and countermeasures are suggested:

Image Noise – White spots, caused by radiation environment, may mask stars captured. The STT's sensor parameter settings may minimize this effect.

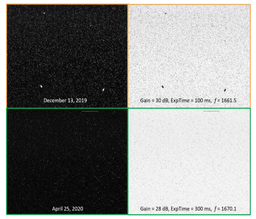


Light Interference – Stray light overexpose the star images. Satellite attitude should account for the sun, earth, and moon incident angles.

Insufficient Bright Stars – A certain number of bright stars are required. For practical purposes, STT detection duration would be extended.

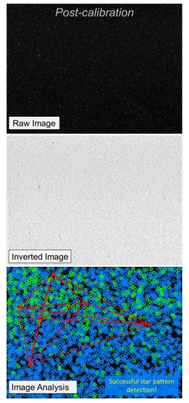
Functional Condition	Reqt
Angular Velocity	< 0.3^o/s
Sun Incident Angle	> 80^o
Moon Incident Angle	> 50^o
Earth Incident Angle	> 120^o
Number of Stars	> 12

In-flight tuning experiments of the sensor parameter settings, duration, and attitude are performed to find the right mix for a successful star pattern detection by the STTs.



STT Parameter Settings to adjust image quality

- *Gain* – Controls apparent light sensitivity; but also amplifies image noise.
- *Exposure Time* – Controls the amount of light detected; but more vulnerable to movement distortion.
- *Focal Length*, *f* – Adjusts the transformation of the image frame into the local frame by onboard software.

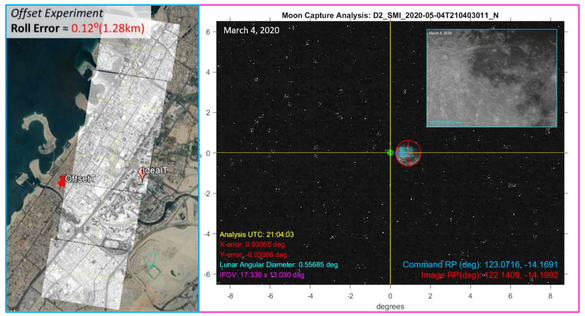


Duration	Attitude	STT Parameter Settings
>15 minutes	φ=30^o, θ=0^o, ψ=180^o	Exp. Time = 400ms, Gain= 28dB, f = 1670.1

- Shown above are the working set of conditions for STT operation
- Post-STT Calibration observation resulted in an accuracy of **1.79°±0.59° RMS**.
- Success of Fine Attitude Determination improved precision significantly.

IV. Target Pointing Calibration(1)

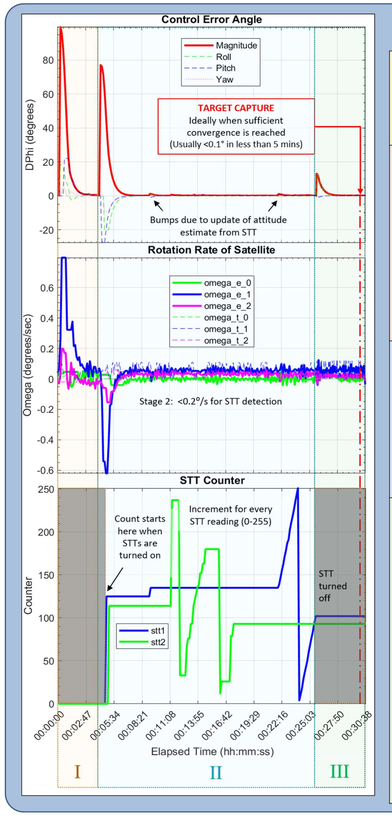
- The Target Pointing Calibration study presents further work on persisting systematic issues:
  - Lunar observation experiments to adjust for system misalignments
  - Deterministic satellite operation management for system latency and orbital model inaccuracies.
- Satisfactory results where achieved: **0.2°±0.12° RMS** pointing accuracy.



[1] E. P. Violan et al., "In-Flight Target Pointing Calibration of the Diwata-2 Earth Observation Microsatellite," 2021 IEEE Aerospace Conference (50100), 2021, pp. 1-15, doi: 10.1109/AERO50100.2021.9438197.

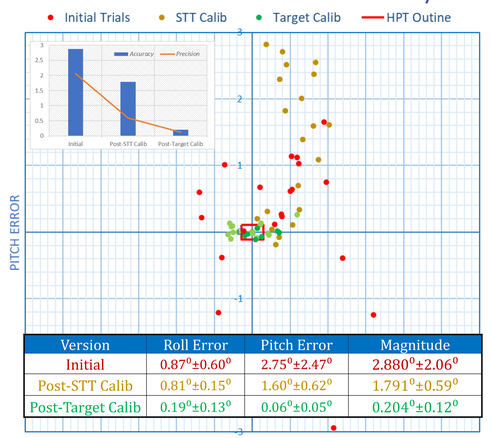
V. Recommended Operating Strategy

- Details of the command timing and the recommended conditions can now be prescribed.
- Attitude flight log data of an actual implementation of this mission procedure are also shown.



	Duration (mm:ss)*	Operation
Stage 0	n/a (Plan prior to the nearest opportunity of target capture)	Target Attitude Calculation: Use latest TLE orbit model
		Synchronize and Update On-board Orbital Model
		Upload of Stored Commands
Stage I: GAS/SAS Phase	S + 0:00 (Begin at least 1 minute after satellite enters sunshine)	Resume ADCS operation: Initialize ACU Turn on Control System and actuators
	S + 1:00	**Coarse attitude determination is activated**
	S + 1:10	Set satellite for optimum SAS detection: φ=-35^o, θ=-45^o, ψ=-180^o
Stage II: STT Phase	S + 3:00	Turn On STT and initialize Parameter Settings: *Gain = 400ms, Exp. Time = 28dB, f = 1670.1*
	S + 5:00	**Fine attitude determination is activated**
	S + 5:10	Set satellite for optimum STT detection: φ=30^o, θ=0^o, ψ=180^o
Stage III: Observation Phase	T - 5:10	Turn Off STT **FOG attitude integration is activated**
	T- 5:00 (At least 5 minutes before mission capture)	Set satellite to target attitude: $[\varphi, \theta, \psi]_{target}$
	T - 4:30	Initialize SHU and Optical Payloads
	T - 3:00	Load capture control Settings for Payloads
	T	**Sequential Image Capture Of Target**
	T + 0:30	Save Images to Flash Memory
	T + 1:00	Turn off SHU and Optical Payloads
	T + 2:00	Release Active Attitude Control: Turn off sensors and actuators

Earth Observation Trials Summary



Version	Roll Error	Pitch Error	Magnitude
Initial	0.87^o±0.60^o	2.75^o±2.47^o	2.880^o±2.06^o
Post-STT Calib	0.81^o±0.15^o	1.60^o±0.62^o	1.791^o±0.59^o
Post-Target Calib	0.19^o±0.13^o	0.06^o±0.05^o	0.204^o±0.12^o

VI. Conclusion

The study presented an operation strategy for successful on-demand earth observations by Diwata-2:

- ✓ Gradually improved the accuracy from 2.8° to 0.2°
- ✓ 0.1° accuracy in at least 24% of its post-target calibration trials
- ✓ Covered 82.8% of the Philippine's land area with over 400 successful Earth observation missions