

METEORIX

A CubeSat mission for detection and characterization of meteors
and space debris

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- ▶ A meteor is a luminous phenomena occurring when a meteoroid enters the Earth's atmosphere:
 - ▶ Meteoroid : small body from asteroids and comets.
 - ▶ Provides information on the history of the solar system.
 - ▶ Allows to estimate the matter flow entering the atmosphere.
- ▶ Meteors detection can be achieved:
 - ▶ on Earth with ground-camera networks like FRIPON[1]
 - ▶ in Space with the ISS Meteor experiment, others CubeSat projects...



Figure 1: An example of meteor from ISS Meteor[2] (Chiba Univ.)

General Context (2)

- ▶ Same phenomena when an artificial satellite re-enters the atmosphere:
 - ▶ Useful detection for space debris.



Figure 2: Re-entry of the ATV cargo (ESA)

Detection and characterization from space

- ▶ Chiba University showed the feasibility of a space observation of meteors.
 - ▶ ISS Meteor experiment[2, 3].
- ▶ 2 advantages : absence of weather constraint and wide coverage.
- ▶ Photometry to study meteor interaction with the atmosphere.
- ▶ Combining ground and space detection to improve trajectory calculation.

The project :

- ▶ First university CubeSat mission of Sorbonne University[4].
- ▶ Several purposes :
 - ▶ **Educational** Enroll students in a space mission.
 - ▶ **Astronomical** Estimate the flux of meteoroids and space debris entering the atmosphere.
 - ▶ **Technological** Show the feasibility of a *real-time* processing chain embedded in a nanosatellite.
- ▶ Observation during the night at nadir.
- ▶ Duration of one year for sporadic meteors and showers.
 - ▶ Detection of 100 expected events.



The CubeSat :

- ▶ CubeSat 3U based on EyeSat
- ▶ Sun-synchronous orbit at an altitude of $\approx 500\text{km}$.
- ▶ Payload :
 - ▶ Camera
 - ▶ Processing chain

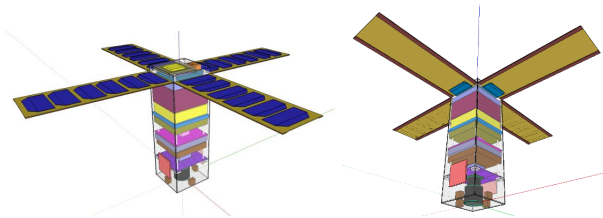


Figure 3: Views of Meteorix's CubeSat[5]

⇒ Currently in phase B.

Table 1: Specifications of the chosen detector.

	Expected specifications	3D Plus 3DCM681
Fps	10	12 or 16
Temperature (°C)	-30 to 40	-40 to 70
Size (mm×mm×mm)	97×97×100	35×35×23
Frame size (px×px)	640×512	2048×2048
Heritage	Yes if possible	EyeSat and Supercam

Table 2: Specifications of the optic.

	Expected specifications	LEICA Summilux-M 24mm
FOV (°)	30 to 40	84/74/53
Focal number	1 - 1.4	1.4
Size (mm×mm)	97×97×100 - Sensor size	58.5×75.6

→ Optic reworked to be compatible with the space environment.

- ▶ Measurement campaign was conducted during the Eta-Aquarids shower.

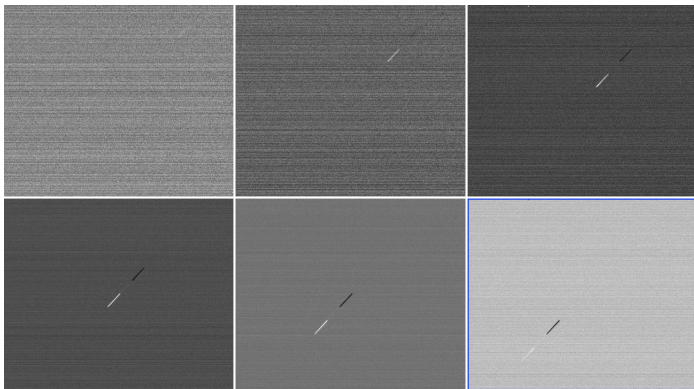


Figure 4: First meteor detected by the Meteorix detector (integration time 100ms).

- ▶ 2 issues have been identified
 - ▶ Spacewire interface is too low (7 fps)
 - ▶ Horizontal pattern noise

Payload - Processing chain (1)

- ▶ Ground detection algorithms unsuited for space detection.
- ▶ Proposal of a suited processing chain :

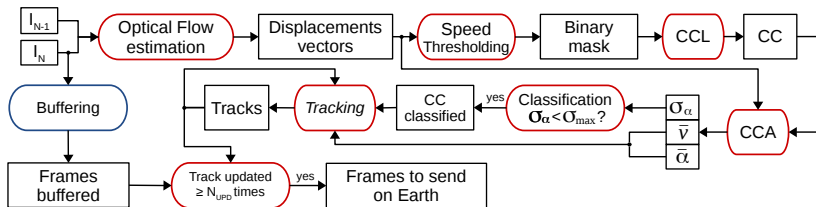


Figure 5: CC = Connected Components, CCL = Connected Components Labelling, CCA = Connected Components Analysis, \bar{v} = average speed, $\bar{\alpha}$ = mean angle, σ_α = angular standard deviation, $\sigma_{max} = 30$ deg, $N_{UPD} = 3$

Payload - Processing chain (2)

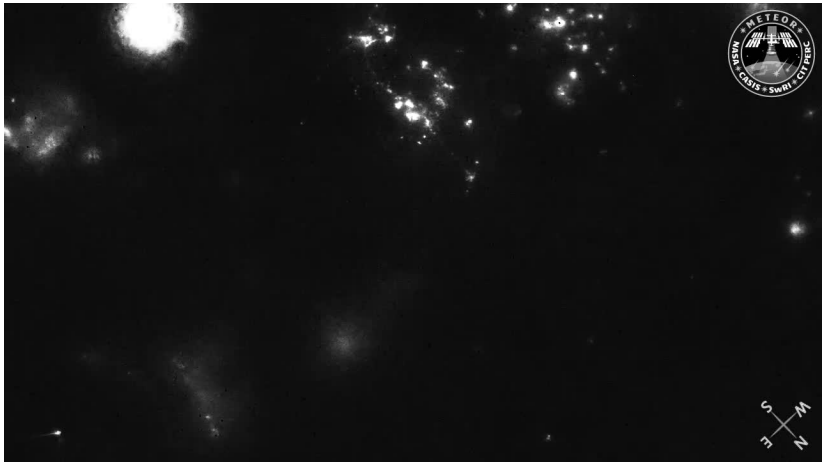


Figure 6: Example : Frame 119 of sequence v86

Payload - Processing chain (3)

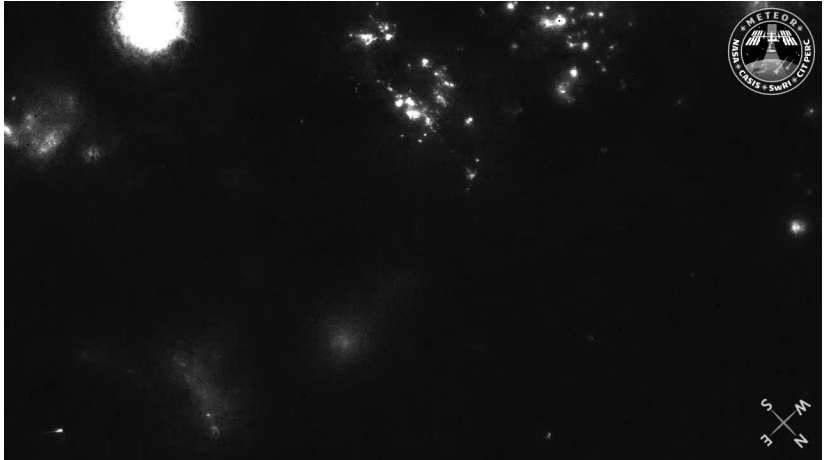


Figure 7: Example : Frame 120 of sequence v86



Figure 8: Example : optical flow between frame 119 and 120

Payload - Processing chain (5)

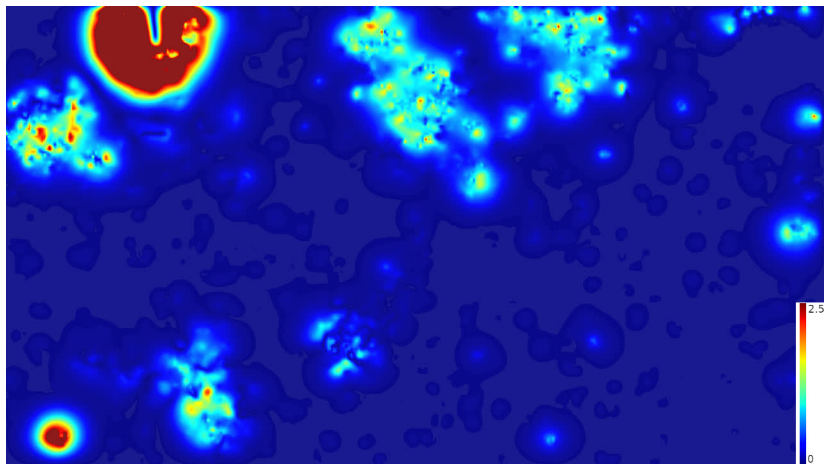


Figure 9: Example : norm of displacements vectors

we keep only the faster pixels, which are in red



Figure 10: Example : Angles

- ▶ A validation bench has been developed to qualify the processing chain.
- ▶ 50 meteors identified in the video sequences[6] of ISS Meteor mission.
 - ▶ Used as inputs
- ▶ 48 out of 50 meteors detected by the processing chain.
 - ▶ Detection probability of 96%.

- ▶ Meteorix is the first university CubeSat of Sorbonne University.
- ▶ Demonstrator for detection and characterization of meteors and space debris from space.
- ▶ The payload consists of a camera and a real-time processing chain.
- ▶ High educational value with multi-disciplinary topics.

Thank you !

And a special thanks for :



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CubeSat components

- ▶ 4 solar panels
- ▶ Li-Ion battery (48kWh)
- ▶ Power board
- ▶ Magnetorquer board
- ▶ Reaction wheel
- ▶ S-band transmitter with two antennas (for scientific mission)
- ▶ UHF/VHF transceiver with one antenna
- ▶ Interface board
- ▶ On-board computer

▶ **Optical Flow**

- ▶ Horn & Schunck [7]
- ▶ Iterative algorithm
- ▶ Pyramidal version [8]

▶ **Connected Component Labeling**

- ▶ Performed with Light Speed Labeling algorithm [9].
- ▶ Available in a parallel version [10].
- ▶ Very fast and energy efficient [11].

▶ **Tracking**

- ▶ Based on a simple state machine.

How to speed up detection ?

Our goal is to reach real-time rate (25 frame/s).

- ▶ **High Level Transforms**

- ▶ reducing time and energy consumption [12, 13, 14].

- ▶ **Algorithm optimizations**

- ▶ Quality [15]/consumption [16]/speed [17] trade-off.
- ▶ Simple and/or efficient algorithms [18, 19].

- ▶ **Consider other hardware architectures (FPGA ?) [20].**

- ▶ **Code parallelization**

- ▶ Multi-threading
- ▶ SIMD (data parallelism) [21]