DTU Space
National Space Institute

Doc. no:	CAMDAVIS-DTU-ESR-01
Rev:	1.0
Date:	2024-05-05

CAM-DAVIS

Executive Summary Report

ESA Contract No. 4000139066/22/NL/GLC/ov

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1. Introduction

1.1 Purpose

The CAMDAVIS project, also named “Imaging at 1-10 microsecond resolution from a space platform” was conducted under the contract ESA Contract No. 4000139066/22/NL/GLC/ov. This document, [CAMDAVIS-DTU-ESR-01] is the Executive Summary Report of the CAMDAVIS project. It gives an overview of the project activities and a summary of the achievements at the end of the project. More details on the activities can be found in the CAMDAVIS final report. [CAMDAVIS-DTU-FR-01].

2. References

2.1 Applicable Documents

The document shall be read together with the documents listed below.

[CAMDAVIS-DTU-FR-01]	CAMDAVIS Final Report	Issue 01

2.2 Reference Documents

[OSIP Idea I-2022-01992]	2nd Round: Imaging at 1-10 microsecond resolution from a space platform.

3. CAMDAVIS Executive Summary.

3.1 Study framework.

The framework of the project is taken from [OSIP Idea I-2022-01992] and is summarized below.

Conventional high-speed video cameras present major limitations for space applications, they are heavy, bulky and require a lot of resources to operate and to space qualify. The study proposes the use of the neuromorphic camera technology for high-speed imaging in space. Neuromorphic cameras, also called event-cameras, offer advantages such as small size, low power consumption, and high temporal resolution, making them suitable for detecting fast phenomena like lightning and space debris. The advantages also make them relatively easy to space-qualify. The project aims to demonstrate the feasibility of using event cameras for lightning imaging, with plans to test a Dynamic Vision Sensor (DVS); a DAVIS 346, on ground and in space and to develop a roadmap for space applications of neuromorphic sensors.

3.2 Objectives and Challenges of the project

3.2.1 Objectives

The objectives of the project are taken from [OSIP Idea I-2022-01992] and are recalled below:

1. Test the DAVIS 346 camera to detect electrical activity in severe storms. Tests will occur both in the laboratory and on the International Space Station (ISS), focusing on how environmental conditions and light sources impact camera performance.

2. Identify the requirements for implementing the technology in future space experiments. The tests will allow for the identification of the optimum operational mode of the DVS sensor (optimal parameter settings) which allows for bracketing the range of light source parameters and their dependence on the environment.

3. To develop a roadmap and a conceptual breadboard of specially designed instruments considering the trend in development, for instance in pixel and time resolution. First outline proposal for continued development.

3.2.2 Challenges

The challenges of the project are listed below a test setup which allow to experiment with the Davis camera in the lab.

- Assess event camera technology.
- Find test setups to calibrate a DAVIS 346 camera.

- Find an easy-to-use solution to deliver the crew a payload allowing to observe from an ISS window.
- Space-qualify the payload.
- Conduct space-based observations.
- Analyse the results from both lab and space experiments.
- Outline proposal for future use of the technology.

3.3 Summary of achievements

3.3.1 Evaluation of event camera technology. (WP 1500)

We have reviewed different event camera models available on the market from the major producers: Inivation, Prophesee, Samsung, Sony, CelePixel and Insightness Rhino3. We compare the characteristics of the latest models from each of them in the final report [FR].

3.3.2 Payload design (WP 2000)

The idea was to mount the DAVIS camera on top of a conventional Nikon D5 camera to be used as reference and to assist the crew in pointing at thunderstorm with the Nikon LiveView showing the scene on screen. The Nikon camera was already on board and the DAVIS camera had to be space qualified and launched. To control and acquire data from the Davis camera, we have chosen to use an Astro PI unit. The Astro Pi unit is based on a Raspberry Pi 4B and serves as a data processing unit and deliver power to the DAVIS camera. The Astro Pi unit was already on board and its usage was supported by ESA Education Office.
The Nikon D5 camera is mounted with lens of focal length 85mm and F-number 1.4, the camera is set with a manual focus and ISO to 6400, and records movies at 60 frame per seconds at a resolution of 1920x1080 which is recorded from either the central part of the camera sensor or from a down scaling of the full sensor. The 2 configurations correspond respectively to 8.3 deg x 4.7 deg and 16.6 deg x 9.4 deg field of view. The Davis camera is mounted with either a 85mm lens or a 50 mm lens. The 2 configurations correspond respectively to 7.3 deg x 5.5 deg or 14.6 deg x 11 deg field of view, i.e. approximately the same as the corresponding mode for the Nikon. The first configuration mode is chosen for close covering about 50 km x 40 km on ground at Nadir (250 x 190 km at limb), the second configuration cover a larger area of about 100 km x 80 km at Nadir (500 x 380 km at limb).

A picture of the setup is given in figure 1, details and the results from the tests are summarized in section 5 of [CAMDAVIS-DTU-FR-01].

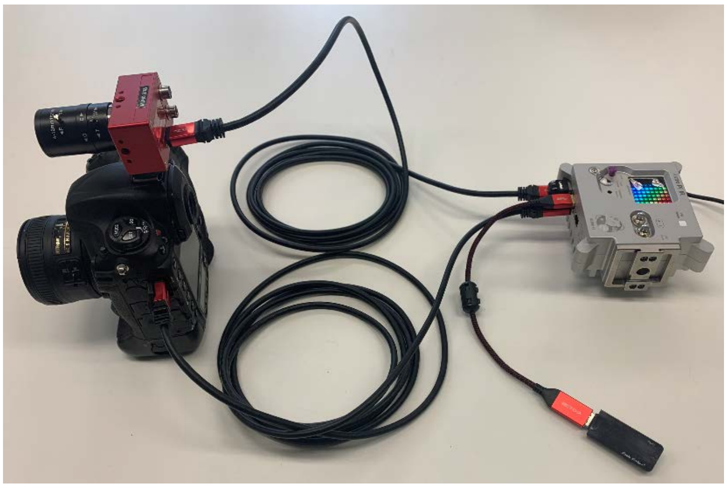

Figure 1: The payload ground model as used at BIOTESC for the test validation of the flight procedure. We see a DAVIS 346 camera mounted on top of a Nikon D5 camera. Credits: DTU Space / Biotesc.

The payload also required to design a SW to make the operation as easy as possible by the crew. It was based on the original linux OS installed on the Astro Pi, supplemented by the DV libraries from Inivation (the DAVIS camera producent) and gpredict to control and the Nikon camera. An overall script was developed to ease the operation by automatising the SW tasks to be performed in order to set the cameras, start/end the recordings and store the data. The design is summarized in section 5 of [CAMDAVIS-DTU-FR-01].

3.3.3 Space qualification of the payload (WP 2000)

Despite the fact the payload was essentially based on a COTS item the payload had to be space-qualified following the engineering and safety standard of the International Space Station. In particular:

- the DAVIS camera was internally inspected against the presence of dangerous component as chemical capacitor.
- the camera was covered by a tape to protect the crew from eventual sharp edges and from eventual too bright illumination. Some shatterable material and some sharp connectors got removed.
- the standby and operational temperatures were also inspected for safety reasons.
- the sealing of the camera and of the lenses was inspected to avoid eventual creation of a sealed container.
- the launch and operational procedures were designed to avoid propagation of shatterable material due to an eventual breakage of glass components.
- the SW was designed and implemented following the safety standard.
- flammable materials were checked and protected by tape to circumscribe eventual fire path.
- Davis lenses were supplemented by a bumper to protect ISS windows from scratches.
- The payload underwent EMC tests and was found to be compatible.

The space qualifications were done in close collaboration with ESA Satety, ESA Engineering, ESA Education and ESA TEC-EPE. They led to the production of a copious documentation including Thor-Davis Activity Requirement Document, Thor-Davis Flight Safety Data Package, Thor-Davis Interface Control Document, Thor-Davis Inspections Reports, Thor-Davis test reports, Thor-Davis SW release order, Thor-Davis SW delivery order Thor-Davis Acceptance Data Package. Results are detailed in section 5 of the final report [CAMDAVIS-DTU-FR-01] and in some of the documents given in the Final Report annexes.

3.3.4 Lab experiment. (WP 3000)

The idea was to experiment in the lab with the camera recording a light source of different light intensity and temporal evolution. The test setup was based on LEDs on which the DAVIS camera focus on. The LEDs are fed with a function generator allowing to control the light emitted. Several tests were made to measure:

- The response of the camera and the thresholding settings.
- The event rate of the camera.
- Characterization of the camera bias settings.
- Characterisation of the temperature influence on noise.

A supplementary test was made to measure the response of the camera from stars moving in the field of view to have some absolute calibration points.

A picture of the setup is given in Figure 2, details and the results from the tests are summarized in section 6 of [CAMDAVIS-DTU-FR-01].

Figure 2: Test setup with a DAVIS 346 camera focused on a LED alimented by a signal generator. Credits: DTU Space /Inivation

3.3.5 Thor-Davis mission procedures. (WP 4000)

The space experiment, Thor-Davis required planification and operational procedures to be defined. It was done by Biotesc in collaboration with DTU Space and led to the production of a Thor-Davis Big Picture Words, Thor-Davis Operations Implementation Concept, Thor-Davis procedures (PODFs) and a Thor-Davis System Validation Test plan and report. For every observational session, storms were forecasted in advance and a target list containing scheduling and position were produced to be sent a day in advance to the crew. The days of observations are summarised in the 2 section 3.3.5 and 3.3.6 below. Details are given in sections 7 of [CAMDAVIS-DTU-FR-01] with the target lists given in annex.

3.3.6 Observations (WP 4000)

The observations are summarised below. The figures 3 gives an overview of the locations of the attempts.

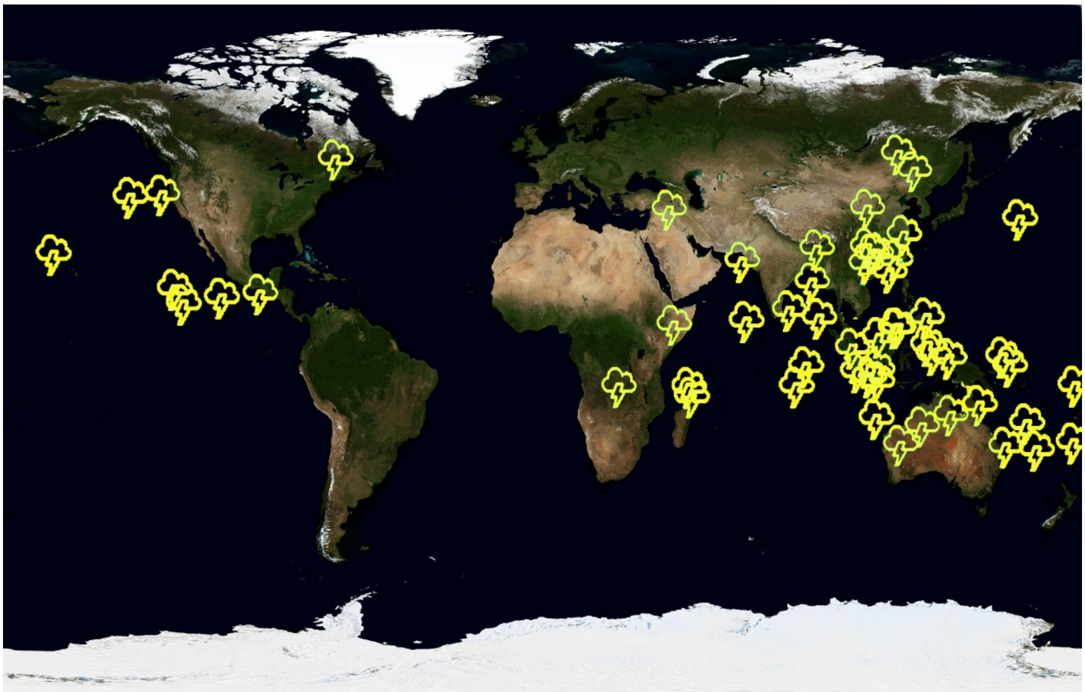

Figure 3: Location of the observation attempts. Credits: DTU Space.

We can see that the observations are predominantly over Asia with few West of America. This is mostly due to the scheduling of the observation that had to be inside the crew working hours.

The exact location are given in the tables in section 7.3.1 and 7.3.2 of the Final Report [CAMDAVIS-DTU-FR-01], which shows that the observational objectives are fulfilled and surpassed.

The Final Report also highlights some observations which shows that the proof of concept is fulfilled.

One observation, particularly relevant is given below in Figure 4. It shows a positive cloud to ground lightning powerful enough to initiate a Sprite above it, the two events are seen in the same frame (60 fps) of the Nikon camera (left), the time evolution at 10000 fps of the 2 events is shown on the right panel. We see than the lightning initiate before the sprite.

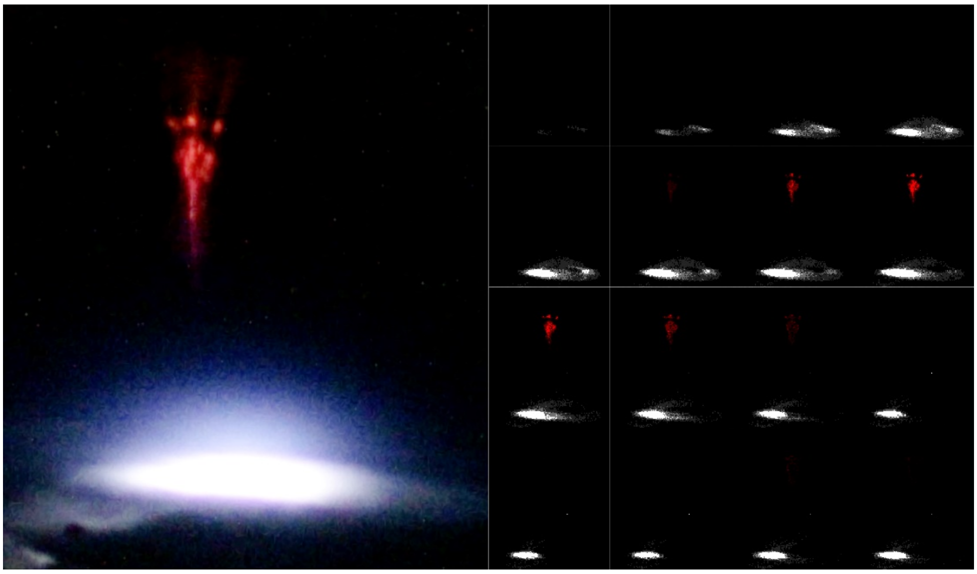

Figure 4: A sprite as observed above a positive cloud to ground lightning. The left panel shows it as observed in the Nikon camera at 60 fps and the left panel shows it as observed in the Davis camera at 10 000 fps.

3.3.7 Roadmap: contribution to space observations (WP 5000)

The aim of the WP is to formulate a roadmap for the development of this technology for use in space applications. It includes a discussion of sensors and applications, and suggestions for the foundation of a business case and associates principles of a conceptual breadboard model (CBBM).

The tasks of the WP include:

- Identify sensors and companies with the most promising development potential
- Identify applications where the technology offers improved solutions as regards fast event capture, high dynamic range, and low power and weight requirements.
- A conceptual bread-board model (CBBM) for a future space instrument

The outcome of the WP are detailed in [CAMDAVIS-DTU-FR-01].