On-board data processing for meteor detection on SLAVIA mission

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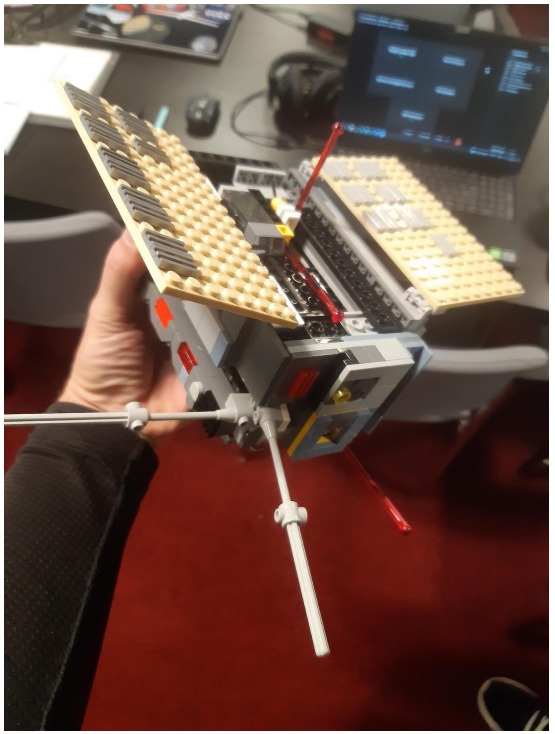
Slavia

- Phase A-B1 (feasibility study & mission definition)
- Tandem flight of two 16U CubeSats
- Payloads: **VESNA** + HANKA + ŘÍP2
- Navigation: Star tracker, Sun sensor, GPS
- Propulsion System (formation, attitude)
- UHF, S-band, X-band communication
- LEO SSO (600-700km)

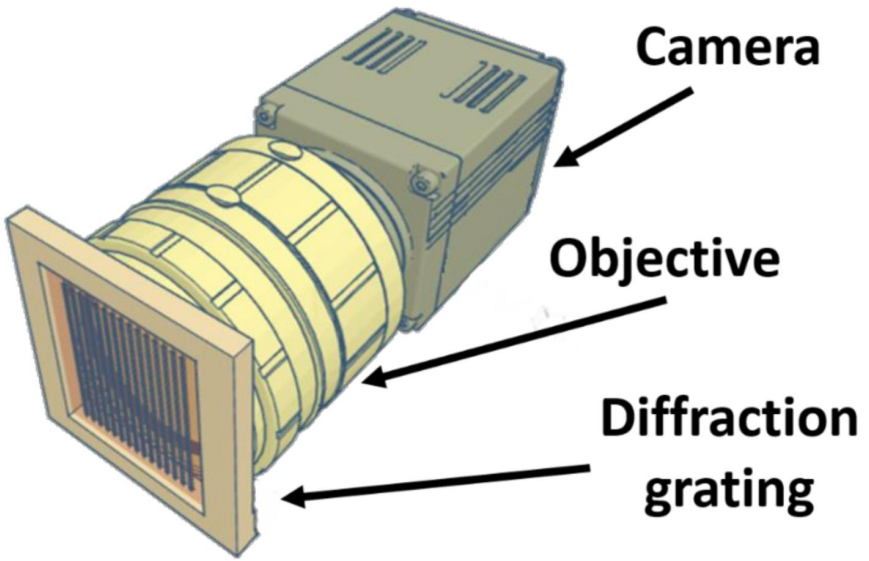


Slavia – VESNA Hyperspectral Camera Payload

- **UV** and VIS optical spectrum range (200–700 nm)

- 2848x2848px, 12bpp, 4FPS
- 2.8k * 2.8k * 2Bpp = 16MB raw image
- (30*60)*4FPS*16MB = 112GB per orbit
- comm. window each 12 hours, ~1.0GB
- 1-5 events/day expected (meteor showers)

→ Filter valuable data to fit data budget



A graphical representation of the arrangement of the VESNA spectral camera.
Credit: SLAVIA consortium

Slavia – Data Processing Unit

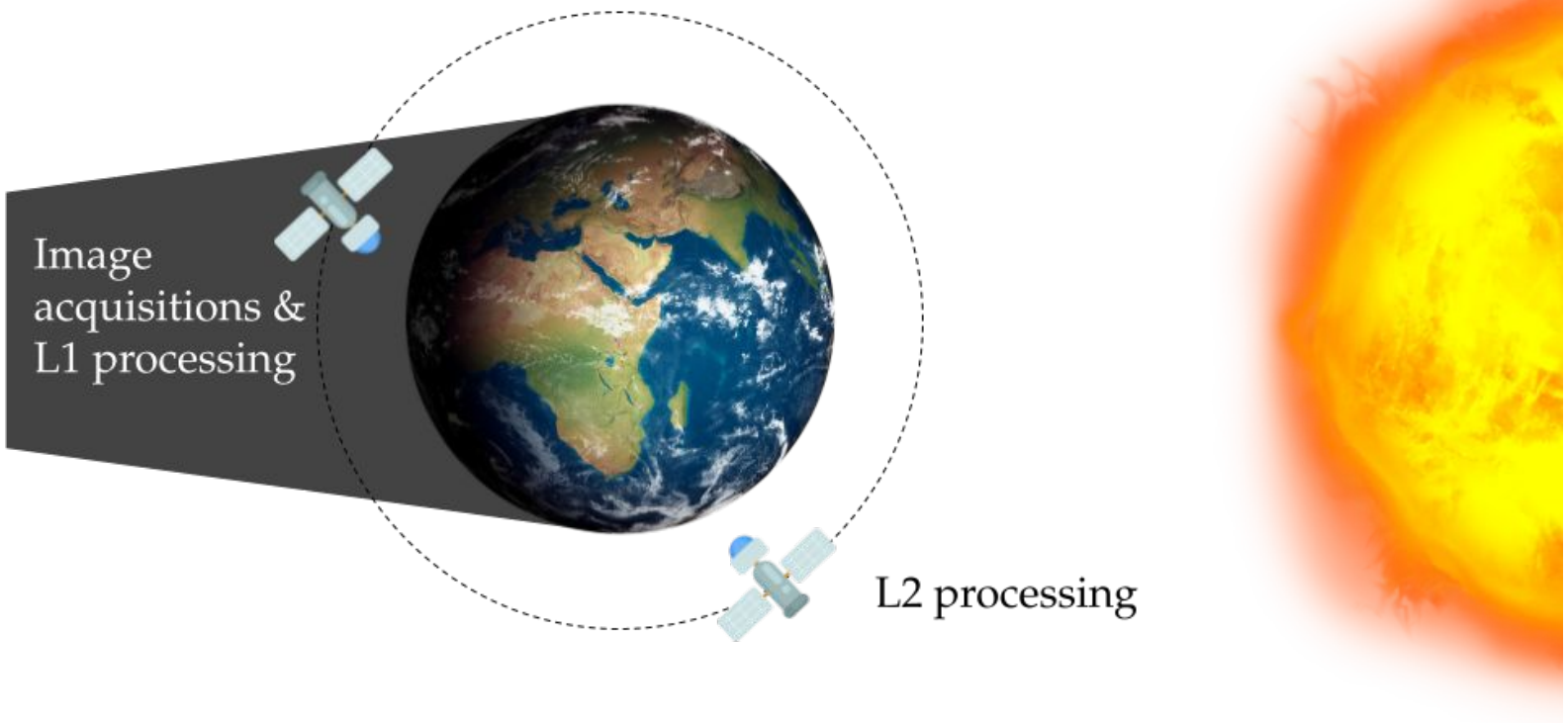
- Xilinx Zynq UltraScale+ SoC (Xiphos Q8)

- Quad-core ARM Cortex-A53 @ 1.2GHz
- 4 GB LPDDR4 DRAM
- 2x eMMC, 128 GB each

- Linux 4.14 LTS
- 4 W - 25 W power consumption, scalable
- USB 3.1 Gen 1, CAN

Xiphos Q8, Credit: Xiphos

Slavia – On-board Data Processing Pipeline



Slavia – Level 1 Processing

- During eclipse (night side of the orbit), ~ 30 min

- Data acquisition by VESNA camera
- Real time (4FPS → ¼ sec for each image)
- Limited power available (shared resources with camera)

- CV methods: primary simple ones due to time limit;
  eg. thresholding, temporal difference, optical flow

- Goal: Basic filtration, lightning detection

Slavia – Level 2 Processing

- During daytime phase

- VESNA Camera is inactive
- Up to 60 min
- Higher power available (up to 16W) then Level 1
- Potential thermal limitation due to sun

- Detection methods: CNN + LSTM (LRCN), ConvLSTM, 3D ConvNets,

- Goal: Image Quality Score + download queue

Slavia – Data processing challenges

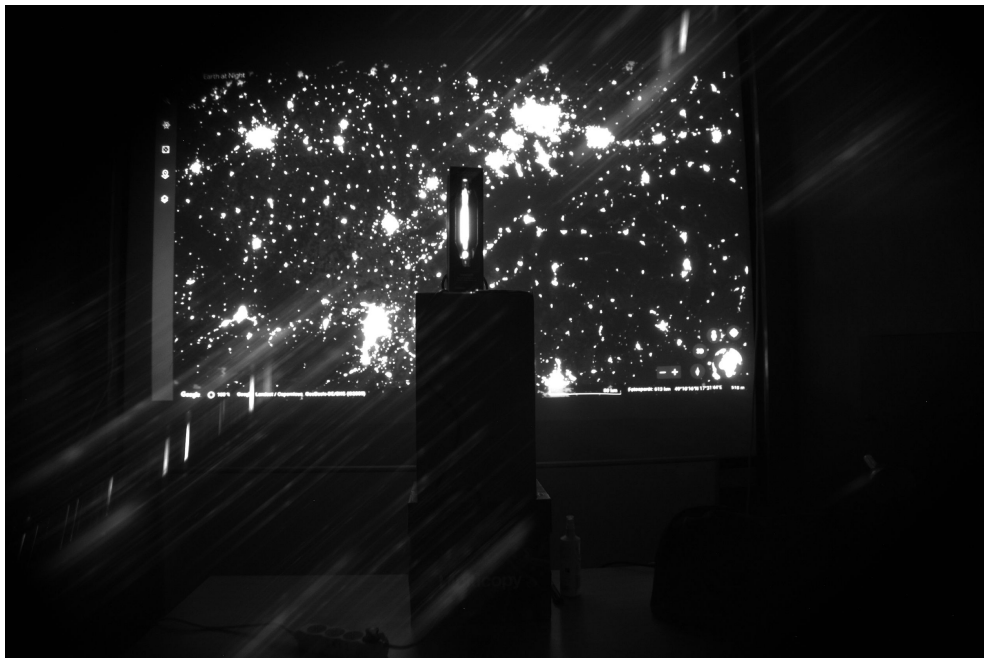
- **Urban areas**
  - Can not fully avoid, high false positives rate expected
  - Connect space based and Earth based observations

- **Oceans**
  - Applies to dark areas like deserts as well
  - Simple thresholding may be enough
  - Moonlight reflections on sea waves

- **Lightnings**
  - Potential scientific value, need to keep them
  - Detection via duration - much shorter than meteors

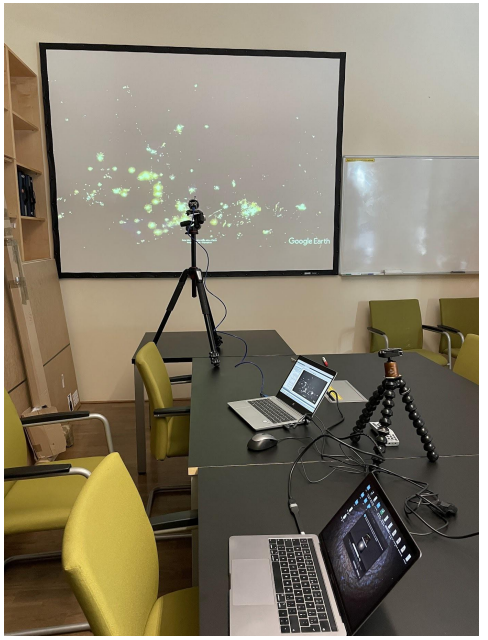
Slavia – Evaluation (synthetic) Data

- Test and evaluation dataset, confirm comparable to the expected in-orbit data
- Sources of night images (processed NASA's Black Marble), disturbances (clouds, storms), categories (sea, city, land)
- Meteor light source, setup geometry



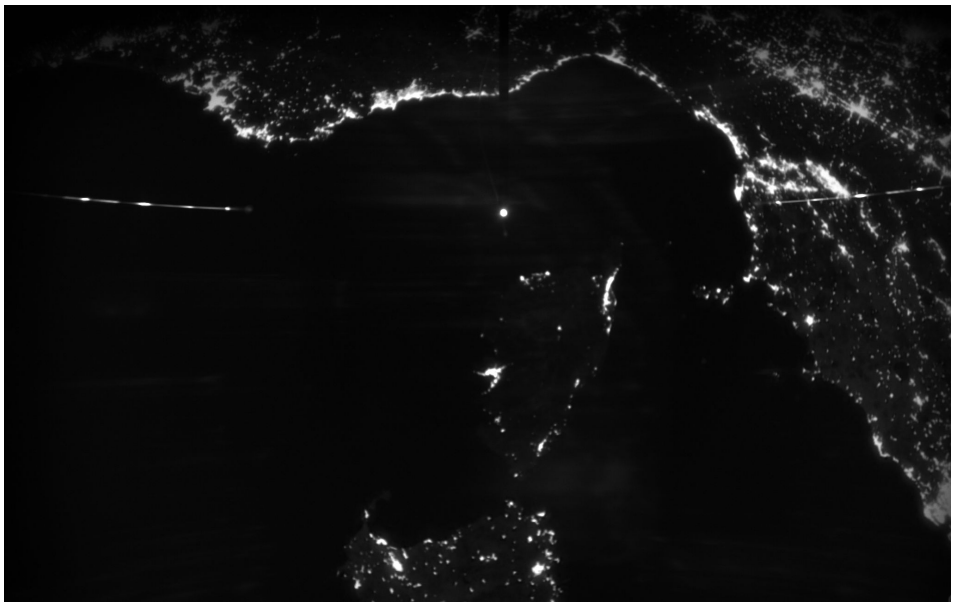
Slavia – Evaluation (synthetic) Data

- Projection screen vs LCD setups
- Input video/images quality (pixels vs compression artefacts)
- Integrated setup for image playback and camera capture



Slavia – Evaluation (synthetic) Data

- Final setup with 4k LCD screen, NB with control SW
- Light source for artificial meteor outside the scene + optical cable
- Meteor intensity changes using ND filter
- Data available on https://merlin.fit.vutbr.cz/slavia/



Slavia – Evaluation (synthetic) Data

Thank you for your attention

Questions?

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