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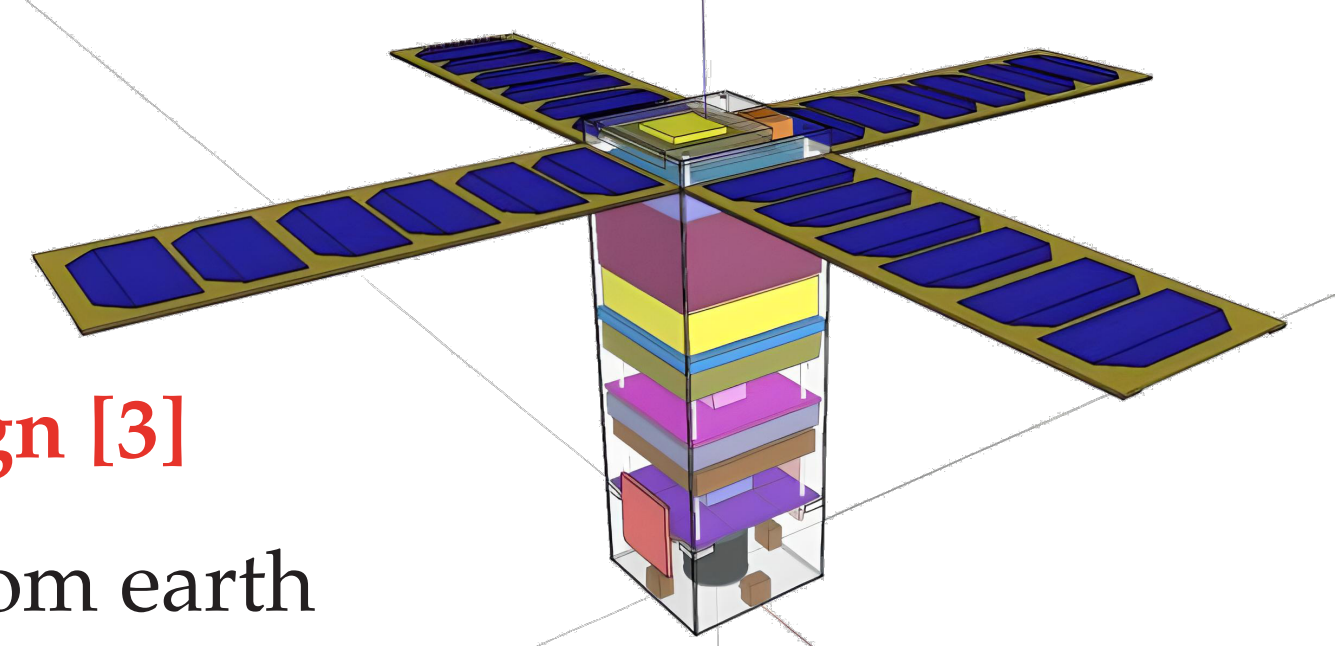
Fast Meteor Detection Toolbox

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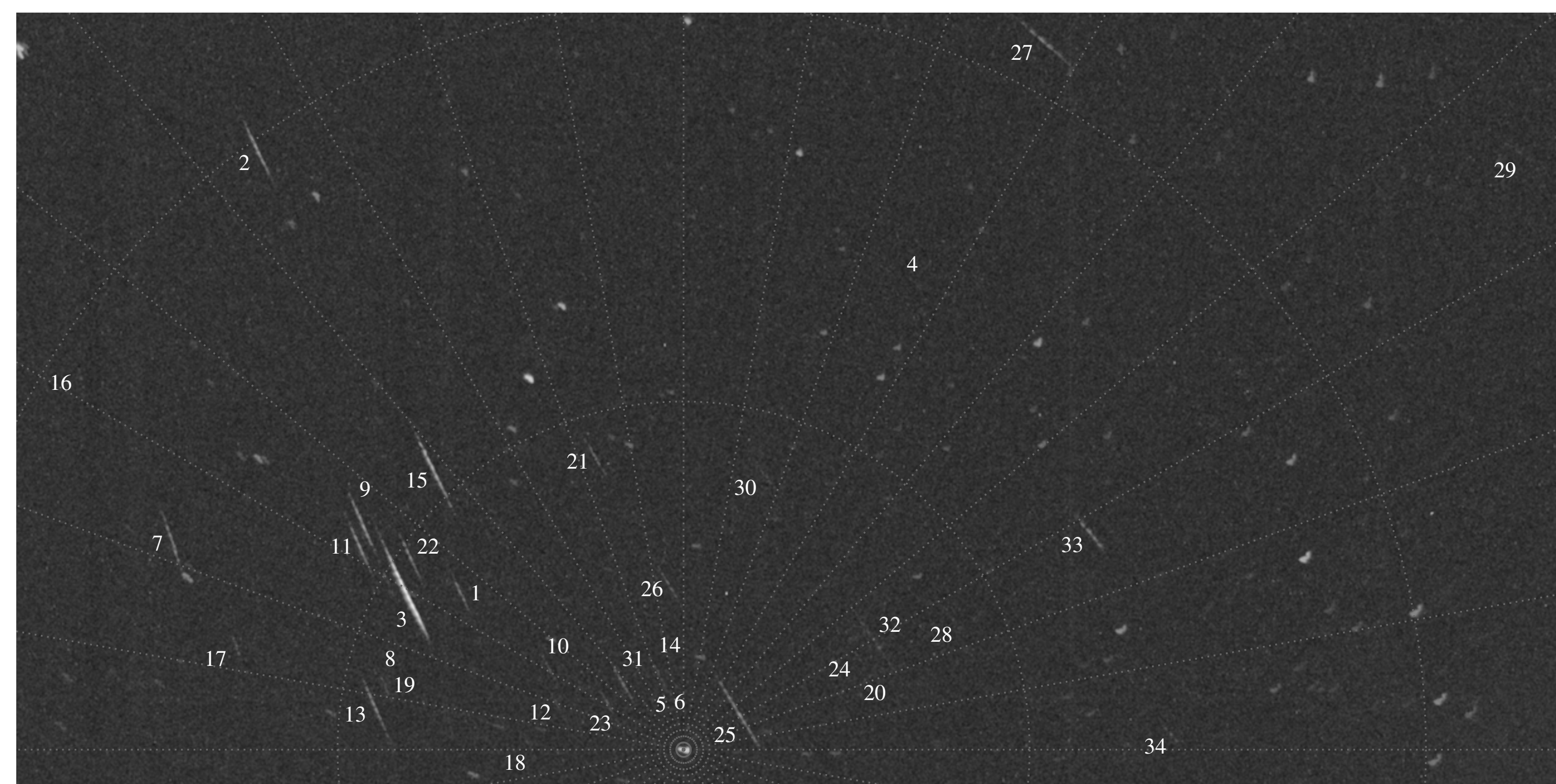


CONTEXT

- **Detection and characterization of meteoroids** and space debris that enter into our atmosphere
 - From satellite (CubeSat) [1, 2]
 - From weather balloon
 - **From aircraft observation campaign [3]**
- Better observation conditions than from earth
- Greyscale input videos, output tracks (= positions of meteors)
- **Real-time constraints & Challenges**
 - Non-stabilized cameras, noisy video sequences
 - Limited computational power: $\lesssim 10$ Watts
 - **Embedded systems** (RPI, Jetson, ...) & RISC architectures [4]
- LIP6/ALSOC & IMCCE joint-team: <https://www.imcce.fr/recherche/campagnes-observations/meteors/2022the>

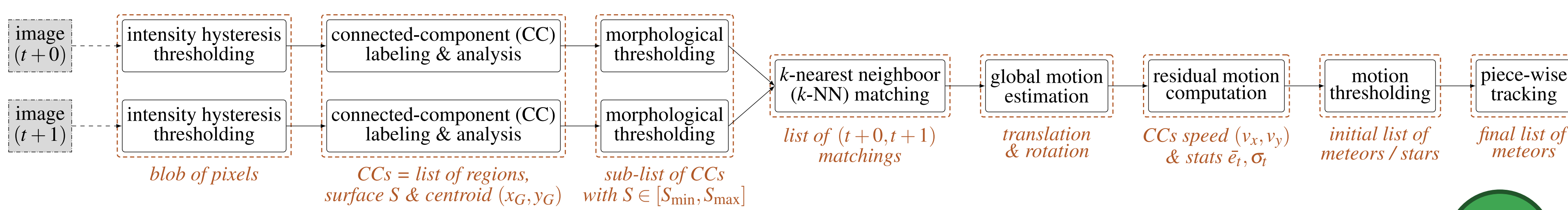


2022 τ -HERCULIDS METEOR CLUSTER



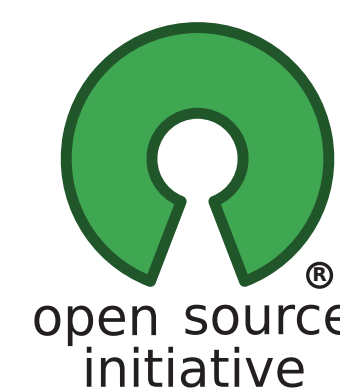
Composite closeup view of the 34 τ -Herculids meteor cluster (duration: 7.5 s) from an airborne observation campaign [3]. Center: *Ursa Minor* constellation.

FMDT: COMPUTER-VISION DETECTION CHAIN

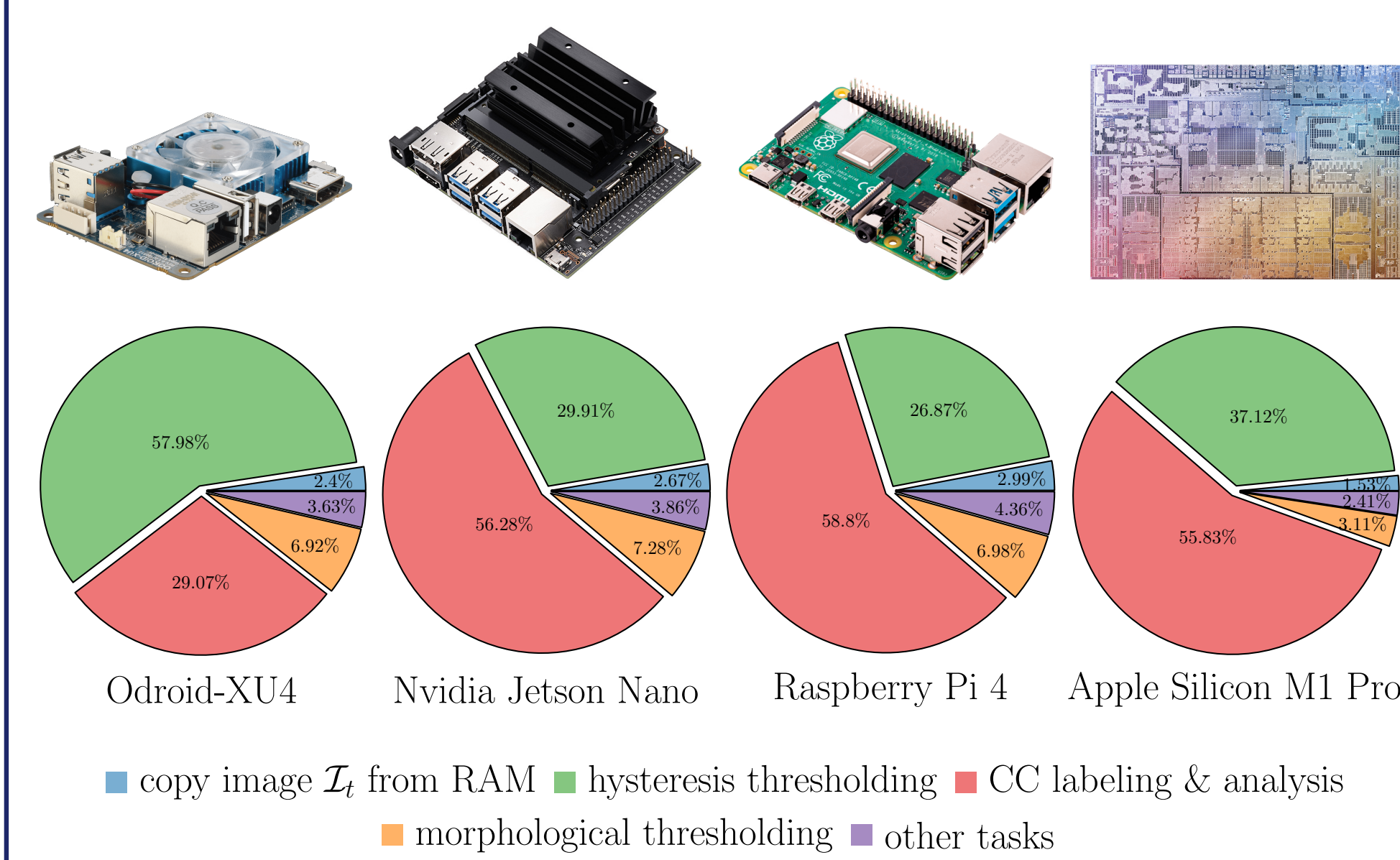


Computer-vision detection detailed chain.

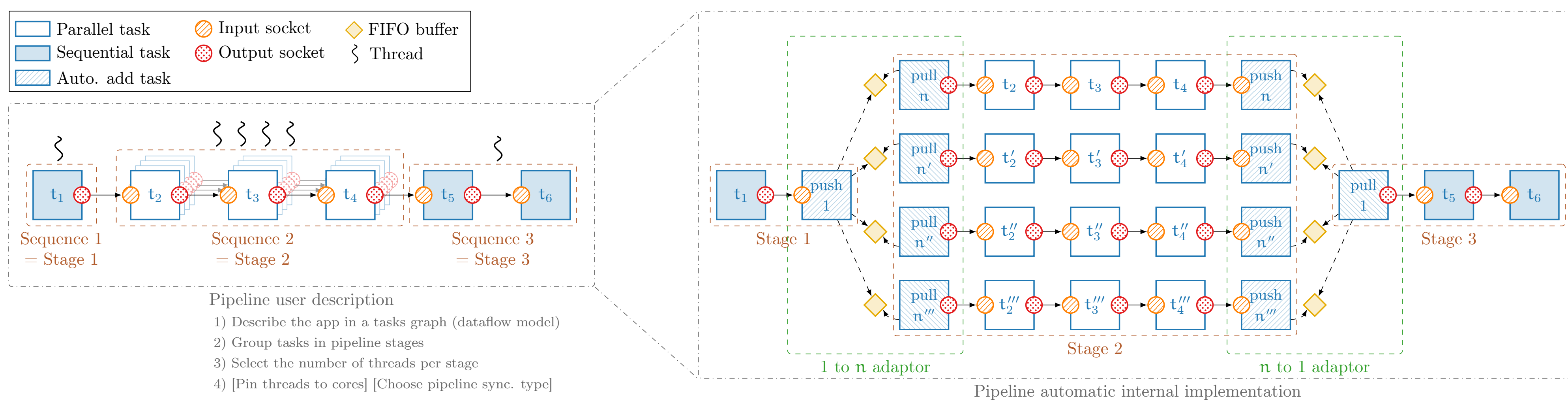
- Source code available on GitHub: <https://github.com/alsoc/fmdt>



SEQUENTIAL TIME DISTRIBUTION



TASKS GRAPH AND MULTI-THREADING WITH AFF3CT

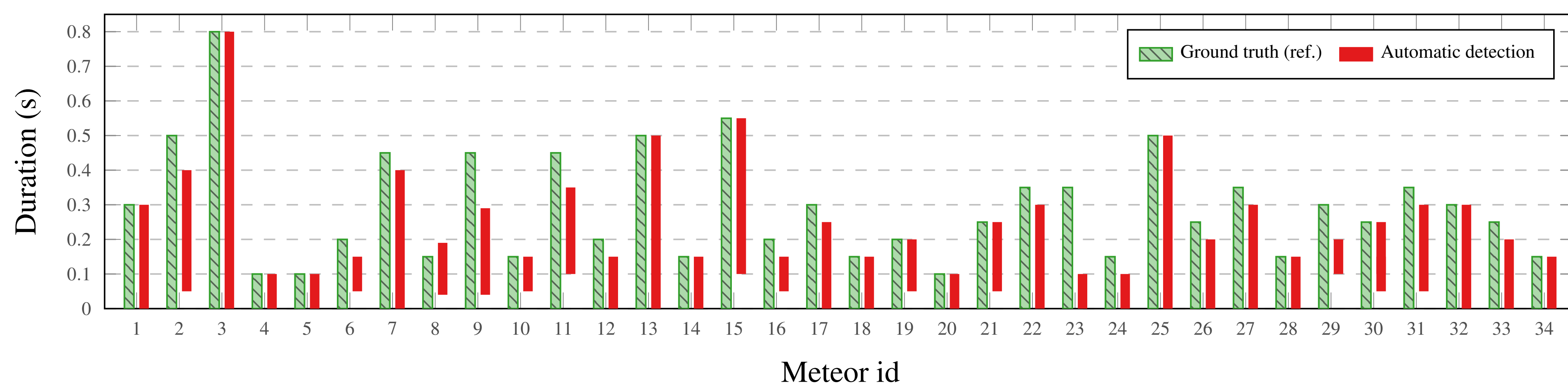


AFF3CT pipeline parallel construct.

A **3-stage pipeline** using the AFF3CT DSEL [5] has been implemented:

- 1) Copy image \mathcal{I}_t (sequential stage)
 - 2) Costly processing tasks from hysteresis to morphological thresholding (**parallel stage**)
 - 3) Lightweight processing tasks from k -NN to tracking (sequential stage)
- Design choice: most tasks of stage 3 are parallel but they are run on a single thread
 - Image processing results from \mathcal{I}_t are **memorized** for iteration $t + 1$
 - **Dependency**: stage 3 tasks require memorized $t - 1$ statistics
 - **Tracking is mainly a sequential task**, history management of statistics

METEORS AUTOMATIC DETECTION EFFICIENCY



REFERENCES

- [1] N. Rambaux et al. Meteorix: a CubeSat mission dedicated to the detection of meteors. In *COSPAR*, 2018.
- [2] M. Millet et al. Meteorix: High performance computer vision app. for Meteor detection from a CubeSat. In *COSPAR*, 2022.
- [3] J. Vaubaillon et al. A 2022 τ -herculid meteor cluster from airborne experiment: automated detection, characterization and consequences for meteoroids. *Astronomy & Astrophysics*, September 2022. (Submitted).
- [4] L. Lacassagne and B. Zavidovique. Light Speed Labeling for RISC architectures. In *ICIP*. IEEE, 2009.
- [5] A. Cassagne et al. A DSEL for high throughput and low latency software-defined radio on multicore CPUs. *Wiley Concurrency and Computation: Practice and Experience*, July 2022. (Submitted).

EXPERIMENTATION RESULTS

- Video resolution: **1920x1200 (HD)**
- GNU compiler: `-O3 -march=native`
- **Odroid-XU4** – Feb. 2016 – 28 nm proc.
 - 4 \times **LITTLE ARMv7 Cortex-A7** CPU @ 1.4 GHz
 - 4 \times **Big ARMv7 Cortex-A15** CPU @ 1.5 GHz

	Conf. [†]	FPS	\mathcal{L} (ms)	\mathcal{E} (mJ)	\mathcal{P} (W)
Seq.	<i>LITTLE</i>	7	142.6	403.7	2.82
Seq.	<i>Big</i>	14	70.4	274.6	3.88
Pip.	1L/4L/1L	26	361.8	153.1	4.04
Pip.	1B/4B/1B	42	216.1	159.9	6.74
Pip.	1/8/1	59	324.0	127.5	7.53

- Nvidia **Jetson Nano** – Mar. 2019 – 20 nm proc.
 - 4 \times **ARMv8 Cortex-A57** CPU @ 1.479 GHz

	Conf. [†]	FPS	\mathcal{L} (ms)	\mathcal{E} (mJ)	\mathcal{P} (W)
Seq.	–	34	29.0	114.9	3.93
Pip.	1/2/1	66	76.5	77.8	5.21
Pip.	1/4/1	91	98.5	68.1	6.25

- **RaspberryPi 4** model B – Jun. 2019 – 28 nm proc.
 - 4 \times **ARMv8 Cortex-A72** CPU @ 1.5 GHz

	Conf. [†]	FPS	\mathcal{L} (ms)	\mathcal{E} (mJ)	\mathcal{P} (W)
Seq.	–	20	48.7	156.5	3.19
Pip.	1/2/1	28	181.9	130.5	3.75
Pip.	1/4/1	30	310.8	123.4	3.79

- Apple Silicon **M1 Pro** – Oct. 2021 – 5 nm proc.
 - 2 \times **E-core ARMv8 Icestorm** CPU @ ≈ 2.0 GHz
 - 8 \times **P-core ARMv8 Firestorm** CPU @ ≈ 3.0 GHz

	Conf. [†]	FPS	\mathcal{L} (ms)	\mathcal{E} (mJ)	\mathcal{P} (W)
Seq.	<i>E-core</i>	60	16.1	34.0	2.04
Seq.	<i>P-core</i>	206	4.8	30.4	6.27
Pip.	1E/2E/1E	118	42.0	19.7	2.33
Pip.	1P/2P/1P	409	12.4	25.8	10.55
Pip.	1/8/1	1280	14.6	21.8	27.98

[†] Pipeline config.: [stage 1, # of threads] / [stage 2, # of threads] / [stage 3, # of threads]
FPS: frames per sec., \mathcal{L} : latency per frame, \mathcal{E} : energy consumption per frame, \mathcal{P} : instant power