

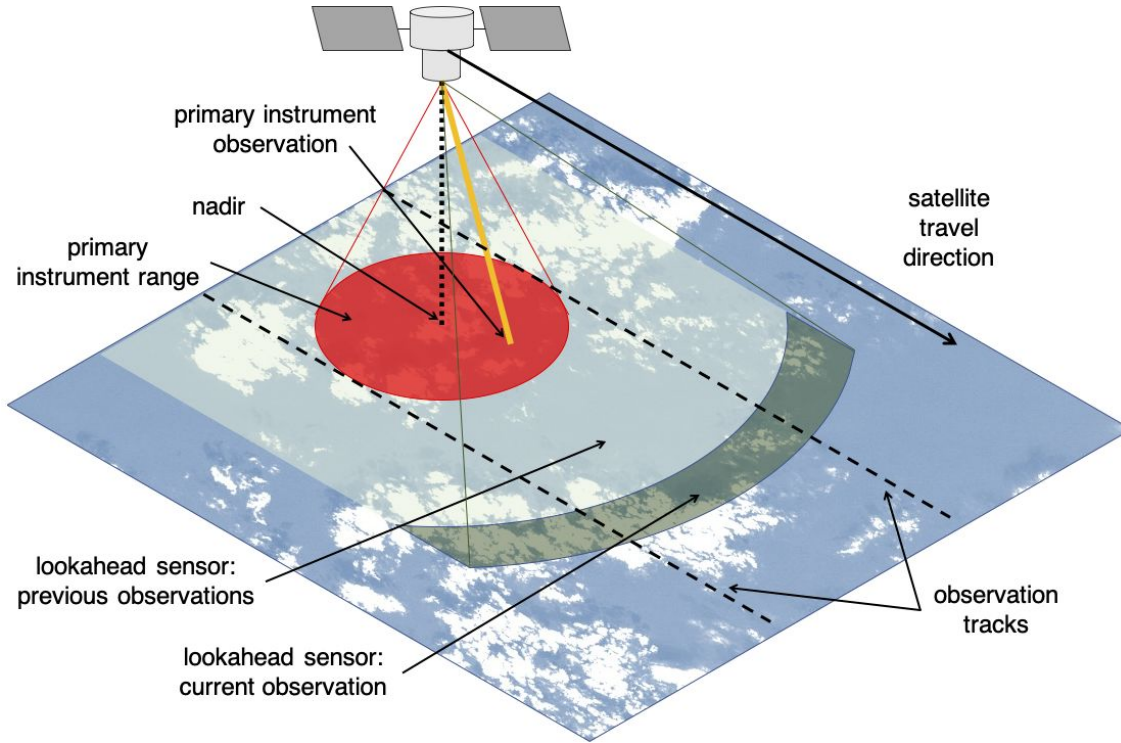
Dynamic Targeting on CogniSAT-6 - Flight Report

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What is Dynamic Targeting?

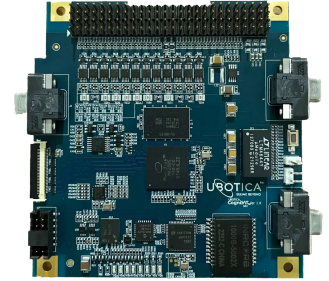


- Use lookahead or wide FOV sensor to acquire data
- Rapidly process data for insights
- Use gleaned knowledge to retarget primary sensor (in the same overflight)

For further details see [Candela et al. 2023 JAIS].

Rapidly Changing Earth Observation Market

- Edge Computing - many such satellites have significant edge computing, at least by conventional flight computing standards
 - Multiple GHz+ ARM cores commonplace
 - Edge AI computing via Intel Myriad, Nvidia, etc.
- Proliferated LEO - many more Earth Observation satellites spurred by new entrants and decreased launch costs
- Intersatellite Link - use of commercial constellations as communications pathway leads to 24/7 connectivity for KB/s notifications (e.g. knowledge not data)



Intel Myriad Edge Processor
Image courtesy Ubotica

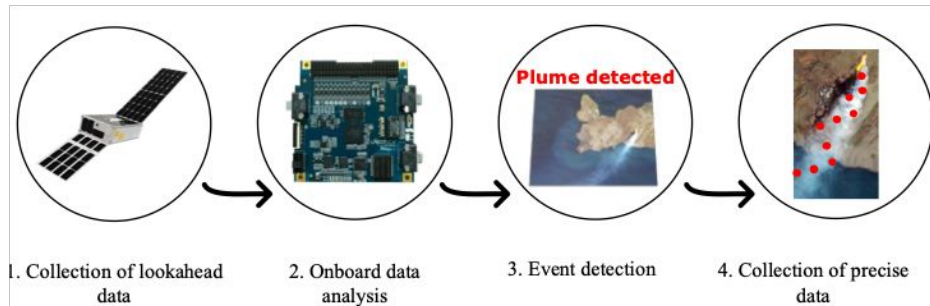
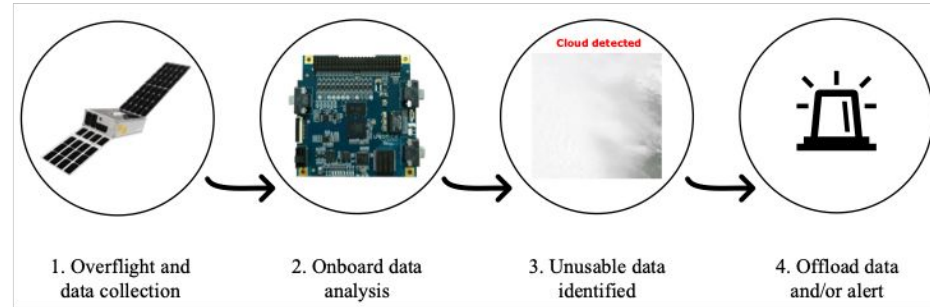


Proliferated LEO and
Intersatellite links

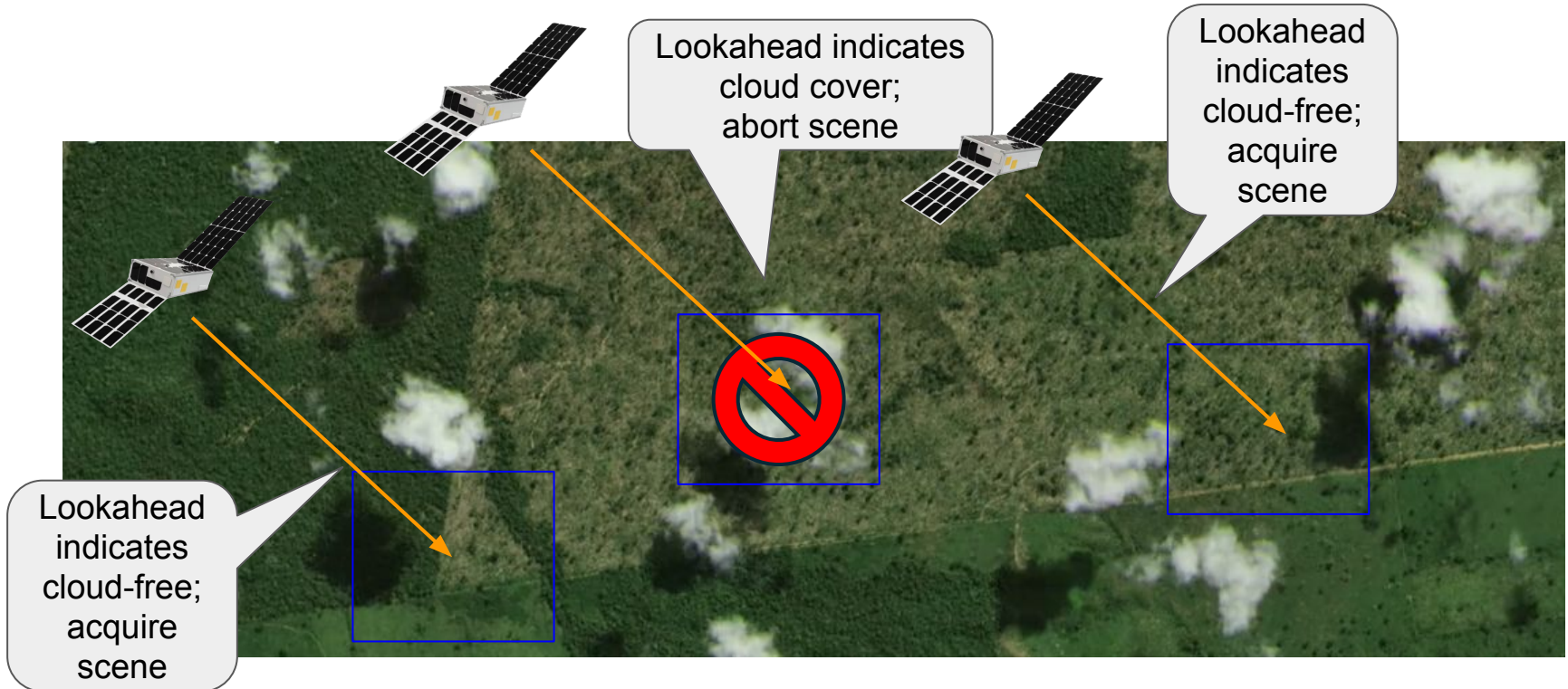
Motivation: Why deploy data analysis at the edge?

Optimization of resources and observations

- Reactive:
 - Acquire data and reject if bad
 - Save storage and downlink
- Proactive (*Dynamic targeting*):
 - Look-ahead data
 - Saves:
 - Storage
 - Downlink
 - Time/energy (slewing)



DT Use Case - Active Cloud Avoidance



e.g. see [Suto et al, 2021 AMT]; also see Deep Convective Ice Storms [Swope et al. 2024] and Planetary Boundary Layer [Candela et al. 2024]

Overview of CogniSAT-6

- 6U Cubesat
- Launched March 2024
- Sun-synchronous orbit at 500 km
- Myriad X Vision Processing Unit (VPU)
 - Rapid computer vision
 - Image signal processing
 - Neural network execution
- Hyperscape 100 Instrument
 - 440nm–884nm
 - Can select 32 out of 442 spectral bands
 - GSD of 5 meters per pixel

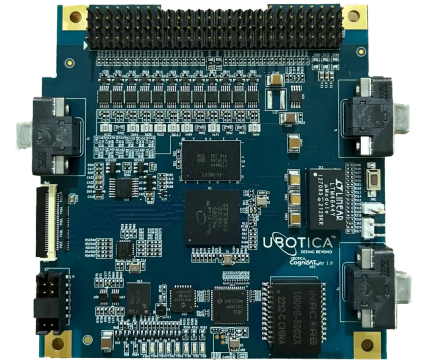
For further details on CS-6 see [Rijlaarsdam et al. 2025 JSTARS].
For further details on onboard analysis see [Chien et al. 2024 IGARSS, Zilberstein et al. 2024 i-SAIRAS]



CogniSAT-6 launch on 4 March 2024 on Transporter-10 from Vandenberg Space Force Base, CA, USA. Image courtesy of SpaceX



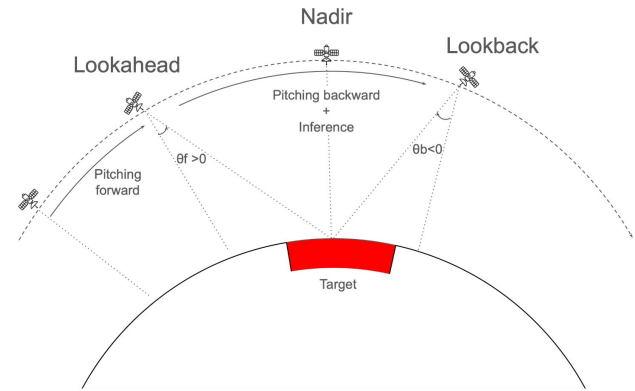
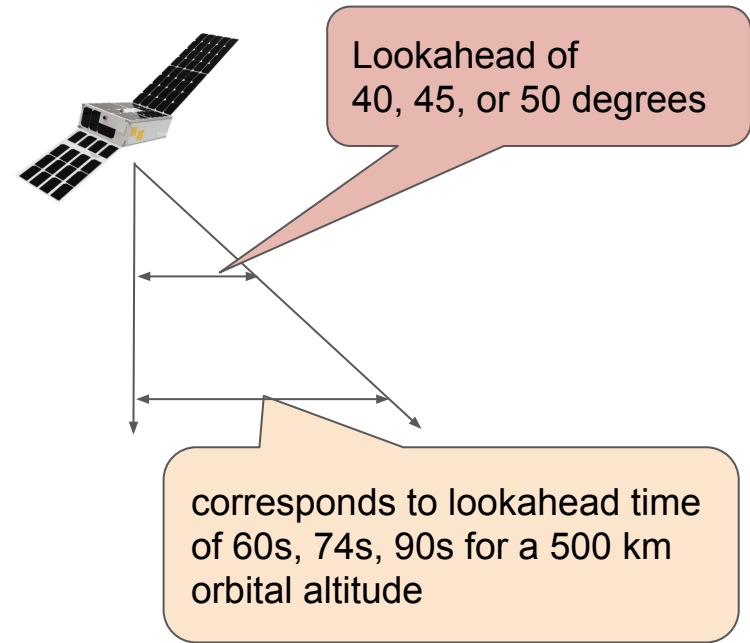
CogniSAT-6 Spacecraft
Image courtesy of Open Cosmos



Intel Myriad X VPU
Image courtesy of Ubotica Technologies

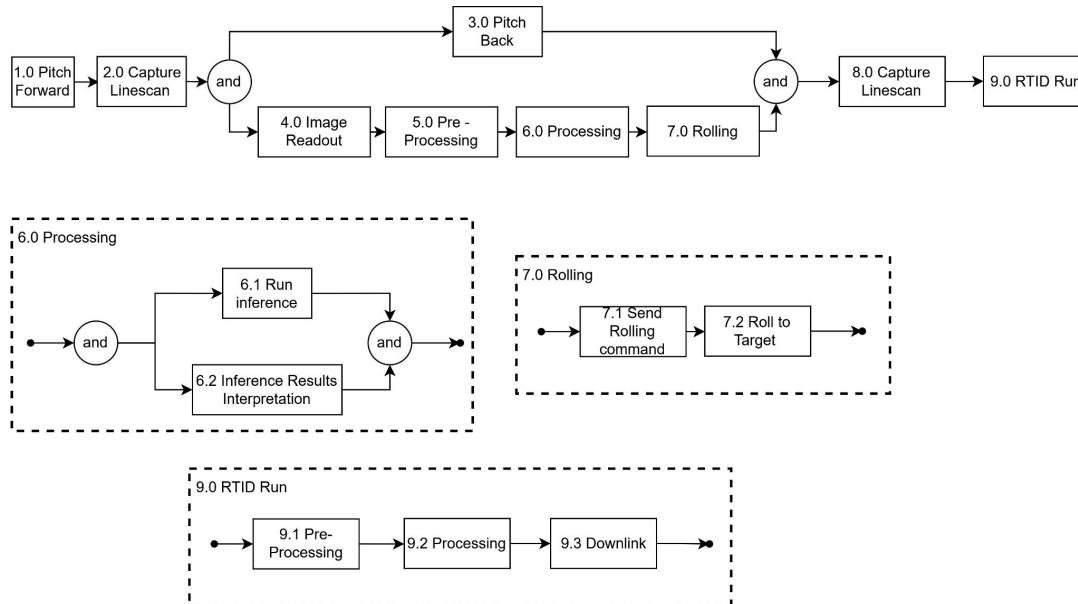
Challenges to flight

- CogniSAT-6 does not carry a dedicated lookahead sensor; therefore slewing from lookahead to nadir must be accounted for in response time.
- Sensor readout on CogniSAT-6 was not designed with DT scenario in mind.
 - To speed readout, reducing data volume that is readout.
 - Readout subsampling of the pan-band for lookahead interpretation.



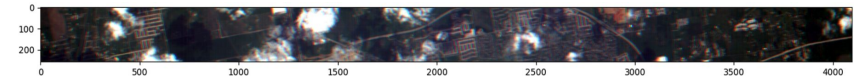
Functional Flow for DT on CogniSAT-6

- After a look-ahead image is acquired the image is processed in parallel as the spacecraft pitches back towards nadir

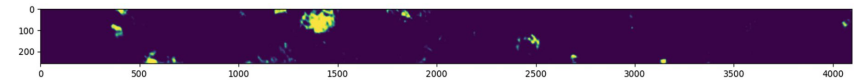


DT Algorithm on CogniSAT-6

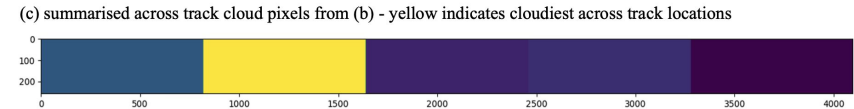
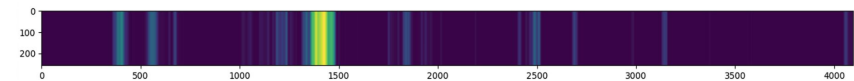
- Input: panchromatic look-ahead imagery
 - Output: roll angle to view
1. Classify look-ahead imagery using CNN
 2. Compute across track cloud presence
 3. Compute fixed window summarization
 4. Select lowest value window and retrieve roll angle from ground computed table



(a) Illustrative "notional" Lookahead image. Includes imagery from CogniSAT-6/HAMMER, 2025, Ubotica. All rights reserved.



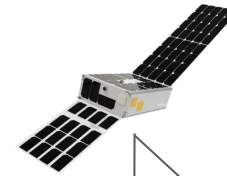
(b) cloud classifier run on (a) - yellow indicates identified clouds



(d) fixed window summarization across track from (c) (brightest = most clouds, darkest = least clouds)

Difficulties encountered in Flight

- 50 degree lookahead along track creates and spectral band sequential readout causes along track spectral band misalignment
- Short Term solution - switch to single (pan) band classifier
- Long Term Solution - build a model of the offset impact as a function of look angle and build an inverse model.



Lookahead of 40, 45, or 50 degrees

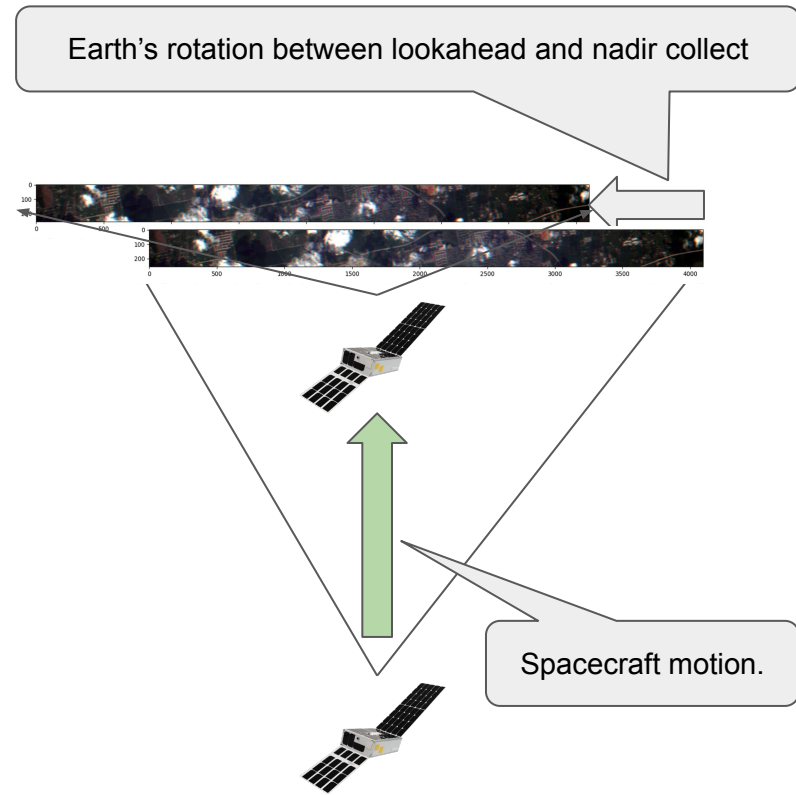
corresponds to lookahead time of 60s, 74s, 90s for a 500 km orbital altitude

Current flights do this.

We are testing this.

Difficulties encountered in Flight

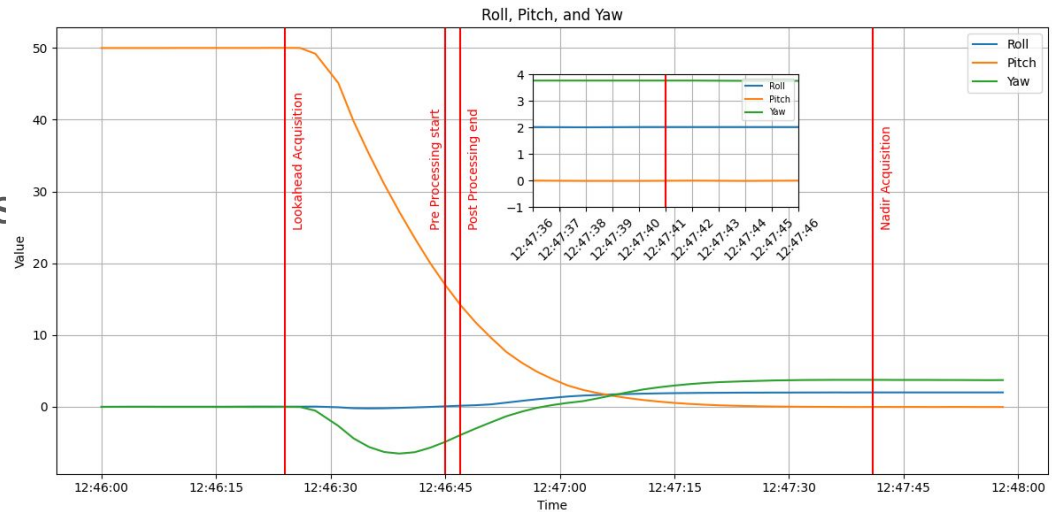
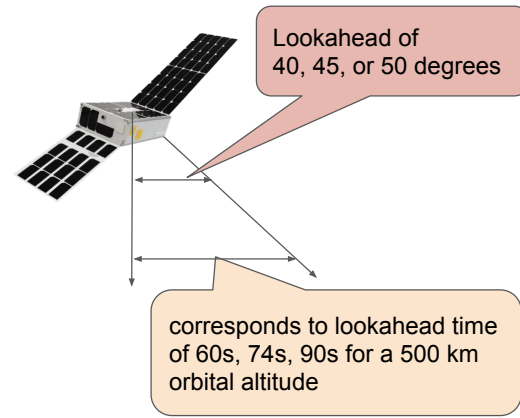
- The Earth's rotation has a maximum surface velocity of ~ 465 m/s at the equator \rightarrow up to 41.85 km in 90 s for a direct N/S trajectory.
- Using lat/lon of the observation and the orbit ground track we pre-calculate the roll angle offset to account for the Earth's rotation in between the lookahead and near nadir acquisitions.
- Alternatively we could have canted the lookahead image to the starboard (right) so that it more closely aligned with the nadir track however that would have increased footprint distortion (which already occurs due to the Earth's curvature).



Mostly daylight is descending node but similar calculations apply for ascending nodes.

Reducing the Timeline

- How much can the lookahead be reduced?
- Shorter lookahead means less distorted images and less time for conditions to change
- Slewing is the driving factor
- CogniSAT-6 performance seems indicate that 74 s / 45 degree lookahead is feasible



Related Work

- Near-real-time onboard spectral Cloud screening for AVIRIS and EMIT [Thompson et al. TGARS 2014]
- Cloud avoidance using lookahead visible sensor TANSO-FTS2 GOSAT2 [Suto et al. AMT 2021]
- Lookahead radiometer to target radar at deep convective ice storms (proposed) SMICES [Swope et al. JAIS, 2024]
- Simulated lookahead for cloud detection and storm measurement [Candela et al. JAIS 2023]
- Simulated Cloud Avoidance [Hasnain et al. IWPSS 2021]

Next Steps

- Deployment of Dynamic Targeting to spacecraft with dedicated lookahead sensor
- Deployment of Dynamic Targeting for Science Missions
- Widespread deployment of onboard image analysis and cross-cue-ing using inter-satellite link – FAME demonstration [Chien et al. 2025 SpaceOps]

Conclusions

- Dynamic Targeting
 - Uses a lookahead sensor to acquire data
 - Rapidly analyzes such data using edge computing
 - Uses this analysis to target a primary sensor; increasing science return
- Several science use cases for dynamic targeting exist including cloud avoidance, hunting for deep convective ice storms, and capturing planetary boundary layer events
- Demonstration of dynamic targeting technology on the CogniSAT-6 spacecraft in July-September 2025.

References

Intel Myriad X <https://www.intel.com/content/www/us/en/products/details/processors/movidius-vpu/movidius-myriad-x/products.html>

Lemoigne, J. New Observing Strategies, <https://esto.nasa.gov/wp-content/uploads/2020/03/20200225IntroNOSWorkshopLeMoigne.pdf>

ESA Φ -lab. <https://philab.esa.int>

Candela A, Swope J, Chien SA. Dynamic targeting to improve earth science missions. *Journal of Aerospace Information Systems*. 2023 Nov; 20(11):679-89.

Suto, H., Kataoka, F., Kikuchi, N., Knuteson, R. O., Butz, A., Haun, M., Buijs, H., Shiomi, K., Imai, H., and Kuze, A.: Thermal and near-infrared sensor for carbon observation Fourier transform spectrometer-2 (TANSO-FTS-2) on the Greenhouse gases Observing SATellite-2 (GOSAT-2) during its first year in orbit, *Atmos. Meas. Tech.*, 14, 2013–2039, <https://doi.org/10.5194/amt-14-2013-2021>, 2021.

Chien S, Candela A, Zilberstein I, Rijlaarsdam D, Hendrix T, Dunne A. Leveraging commercial assets, edge computing, and near real-time communications for an enhanced New Observing Strategies (NOS) flight demonstration. In *IEEE Geoscience and Remote Sensing Symposium 2024*.

Swope J, Chien S, Bosch-Lluis X, Dunkel E, Yue Q, Ogut M, Ramos I, Kangaslahti P, Deal W, Cooke C. Storm Classification and Dynamic Targeting for a Smart Ice Cloud Sensing Satellite. *Journal of Aerospace Information Systems*. 2024 Oct:1-4.

References

- Teixeira J, Piepmeier JR, Nehrir AR, Ao CO, Chen SS, Clayson CA, Fridlind AM, Lebsock M, McCarty W, Salmun H, Santanello JA. Toward a global planetary boundary layer observing system: The NASA PBL incubation study team report. Toward a Global Planetary Boundary Layer Observing System: The NASA PBL Incubation Study Team Report. 2021 Nov 20.
- Candela A, Victoria JD, Zilberstein I, Kurowski M, Yue Q, Chien S. Dynamic Targeting Scenario to Study the Planetary Boundary Layer. InIGARSS 2024-2024 IEEE International Geoscience and Remote Sensing Symposium 2024 Jul 7 (pp. 1426-1429). IEEE.
- Rijlaarsdam D, Hendrix T, González PT, Velasco-Mata A, Buckley L, Miquel JP, Casaled OA, Dunne A. The Next Era for Earth Observation Spacecraft: An Overview of CogniSAT-6. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 2024 Dec 2.
- Zilberstein I, Candela A, Chien S, Rijlaarsdam D, Hendrix T, Buckley L, Dunne A. Demonstrating Onboard Inference for Earth Science Applications with Spectral Algorithms and Deep Learning. Intl Symposium on Artificial Intelligence, Robotics, and Automation for Space, Brisbane, Australia, November 2024.
- Thompson DR, Green RO, Keymeulen D, Lundeen SK, Mouradi Y, Nunes DC, Castaño R, Chien SA. Rapid spectral cloud screening onboard aircraft and spacecraft. IEEE Transactions on Geoscience and Remote Sensing. 2014 Feb 19;52(11):6779-92.
- Hasnain, Z.; Mason, J.; Swope, J.; Vander Hook, J.; and Chien, S. Agile Spacecraft Imaging Algorithm Comparison for Earth Science. In International Workshop on Planning & Scheduling for Space (IWSPSS), July 2021.
- Chien, S.; Zilberstein, I.; Candela, A.; et al. Multi-Asset New Observing Systems Flight Demonstratio. International Conference on Space Operations, May 2025.



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