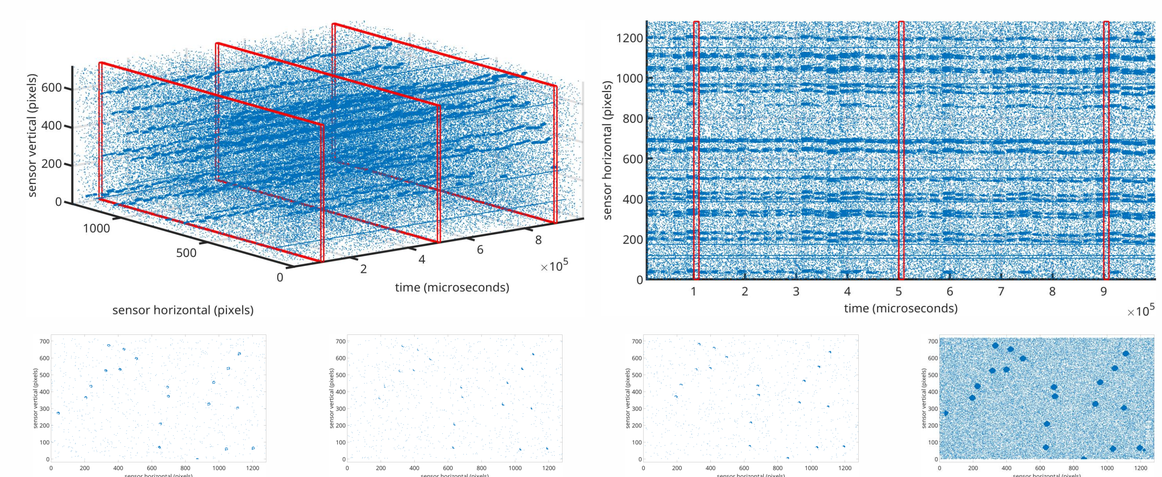
High Frequency, High Accuracy Pointing onboard Nanosats using Neuromorphic Event Sensing and Piezoelectric Actuation

Yasir Latif[1], Peter Anastasiou[2], Yonhon Ng[3], Zebb Prime[2], Tien-Fu Lu[1], Matthew Tetlow[2], Robert Mahony[3], and Tat-Jun Chin[1]

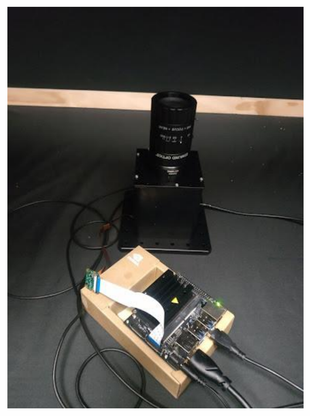
The need for stable pointing

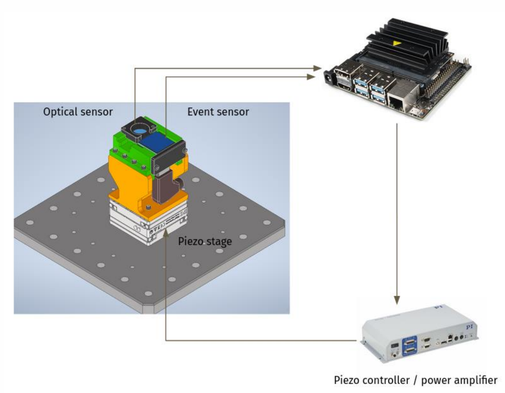
Space-based applications require **precise control of spacecraft attitude** to accurately and consistently point onboard sensors towards target objects or regions in a distant orbit.

Attitude control remains an obstacle on nanosatellites due to **limited sensing** capabilities present on-board and external and internal factors sources of **perturbations** (e.g., atmospheric drag, unwanted torques from reaction wheels).



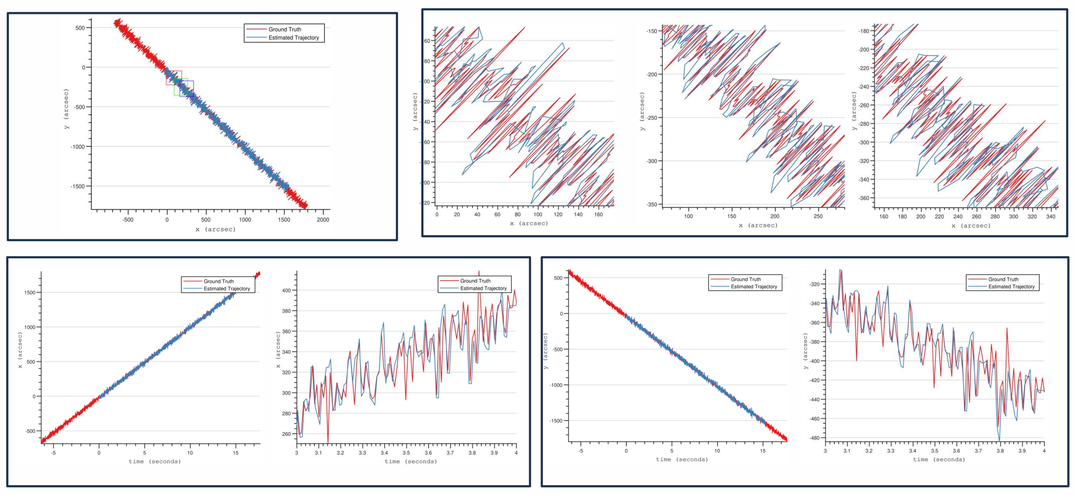
(Top) Space-time Event volume observing jitter in stars (Bottom) 10ms event batches extracted from the stream (1-3) and the spread of light over multiple pixels caused by perturbation in the 1-second-long exposure (4)





(Left) System Prototype (Right) Hardware components

100Hz Ultra-fine tracking



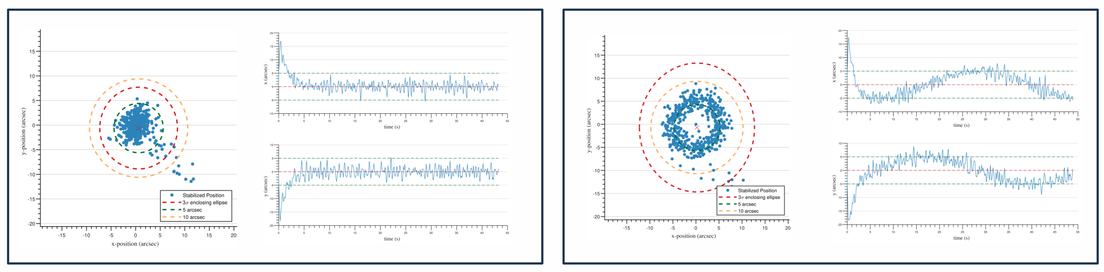
Tracking under high frequency perturbations: (Top) The executed noisy track along with tracking results (Bottom) Tracking performance along the x- and y- direction over time along with a zoomed in view for the 3-4 second time window.

High frequency sensing using event cameras

Building on the **high-frequency sensing** provided by the neuromorphic event sensor, we detect high-frequency perturbation experienced by the mission sensor. The **event cameras** provides relative attitude estimates at 100Hz, enabling "**ultra-fine attitude estimation**". The **piezoelectric stage** corrects for the estimated perturbations leading to "**ultra-fine stabilisation**" for both the event sensor and mission sensor.

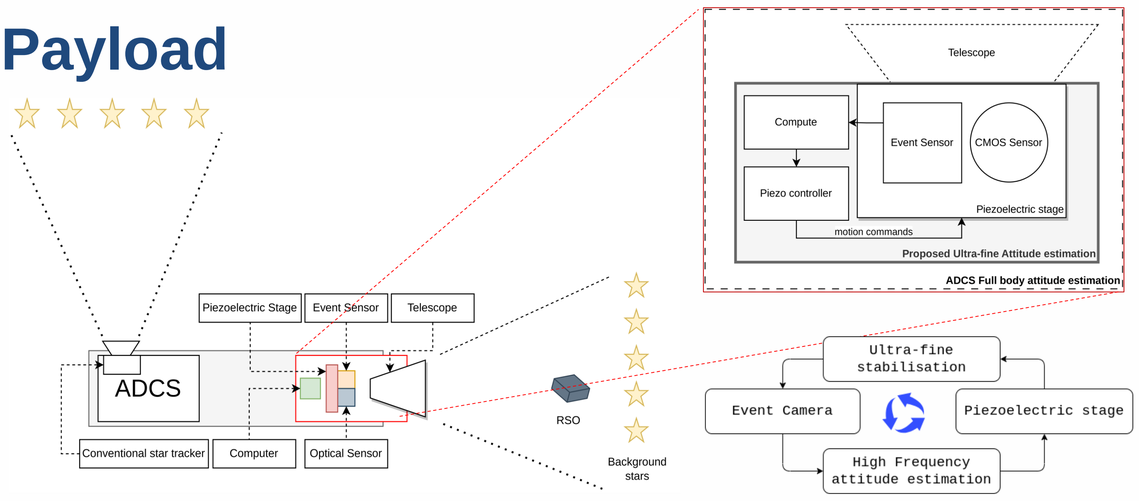
Why event sensor?	Event Sensor	COTS star trackers
Equivalent framerate (fps)	1,000,000	1-16
Dynamic range (dB)	120	44.6 (High end DSLR)
Power consumption (mW)	< 10	100 – 1500

50Hz capable Ultra-fine stabilisation



Stabilised pointing over time: *Left:* Linear *right:* Circular trajectory. Each box contains the spread around the stabilised pointing direction and evolution of pointing error over time.

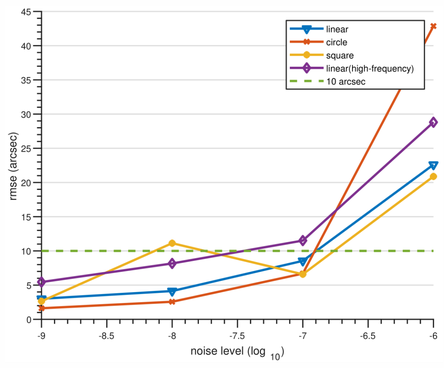
Payload



(Left) Payload in relation to the ADCS (Inset) Hardware components at the block level for the payload

Performance statistics

- Tracking accuracy in the range of **<5 arcseconds**
- Operational frequency **~ 50Hz tracking / 10Hz stabilisation.**



Tracking results for various noise levels

trajectory		noise level (degrees) 10^{-9}	10^{-8}	10^{-7}
linear	σ_x	3.36	2.61	3.62
	σ_y	2.61	2.73	3.70
square	σ_x	3.28	3.87	4.59
	σ_y	3.74	4.29	5.22
circle	σ_x	7.79	3.74	4.71
	σ_y	4.21	4.63	5.01

Stabilisation results: 1σ pointing accuracy for various levels reported in arcsec

[1]Australian Institute for Machine Learning, University of Adelaide, [2]Inovor Technologies, [3]Australian National University

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